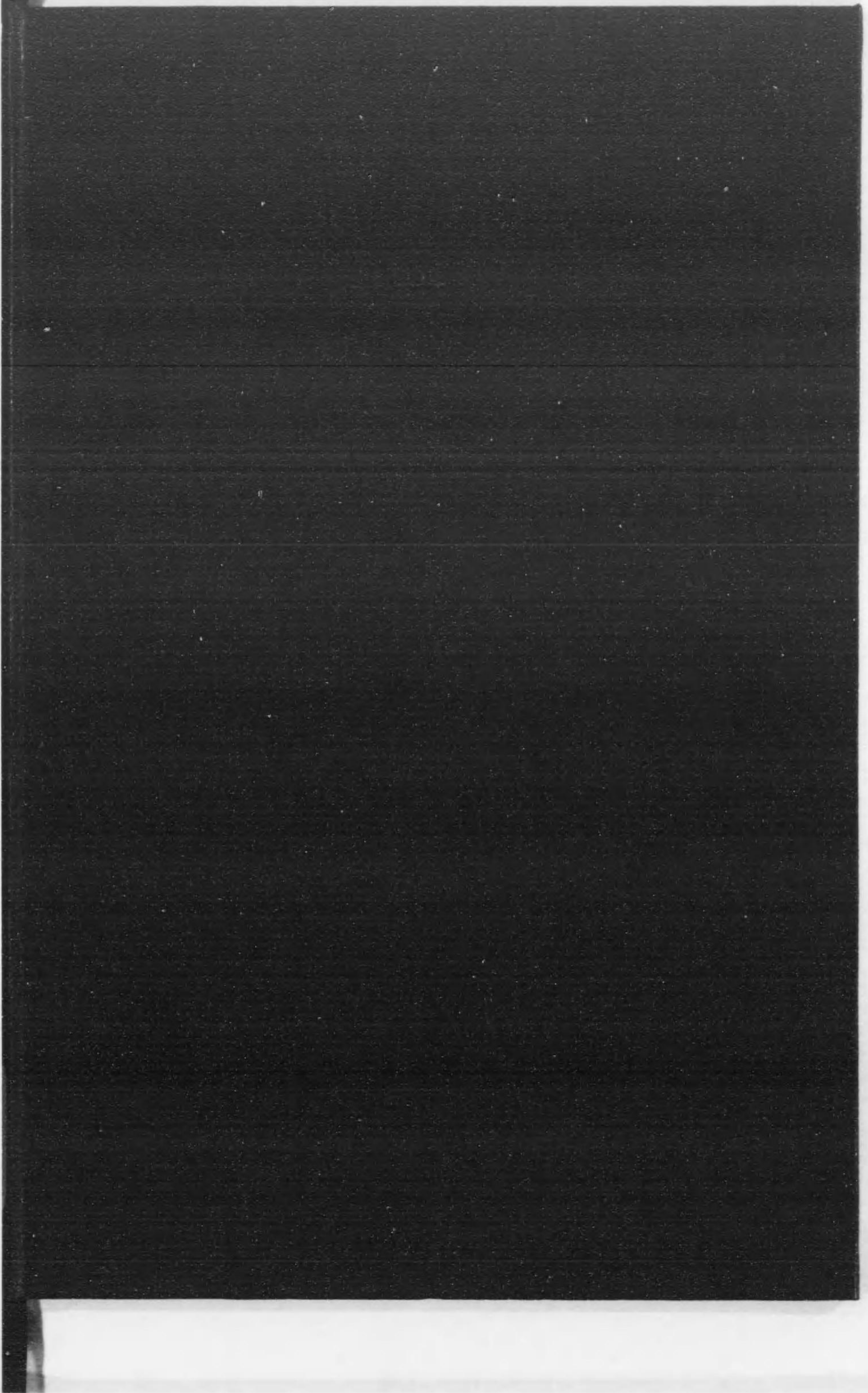




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"RIGAKU" 4 no Maki

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RIKIGAKU NO KYOKWASYO

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Rigakuhakusi

Tamaru-Takurô

arawasu.

TÔKYÔ

NIPPON-NO-RÔMAZI-SYA

Taisvô 14 nen

大正

14, 4 20

丙 父

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*Kono Syomotu wo hokano Kotoba
matawa hokano Mozi ni kakicaeru koto
wo yurusanai.*

Hasigaki.

Kono Syomotu wa Kôtôgakkô ya Senmongakkô ni okeru Rikigaku no Kyôkwasyo tosite tukau tameni tukutta mono de aru ga, Kozin no Kenkyû no tamenimo hutekitô dewa nai Mikomi de aru.

Kôtôgakkô to Senmongakkô to dewa, Rikigaku wo narau Kumi ga tigau si, mata Senmongakkô no naka demo, Rikigaku wo ôku osieru Tokoro ya sukunaku osieru Tokoro nado iroiro aru node, subeteno Osiekata ni Sasitukae no nai yôni Naiyô wo seirisuru koto ni tokubetuna Tyûi wo haratta. Sore no Yôten wa—

(i) Bibungaku ya Sekibungaku ga iriyô de nakute, sikamo zissaino Tukaimiti ni koton hituyôna *Turiai* no Mondai wo hazimeni dasita koto ;

(ii) Wakariyasukute, sikamo zissaino Mondai ni mottomo ôku dete kuru yôyôna Baai tosite, Tikara ga hitotuno Heimen ni aru Baai wo omoni ronzi koto ;

(iii) Sore to dôzini, iroirona Kenkyûsya no Bengi wo hakaru tameni, *kanari tebiroi "Huroku"* wo môkete, ippô dewa kôtôna Sûgaku wo manabu Ori wo motanai Kenkyûsya no tameni *Bibun-gaku to Sekibungaku no Ooduna* wo tokiakasi, ippô dewa, Honmon wo mananda ueni nao susunde kenkyûsiyô to suru Hito no tameni Honmon ni irenakatta Mondai de, Omosiromi to Yakudati-doai no ôi ikutu kano Daimoku wo toita. Korerano Daimoku wa *Dimension no Riron, Kûkan ni okeru Undô ya Tikara no Turiai, Ito no Turiai, kwaitensuru Gôtai no Dikuuke ni okeru Han-kôryoku, Koma no Undô* nado de aru.

Konoyôna Hôhō ni yotte, iroirona Syurui no Kenkyûsya ni sôtôni Manzoku wo ataete, kono Gakumon no Kenkyû no tameni sôtôna Kikime wo arawasu yôni nareba, Kakite no mottomo yorokobu tokoro de aru.

Kono Hon wo dasu ni tuite, Genkô no Seiri ni tuitewa Rigakusi Tauti-Morisaburô Kun to Miyake-Yutaka Kun, Kôsei ni tuitewa Kôgakusi Ozawa-Rinzô Kun to Satô-Kôzi Kun no Osewa ni natta. Kono Ori wo riyôsite, korerano Katagata ni atuku Orei wo môsinoberu.

Taisyô 14 n. 2 gt.

Tamaru-Takurô.

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Daiitino Oowake.

TIKARA NO TURIAI.



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SYOO I.
Hitotuno Ten ni hataraku
Tikara no Turiai.

1. **Tikara.** Seisisite iru Buttai wo ugokasô to site, Hito ga sore wo *osi* matawa *hiku* tokini, "Hito ga Buttai ni *Tikara* wo kuwaeru," "Buttai ga *Tikara* wo ukeru," "*Tikara* ga Buttai ni hataraku" nado to iu.

Ippanni, seisisite iru Buttai ni sayôsite, betuni sore wo sasaeru yôna Sayô matawa *Sôti* ga nai Baai ni, sore wo ugokasu yôna Sayô wo *Tikara* to iu.

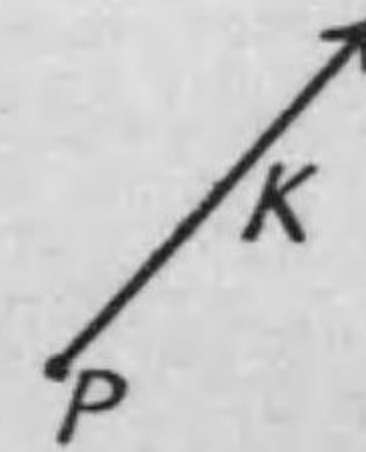
Buturigaku ya Rikigaku de iu "*Tikara*" wa, *genzai hataraitte iru tokorono ueno yôna Sayô* ni kagiru no de, "*Tikara* wo motte iru" toka, "Ano Otoko wa *Tikara* ga aru" toka to iu Baai no yôna Imi ni sore wo tukau koto wa nai.

2. **Tikara no Hatarakikata** ni tuitewa, sore ga
dono Ten ni hataraku ka?
dono Hôkô ni hataraku ka?
doredakeno Ooisa wo motte iru ka?

wo simesu koto ga hituyô de aru.

Tikara no sayôsuru Ten wo "*Tikara* no *Sayôten*" to tonaeru. Mata *Sayôten* kara *Tikara* no Hôkô ni hiita Tyokusen wo "*Tikara* no *Sayôsen*" to tonaeru.

Tikara wo Du ni arawasu niwa, *Sayôten P* kara *Tikara K* no Hôkô ni, sore no Ooisa ni hireisuru Nagasa wo motta Ya wo hiite arawasu (Du 1).



Du 1.

3. ***Tikara no Tan'i.*** *Tikara* no Ooisa wo arawasu Tan'i niwa, notini (§ 139) tokiakasu *Zettai-tan'i* to iu no ga aru ga, hutûno zituyôzyôno Tan'i wa Situryô no iroirona Tan'i no Omosa de aru :—"Guramu no Omosa," "Kiroguramu no Omosa,"

“Pondo no Omosa,” “Kwan no Omosa” nado. Korera wo Tikara no *Dyûryoku-tan'i* to iu.

4. **Hansayô.** Buttai *A* ga Buttai *B* ni Tikara wo oyobosite iru tokiniwa, dôzini kanarazu *B* ga *A* ni Tikara wo oyobosu mono de aru. Korerano hutatuno Tikara no utide dotira ka hitotu dake wo mirutokini, sore wo “Tikara” to tonae, sore ni taisite mohitotuno Tikara wo “Hansayô” to tonaeru.

Hansayô ni tuitewa tugino Hôsoku ga aru (§ 151):—

Tikara (Sayô) to sore no Hansayô to wa Ooisa ga hitosikute, Hôkô ga tyôdo hantai de aru.

Tumari, Tikara ga hataraku tokini, soko ni okonawareru Kotogara wa, kanarazu hutatuno Buttai no Osiâi matawa Hikiai de aru; sosite sono Osiâi matawa Hikiai no Tikara ga tagaini hitosikute, tyôdo hantaino Hôkô wo motte iru no de aru.

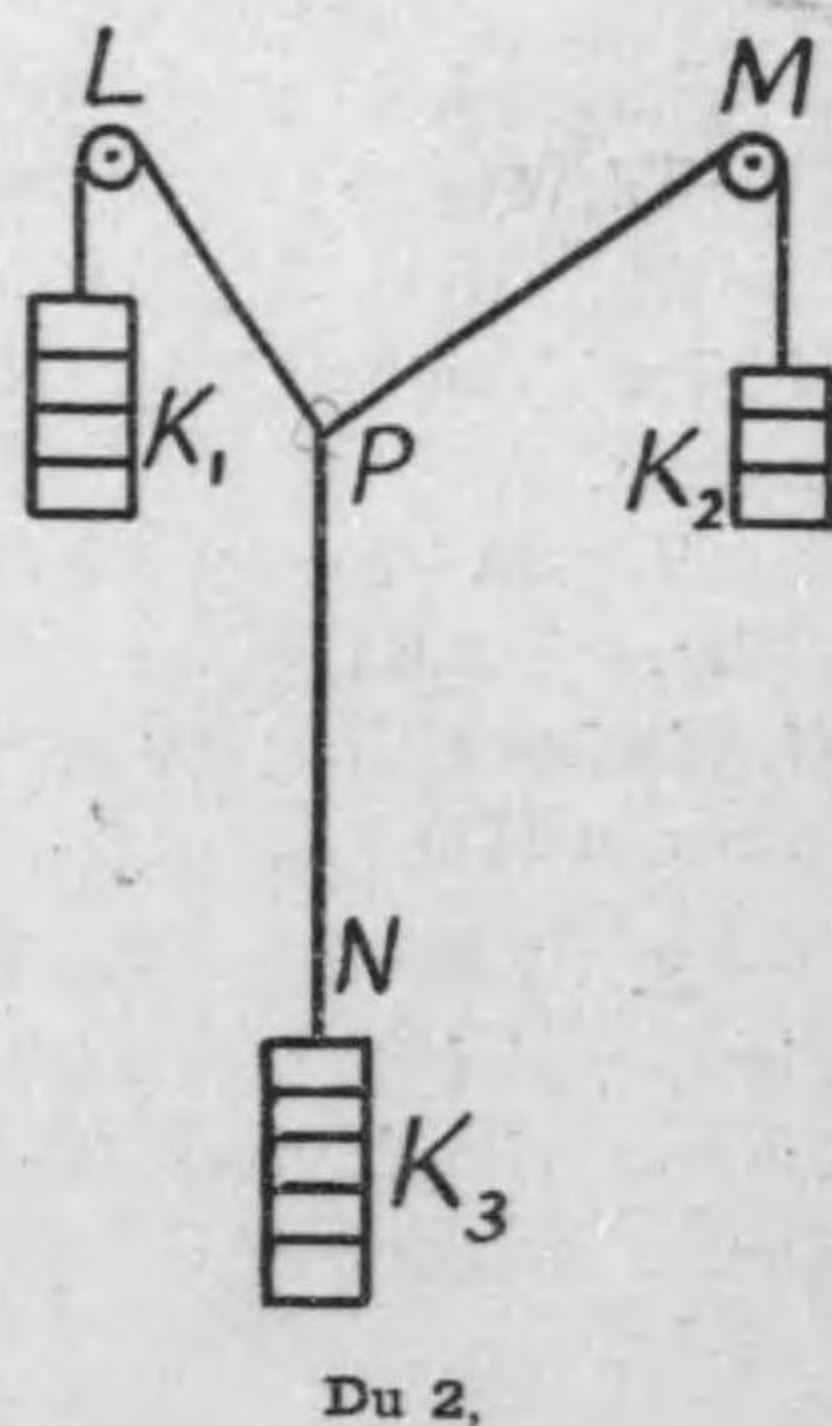
5. **Tikara no Turiai.** Hitotuno Ten matawa Buttai ni ikutu kano Tikara ga hataraitte iru kekkwa, Tikara ga mattaku hataraitte inai to onazi de aru Baai ni, “sorerano Tikara ga turiatte iru” to iu.

Seisisite iru Buttai ni hataraku Tikara ga turiatte iru tameni, Buttai ga hikituduki seisisite iru tokini, “Buttai ga turiatte iru” to iu.

Kono Syô dewa hitotuno Ten ni hataraku Tikara no Turiai dake wo siraberu.

6. **Hitotuno Ten ni hataraku mittuno Tikara no Turiai.** Mittuno Tikara ga hitotuno Ten ni hataraitte turiau Baai no Kwankei wa Du 2 no yôna Sôti de zikkentekini siraberareru.

Sanbonno hosoi Ito wo hitotuno Ten *P* de musubitukete, nihon wa namerakani mawaru Kuruma *L, M* ni kakete, sore no Hazi ni K_1, K_2 no Omori wo kake, nokorino Ito *PN* niwa tyokusetuni K_3 no Omori wo kakeru. Omori ya Ito ga hokano Mono ni



Du 2,

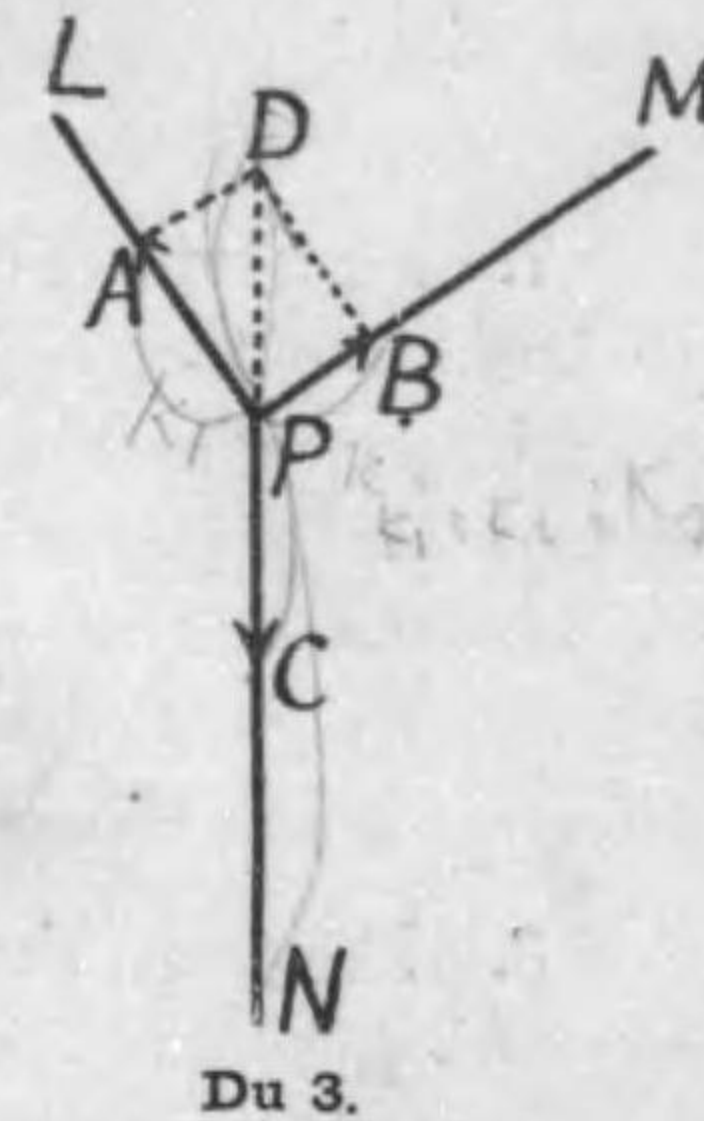
sawaranaide, Sôti zentai ga seisisite iru Baai niwa, Ten *P* niwa Tikara K_1, K_2, K_3 ga Ito no Hôkô ni sayôsise, turiatte iru⁽¹⁾. Konotoki Ito wa tagaini *kimatta Kakudo* wo nasite seisisuru: kotosarani Musubime no Iti wo (Te de tukande) kaete mitemo, sore wo hanaseba, subeteno Ito ga motono Muki ni kaette seisisuru.

Konoyôni kimatte iru mittuno Ito no Hôkô wo Kami ni utusitotte, Du 3 no yôni, *PN* wo ueni nobasita Sen no ueno kattena Ten *D* kara *PL* to *PM* ni heikôna Tyokusen *DB, DA* wo hiite, *PM, PL* tono Kiriaiten *B, A* wo motome, *PA, PB, PD* no Nagasa wo hakatte miruto, tugino Kwankei ga okonawareru koto ga sireru:—

$$PA : PB : PD = K_1 : K_2 : K_3.$$

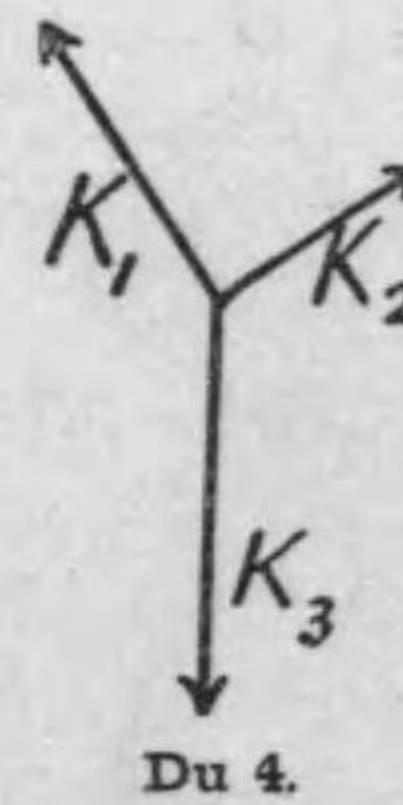
Ima *PN* no Hôkô ni *PC* wo *PD* ni hitosiku toreba, *PA, PB, PC* no *Ya* ga sorezore K_1, K_2, K_3 no Tikara wo daihyôsuru koto wa akiraka de aru. Soreyueni,

Ten P ni hataraku mittuno Tikara ga turiau tokiniwa, sorerano Tikara wo daihyôsuru Ya PA, PB, PC wo (sorezoreno Tikara no Hôkô ni, Ooisa ni hireisite) hiite, sorera no utino hutatu *PA PB* wo Hen to suru Heikôsihenkei wo tukuruto, sore no *P* wo tôru Taikakusen *PD* wa, *PC* to hantaino Hôkô ni hitotuno Tyokusen wo nasite, katu Nagasa ga sore ni hitosii.

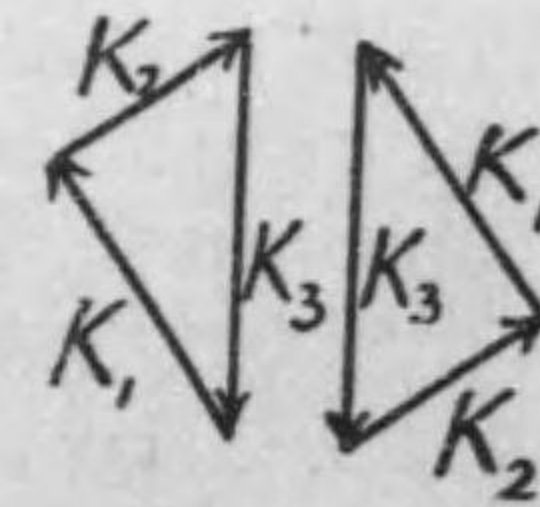


Du 3.

Onazi Kwankei wo, tatoeba Du 4 no Tikara no Turiai wo Du 5 no yôni site iiarawasu koto mo dekiru. Hitotuno Tikara (K_1) wo arawasu *Ya* no Yasaki kara, tugino Tikara (K_2 matawa K_3) wo arawasu *Ya* wo hiki, sore



Du 4.



Du 5

⁽¹⁾ Kono Baai ni *PL, PM* no Ito ga Hazi ni kaketa Omori no Omosa to hitosii Tikara de onôno zibun no Hôko ni Ten *P* wo hiite iru to iu koto wa koko de wa tada kôiu Sôti ni tuite Zikken kara sireta Zizitu da to suru.

no Yasaki kara nokorino Tikara wo arawasu Ya wo hikuto, sore no Yasaki ga tyôdo hazimeno Tikara no Yaziri ni ittisuru.

Tyûi. Ueno yôna Zikken ya Sokutei niwa Seimitusa ni Kagiri ga aru kara, sore dake wo Moto ni site ueno Hôsoku ga *seimituni* tadasii koto wo mitomeru wake niwa yukanai. Sikasi, kono Hôsoku wo tukatte keisansite eta Kekkwa ga donna Baai nimo Zissai to tigatte inai to iu *Zisitu* kara, wareware wa ueno Hôsoku ga *seimituni* tadasii mono to mitomeru no de aru.

7. Hutatuno Tikara no Turiai. Hitotuno Ten P ni K_1 , K_2 no hutatuno Tikara ga hataraite turiau Baai wa ueno Du de PD ga rei ni naru Baai de aru. Sore niwa, PA to PB to ga hitosikute tyôdo hantaino Hôkô ni nakereba naranai. Soreyueni,

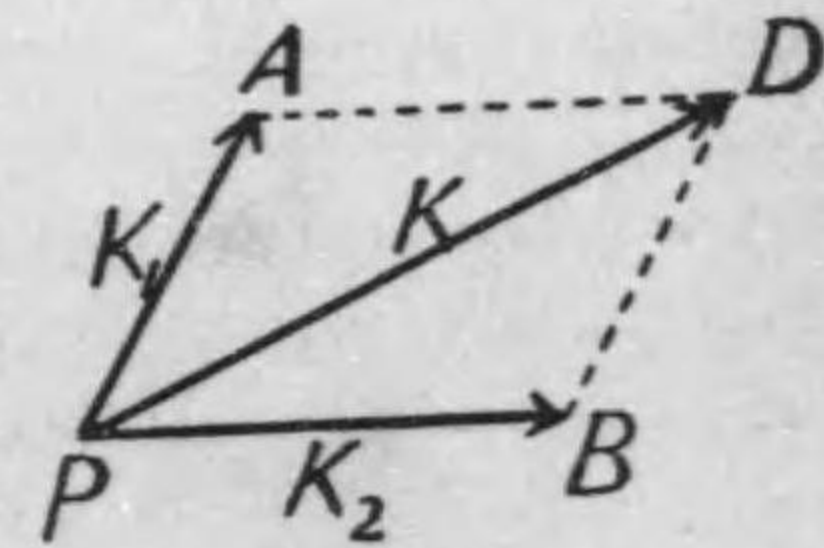
Hitotuno Ten ni hataraku hutatuno Tikara no turiau no wa, sorera ga Ooisa ga hitosikute, onazi Tyokusen ni sôte hantaini hataraku Baai ni kagiru.

8. Hitotuno Ten ni hataraku hutatuno Tikara no Gôryoku. Ippanni, hitotuno Ten matawa Buttai ni ikutu kano Tikara ga hataraku koto no Kekkwa ga, aru tada hitotuno Tikara ga hataraku no to onazi de aru tokini, kono hitotuno Tikara wo sorerano ikutu kano Tikara no *Gôryoku* to nadukeru; sosite *Gôryoku* ni taisite, sore to dôtona ikutu kano Tikara wo *Bunryoku* matawa *Seibun* to iu.

Ikutu kano Tikara kara, sorera no *Gôryoku* wo tukuru koto wo, sorerano Tikara wo *gôseisuru* to tonaeru.

Du 3 no Baai ni, $K_1 (=PA)$ to $K_2 (=PB)$ to ga hataraite $K_3 (=PC)$ to turiate iru. Sikaruni, hitotuno Tikara de K_3 to turiau no wa, maeno § ni yotte, PD de daihyôsareru Tikara de aru. Soreyueni (Du 6),

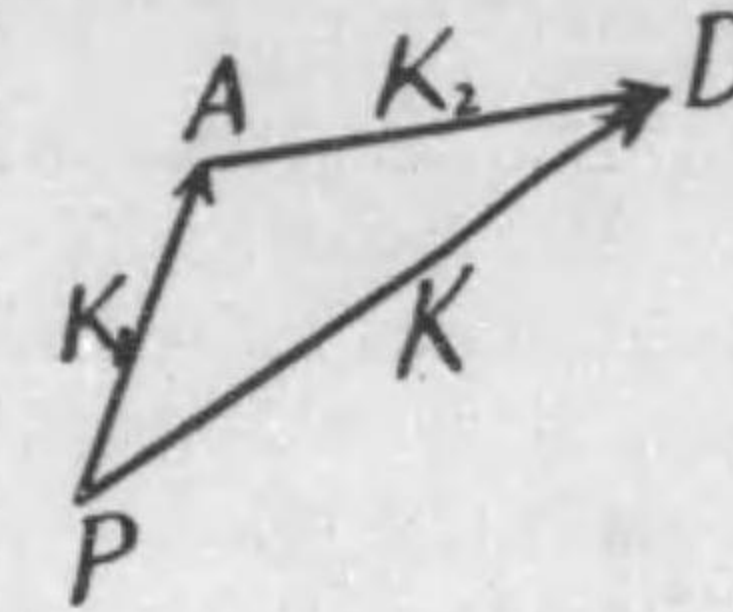
Ten P ni hataraku tokorono, PA PB de arawasareru hutatuno Tikara no Gôryoku wa, PA to PB wo Hen to suru Heikôsihenkei no P wo tôru Taikakusen PD de arawasareru Tikara de aru.



Du 6.

Kono Sakuduhô wo “Tikara no Heikôsihenkei” to tonaeru.

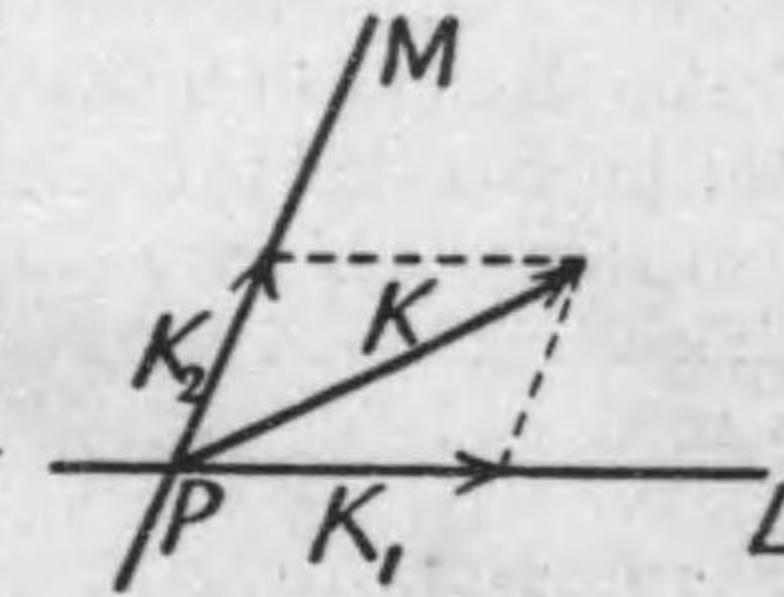
9. Tikara K_1 to K_2 to no Gôryoku wo motomeru no ni, Du 7 no yôni, Ten P kara K_1 wo daihyôsuru Ya PA wo kaki, sore no Yasaki A kara K_2 wo daihyôsuru Ya AD wo kaki, sore no Yasaki D e P kara Sen wo hiitemo yoi. Kono Sen PD de arawasareru Tikara ga K_1 , K_2 no *Gôryoku* K de aru. Kono Sakudu wo “Tikara no *Sankakukei*” to tonaeru.



Du 7.

Tyûi. “Tikara no *Sankakukei*” wa *Gôryoku* no Hôkô to Ooisa dake wo siru tameno Sakudu de atte, Sayôsen no Iti wa sore dewa tadasiku arawarenai.

10. Tikara no Bunkai. Ataerareta Tikara K no Sayôsen wo hukumu Heimen de hutatuno Hôkô PL , PM wo ataeru tokiniwa (Du 8), sorerano Hôkô ni okeru K no *Bunryoku* K_1 , K_2 wa, Du 8 ni simesu yôni, mattaku kimaru. K kara konoyôna K_1 , K_2 wo kimeru koto wo “Tikara K wo PL , PM no Hôkô ni *bunkaisuru*” to tonaeru.

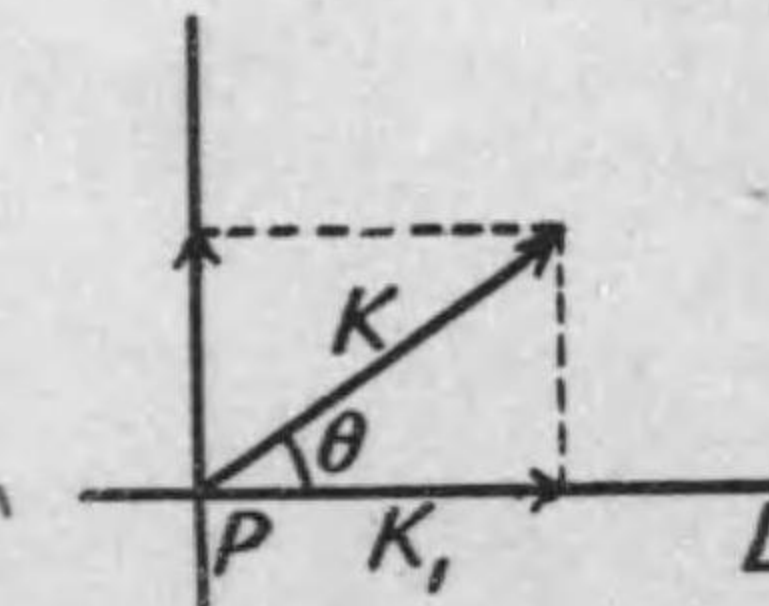


Du 8.

11. Tikara no Tyokkaku-seibun. “Ooisa K no Tikara no, aru Hôkô PL no (matawa aru Tyokusen PL ni sôta) *Tyokkaku-seibun*” to iu no wa (Du 9), sore (K) wo sono Hôkô (PL) to sore ni *suityokuna* Hôkô to ni *bunkaisita* Baai no, sono Hôkô no *Bunryoku* K_1 no koto de aru. K to PL to no aidano Kaku wo θ to sureba, PL -Hôkô no *Tyokkaku-seibun* K_1 no Ooisa wa tugino Siki de ataerareru:—

$$K_1 = K \cos \theta.$$

Tyûi. Kono Siki wa θ ga 90° yôrimo ôkikutemo okonawareru. Konotoki K_1 ga huno Ryô ni naru koto wa, motomeru



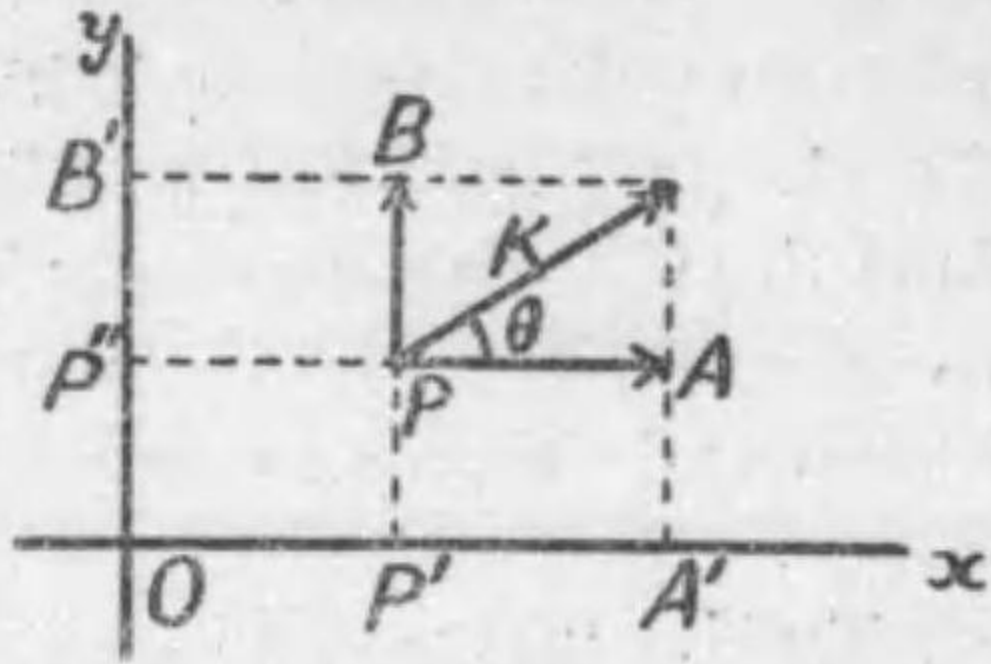
Du 9.

Tyokkaku-seibun ga PL to hantaino Hôkô ni multe iru kôto wo imisuru.

12. Zahyôdiku no Hôkô no Bunryoku. Tikara (Ooisa K) no Sayôsen ga Tyokkaku-zahyôdiku x, y no Heimen ni, atte, x -Diku to Kaku θ wo nasu tokiniwa (Du 10),

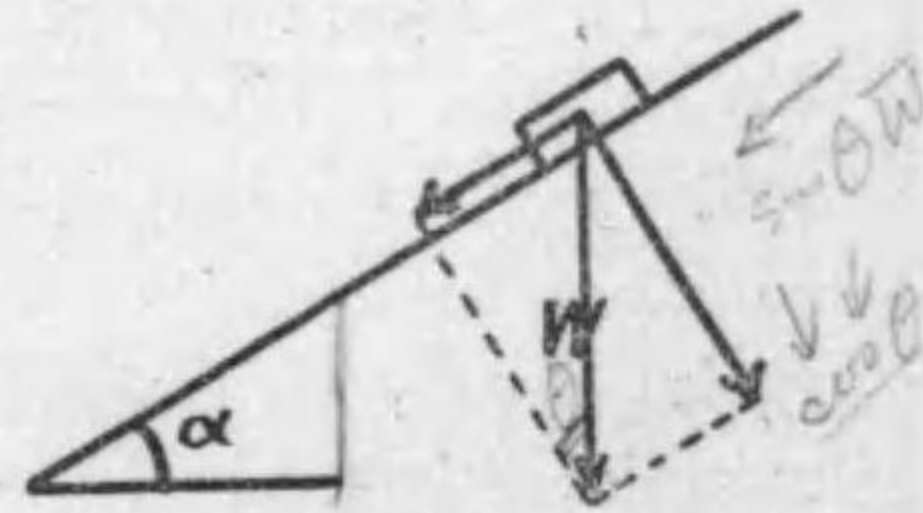
Tikara no x -Seibun $X = K \cos \theta$,
 y -Seibun $Y = K \sin \theta$.

Korerano Siki mo θ no subeteno Atai ni taisite tadasii. Korera-no Seibun wa, K wo x -, y -Diku no ueni *syacisita* mono $P'A'$, $P''B'$ to onazimono de aru.



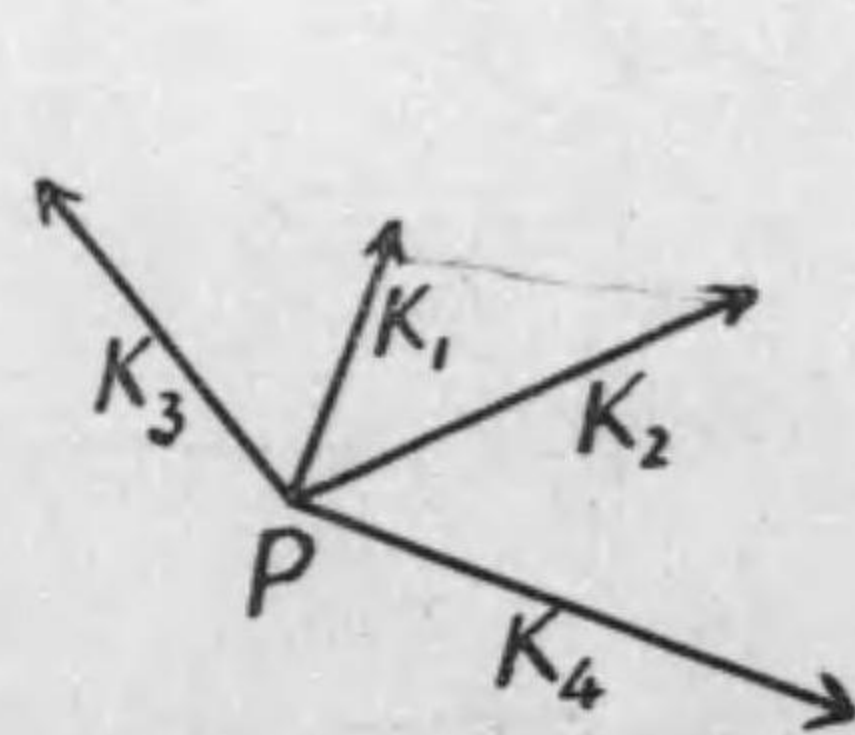
Du 10.

Mondai. Suiheimen ni taisite α dake no Katamuki wo motta Syamen ni notte iru Buttai ni hataraku Dyûryoku W wa, Syamen ni suityokuna Hôkô to heikôna Hôkô to ni ikura no Bunryoku wo motu ka?

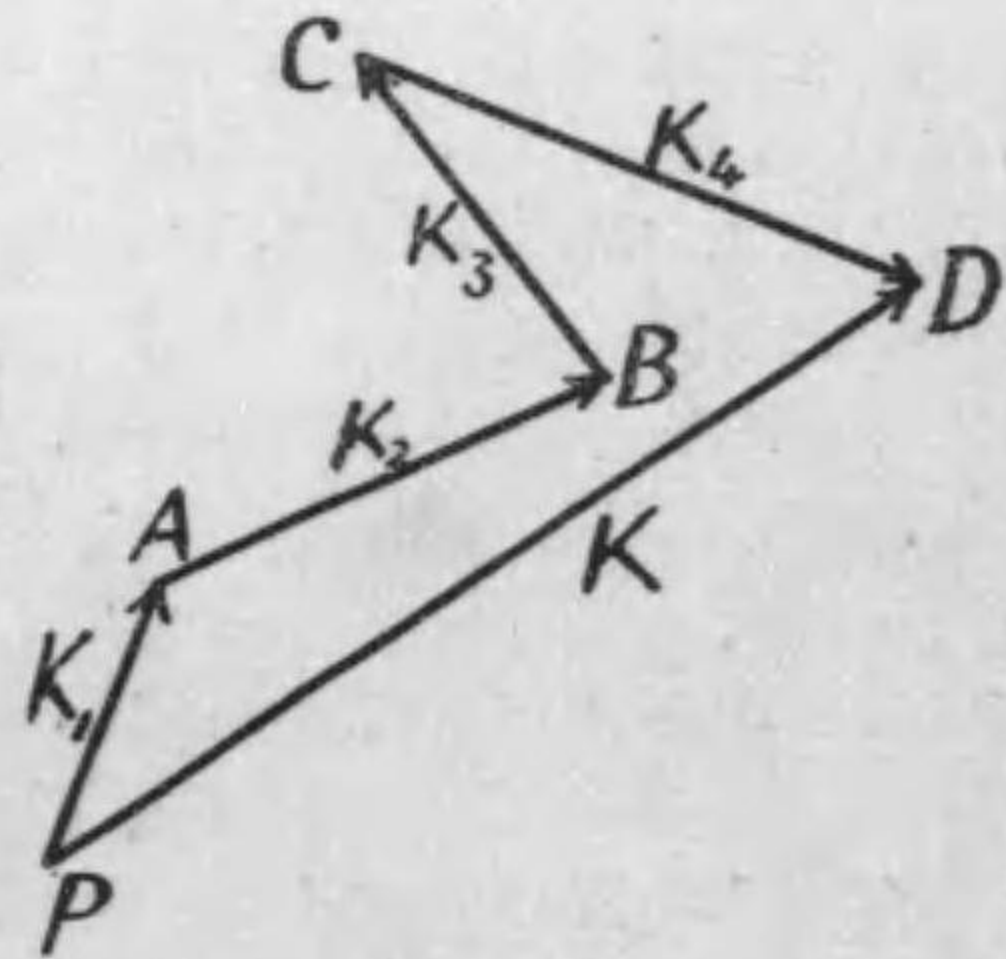


Du 11.

13. Hutatu izyôno Tikara no Gôryoku. Hitotuno Ten P ni hutatu yorimo ôkuno Tikara $K_1, K_2, K_3 \dots$ ga hataraku tokino (Du 12) Gôryoku wo motomeru no ni, Sayôten wa P to kimatte



Du 12.



Du 13.

iru kara, tada Tikara no Ooisa to Hôkô dake ni tuite kangae-reba yoi. Sore niwa, "Tikara no Sankakukei" wo tukatte, K_1 to K_2 to no Gôryoku PB (Du 13, Sen wa hiite nai) wo e, sore to K_3 to no Gôryoku PC wo e, sore to K_4 to no Gôryoku PD wo eru to iu yôni site, subeteno Tikara wo gôseisureba yoi.

Du 13 no yôna Sakudu wo site Gôryoku K wo motomeru Hôhô wo "Tikara no *Tahenkei*" to tonaeru.

Tokubetuna Baai tosite, Tikara ga subete onazi Tyokusen no ueni aru naraba, hitotuno Hôkô ni muku Tikara ni "+" Kigô wo, hantaina Hôkô no Tikara ni "-" Kigô wo soete korerano Tikara no Daisûwa wo keisansureba, sore no Ooisa ga Gôryoku no Ooisa wo arawasi, Kigô wa Hôkô wo kimeru.

14. Kaisekitekino Motomekata. Ataerareta subeteno Tikara ga Tyokkaku-zahyôdiku x, y no Heimen ni aru to si⁽¹⁾, sorera no Ooisa to, Sayôsen ga x -Diku to tukuru Kaku to wo

$$K_1, \theta_1; K_2, \theta_2; \dots$$

to si; Gôryoku no Ooisa to, Sayôsen ga x -Diku to tukuru Kaku to wo

$$K, \theta$$

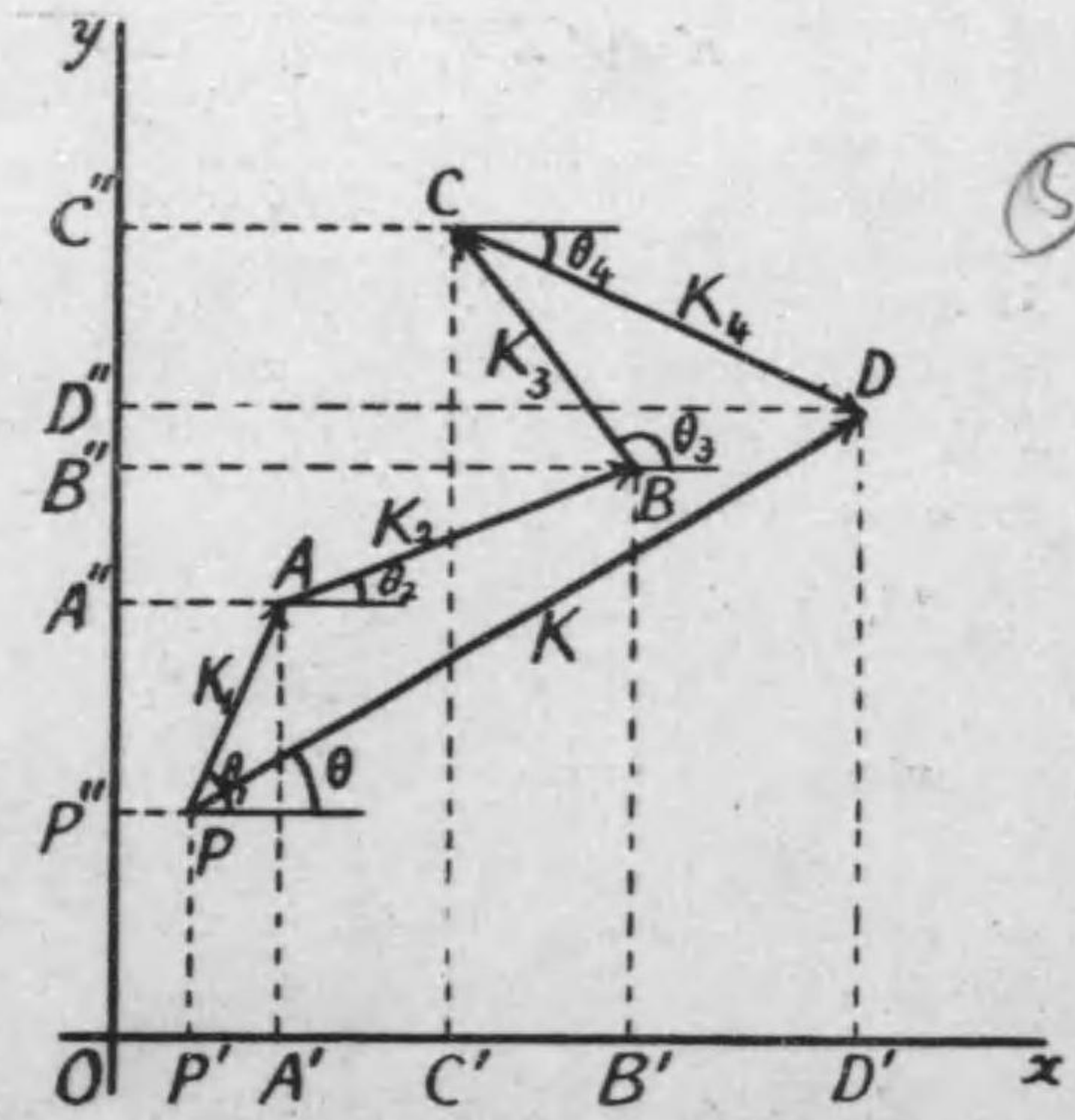
to suru. Mata atae-rareta Tikara no x -, y -Seibun wo sore-zore

$X_1 Y_1; X_2, Y_2; \dots$
 Gôryoku no x -, y -Seibun wo

$$X, Y$$

to suru. Sôsûreba, Du 14 de mieru tôri,

$$\begin{aligned} X &= K \cos \theta \\ &= P'D' \\ &= P'A' + A'B' \\ &\quad - B'C' + C'D', \end{aligned}$$



Du 14.

(¹) Subeteno Tikara ga hitotuno Heimen ni nai Baai wa Huroku § 293 ni aru.

Sikaruni,

$$P'A' = K_1 \text{ no } x\text{-Seibun} = X_1,$$

$$A'B' = K_2 \text{ no } x\text{-Seibun} = X_2,$$

$$-B'C' = K_3 \text{ no } x\text{-Seibun} = X_3,$$

$$C'D' = K_4 \text{ no } x\text{-Seibun} = X_4;$$

soreyueni,

$$X = K \cos \theta = X_1 + X_2 + X_3 + X_4.$$

Dôyôni,

$$Y = K \sin \theta = Y_1 + Y_2 + Y_3 + Y_4.$$

Tikara no Kazu ga ikutu attemo dôyô de aru koto wa akiraka de aru kara, ippanni,

$$\left. \begin{aligned} X &= K \cos \theta = \sum X_i = \sum K_i \cos \theta_i, \\ Y &= K \sin \theta = \sum Y_i = \sum K_i \sin \theta_i \end{aligned} \right\} \dots \dots (1).$$

Gôryoku no Ooisa to Hôkô to wa

$$\left. \begin{aligned} K &= \sqrt{(\sum K_i \cos \theta_i)^2 + (\sum K_i \sin \theta_i)^2}, \\ \tan \theta &= \frac{\sum K_i \sin \theta_i}{\sum K_i \cos \theta_i} \end{aligned} \right\} \dots \dots (2)$$

de ataerareru. Tadasî, Hôkô wa, $\tan \theta$ dake de miruto, tyôdo hantaina hutatuno Hôkô no uti dotira tomo kimaranai kara, $\sum K_i \cos \theta_i$ matawa $\sum K_i \sin \theta_i$ no Kigô wo mite, dotirano Hôkô de aru ka wo kimêru.

15. Ueni eta Kwankei

$$X = \sum X_i$$

wo mite tugino ippanno Teiri ga wakarû:—

Gôryoku no aru Hôkô no Tyokkaku-seibun wa, Bunryoku no onazi Hôkô no Tyokkaku-seibun no (daisûtekino) Wa ni hitosii.

16. Hitotuno Ten ni hataraku ôkuno Tikara no Turiai.

Hitotuno Ten ni hataraku ôkuno Tikara ga turiau no wa, Gôryoku ga rei de aru Baai de aru. Kore wa Du 13

de $PD=0$ ni naru Baai, sunawati anoyôna Toriatukai wo sita kekkwa, owarino Yasaki D ga P to ittisuru Baai de aru. Soreyueni,

Hitotuno Ten ni hataraku ikutu kano Tikara ga turiau no wa, sorerano Tikara de tukutta "Tikara no Tahenkei" ga todiru Baai de aru.

17. Kaisekitekini iiarawaseba, § 14 no (2) de $K=0$ ni naru tameni hituyô de zyûbunna Dyôken tosite,

$$\sum K_i \cos \theta_i = 0, \quad \sum K_i \sin \theta_i = 0 \quad \dots (1)$$

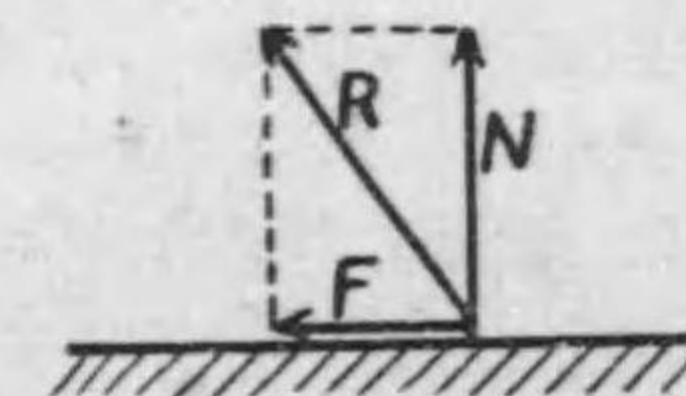
wo eru. Kore ga, hitotuno Heimen ni oite hitotuno Ten ni hataraku ikutu kano Tikara no Turiai no Dyôken de aru.

18. Men no Hankôryoku. Aru Buttai A ga hokano Buttai B no Men wo osu tokini, B no Men ga A wo osikaesu Hansayô wo B -Men no "Hankôryoku" to tonaeru.

Buttai oyobi Hyômen no Seisitu ni yotte, Hankôryoku ga Men ni suityokuni yori hokani hataraki enai Baai niwa, "kono Men ga nameraka de aru" to iu.

19. Mosi, Hankôryoku ga Men ni tateta Suityokusen ni taisite aru Kakudo wo nasu koto ga dekiru naraba, "kono Men ga arai" to iu.

Arai Men no Hankôryoku R wo, Men ni suityokuna Hôkô to heikôna Hôkô to ni bunkaisite (Du 15), Men ni suityokuna Bunryoku N wo "Suityoku-hankôryoku," Men ni heikôna Bunryoku F wo "Masatoryoku" to iu.



Du 15.

20. Masatoryoku no Hôsoku. Masatoryoku ni tuitewa, zikkentekino Torisirabe no Kekkwa tosite, tugino Hôsoku ga okonawareru koto ga sirete iru:—

(1) Masatoryoku wa, sore ga nakatta Baai ni hureatte iru hutatuno Buttai ga suberubeki Hôkô ni hantaina Hôkô (sunawati suberu koto wo samatageru yôna Hôkô) ni hataraku.

(2) Masaturyoku no Ooisa wa, sore no Suitiyoku-hankôryoku⁽¹⁾ ni taisuru Hi ga, hutatuno Buttai no Seisitu oyobi hureatte iru Hyômen no Seisitu ni yotte kimatte iru Atai (μ) wo kôenai Han'i ni oite, Hureai no Suberi wo samatageru no ni hituyôna dakeno Atai wo motu. Kono μ , sunawati (Masaturyoku / Suitiyoku-hankôryoku) no *saidaino* Atai wo "Masatu no Keisû" (matawa "Seisi no Masatu-keisû") to tonaeru.

(3) Masaturyoku $\leq \mu \times$ Suitiyoku-hankôryoku no Han'i de, hureatte iru Men no Suberi wo husegu ni tarinai Baai niwa, Suberi ga okori, katu Masaturyoku wa, Suberi wo samatageru Hôkô ni oite Suitiyoku-hankôryoku ni taisite kimatta Hi (μ') wo tamotu Ooisa wo motte hataraku. Kono μ' wo "Undô no Masatu-keisû" to tonaeru; ôkuno Baai ni μ' wa μ yorimo ikuraka tiisai Kazu de aru.

21. Ueno Hôsoku (2) wo tyokusetuni setumeisuru Zikken wa Du 16 no yôna Sôti de dekuru.

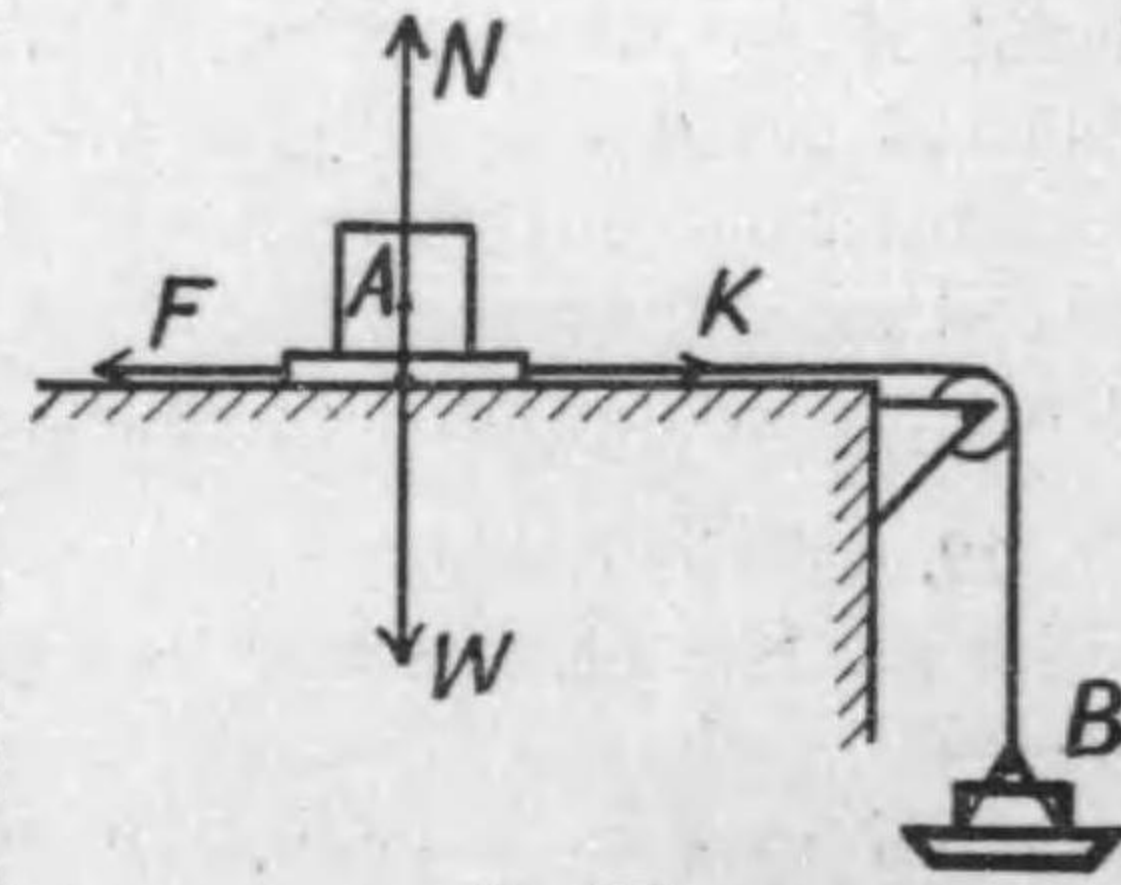
Suiheina Dai no ueni Ita wo oki, sore wo migini hipparu Ito wo tukete, Kwassya ni kakete, Omori B (Omosa, K) de hikaseru. Ita no ueni Omori A (Omosa, Ita wo awasete, W) wo okuto, Tikara no Hatarakikata ga Du no yôni natte, turiatte iru Baai niwa, tugino Kwankei ga okonawareru.

$$F=K, N=W.$$

Sidaini Omori no Omosa K wo masite, K ga aru Atai K_1 yorimo sukosi demo ôkii tokini Omori A wo noseta Ita ga suberidasu. Kono K_1 ga sunawati *saidaino* Masaturyoku F_1 ni hitosii.

Omori A wo iroironi kaete, sonotabigotoni K_1 sunawati F_1 wo kimeruto,

(1) Suitiyoku-hankôryoku wa, ataete aru ka, matawa hokano Zizyô ni yotte kimaru mono to suru.



Du 16.

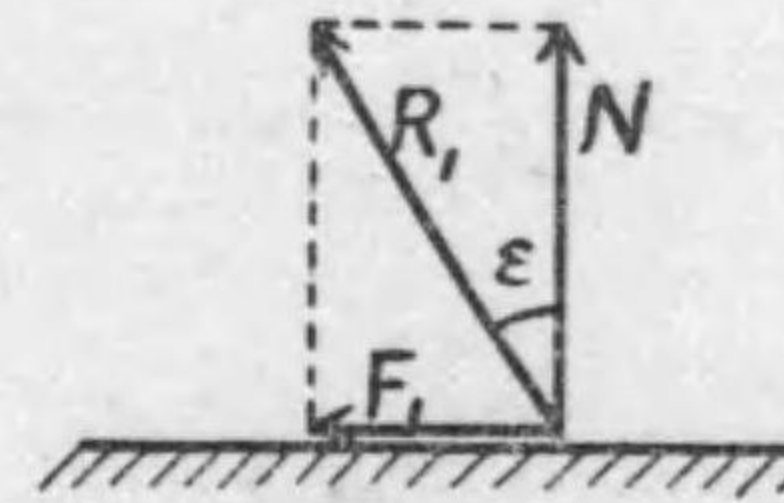
$$\frac{K_1}{W} \text{ sunawati } \frac{F_1}{N} = \mu$$

ga itumo kimatta Ooisa ni naru.

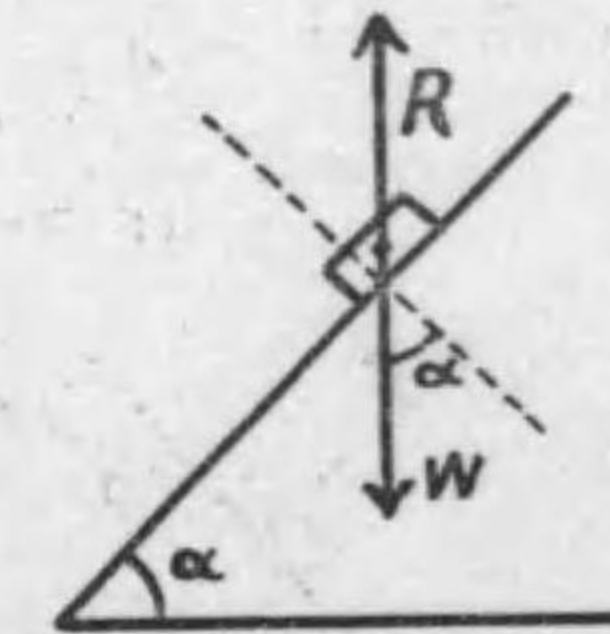
22. Ueno Hôsoku no Kekwa tosite, zentaino Hankôryoku R wa, Hureai-ten de Men ni tateta Suitiyokusen ni taisite kimatta Kaku ε yorimo ôkina Ooisa wo nasi enai. Kono Kaku ε wa μ ni taisite (Du 17)

$$\frac{F_1}{N} = \tan \varepsilon = \mu$$

no Kwankei wo nasu Kaku de, kore wo "Masatukaku" matawa "Seisikaku" to tonaeru.



Du 17.



Du 18.

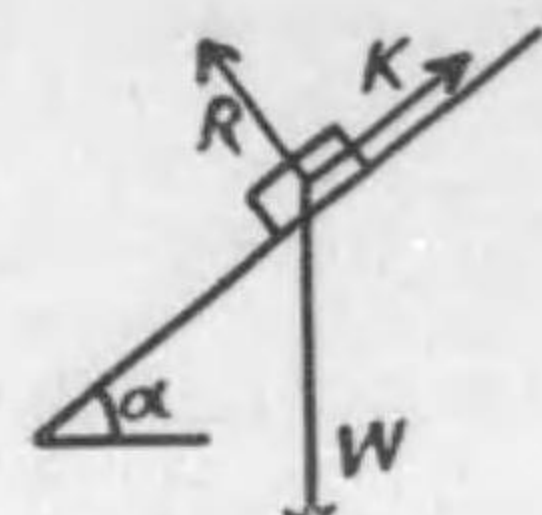
23. Arai Syamen no ueni, korogaranai yôna Buttai ga notte ite, suberazuni tomatte iru tokiniwa (Du 18), Hankôryoku wa Dyûryoku to tyôdo hantaini natte iru kara, Hankôryoku to Men no Suitiyokusen to no aidano Kaku ga Syamen no Katamuki no Kaku α ni hitosii. Soreyueni, kono Buttai ga suberitoinai Dyôken wa

$$\alpha \leq \varepsilon$$

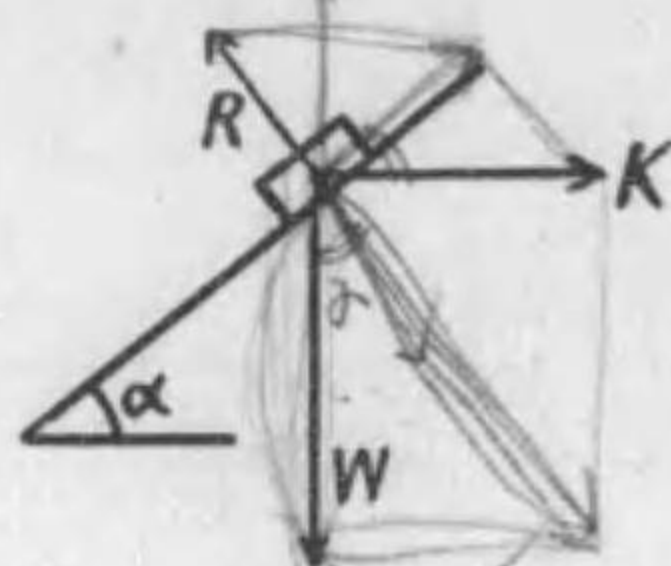
de aru.

"Seisikaku" to iu Kotoba wa kono Kwankei kara dete iru mono de arô.

24. Reidai 1. Suiheimen ni taisite Kaku α no Katamuki wo nasu namerakana Syamen no ueni aru Buttai wo saseru no ni ikura no Tikara K wo yôsuru ka? Kore wa sono Tikara no Hôkô ni yotte tigau; Syamen no Hankôryoku R mo dôyô.



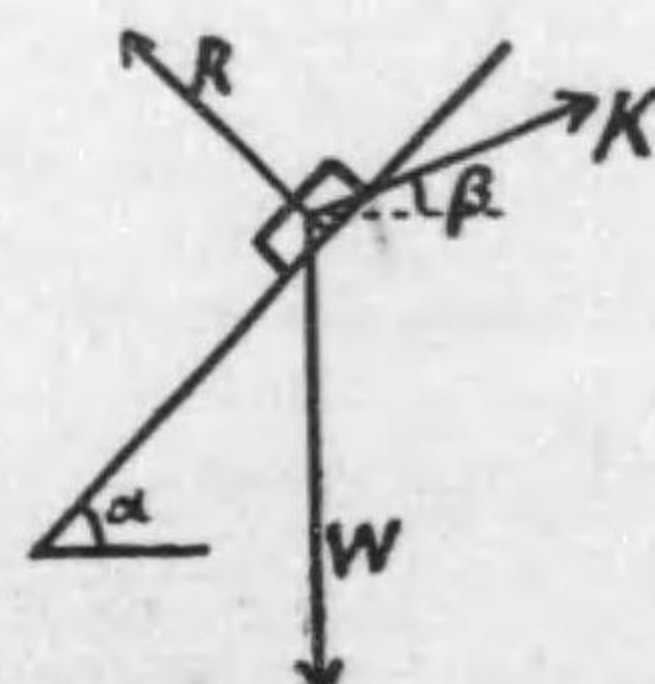
Du 19.



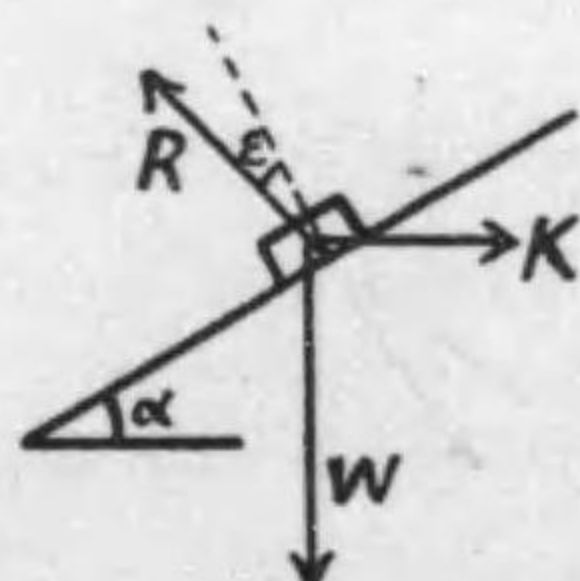
Du 20.

- (a) Syamen ni sôta Hôkô ni Tikara wo kuwaereba (Du 19),
 $K = W \sin \alpha, R = W \cos \alpha.$
 (b) K wo suiheini hatarakasereba (Du 20),
 $K = W \tan \alpha, R = W \sec \alpha.$
 (c) K ga Suihei-hôkô kara ue e Kaku β wo nasu Hôkô ni hatarakeba (Du 21),

$$K = W \frac{\sin \alpha}{\cos(\alpha - \beta)}, R = W \frac{\cos \beta}{\cos(\alpha - \beta)}$$



Du 21.



Du 22.

25. Reidai 2. Arai Syamen (Keisya= α , Masatukaku= ϵ) ni notte iru Buttai wo ueni osiageru no ni hituyôna saisyôno Tikara K wa ikura ka?

K ga Syamen ni heikô nareba,

$$K = W(\sin \alpha + \mu \cos \alpha) = W \frac{\sin(\alpha + \epsilon)}{\cos \epsilon};$$

K ga suihei nareba (Du 22), $K = W \tan(\alpha + \epsilon).$

Rensyû-mondai I.

1. Omosa 4 kg. no Buttai ni nihonno Ito wo torituke, sorera wo 2 kg. no Omosa ni hitosii Tikara to, 3 kg. no Omosa ni hitosii Tikara to de sasacru to sureba, Ito no Hôkô wa dô naru ka?

2. Omosa 4 kg. no Buttai ni nihonno Ito wo torituke, sorera wo 5 kg. no Omosa ni hitosii Tikara to, 6 kg. no Omosa ni hitosii Tikara to de sasacru to sureba, Ito no Hôkô wa dô naru ka?

3. Omosa 10 kg. no Buttai ga nihonno Tuna de sasacru arete iru. Sorerano Tuna no Entyokusen ni taisuru Katamuki ga 30° to 60° de areba, sorerano Tuna no Tyôryoku wa ikura ka?

4. Onazi Takasa de 2 m. hedatatta nihonno Kugi no aidani Ito wo massuguni hariwatasi, Mannaka ni 1 kg. no Buttai wo turisageta tokoro, Ito ga sukosi nobite, sono Ten ga 5 cm orita. Ito ga ikurano Tikara de hararete iru ka?

5. Hitotuno Ten ni hataraku tugino Tikara no Gôryoku no Hôkô oyobi Ooisa wo keisansei!

Suiheisen kara ue e 30° no Katamuki ni 10,
” ” 10° ” 5,
” sita e 10° ” 15.

6. Hitotuno Ten ni hataraku tugino Tikara no Gôryoku wo kimei!

$\theta = 0^\circ$ no Hôkô ni 10, $\theta = 60^\circ$ no Hôkô ni 20, $\theta = 150^\circ$ no Hôkô ni 30, $\theta = 240^\circ$ no Hôkô ni 15.

7. Omosa w kg. no Omori ga Nagasa l m. no Tuna de ugokanai Ten ni turusite aru. P kg. dakeno Tikara de sore wo suiheini hiite sasacru oku tokini, Omori ga suiheini iku-m. hikarete iru ka?

8. Omosa w kg. dutu no hutatuno Buttai A, B ga Ito no Ryôhazi ni tunaide aru. A wa namerakana Syamen (Suiheimen ni taisuru Katamuki no Kaku= 30°) ni natte iru; soko kara Ito ga Syamen ni heikôni ueni itte, Kwassya ni kakatte, sore

kara sakino Bubun wa entyokuni tarete, suiheina Ita no ueni aru Buttai B ni musubitukete aru. B to Ita to no osiau Tikara wa ikura ka?

9. Arai suiheina Ita no ueni aru Buttai (Omosa w kg.) ni Tuna wo tukete suiheini ugokasô to suru no ni, Tuna wo hiku Hôkô (Suiheisen ni taisite ue e α) ni yotte Tikara ga dô kawaru ka? Tikara ga itiban tiisakute sumu Hôkô wa dore ka? Tadasî, suiheina Ita no Masatukaku wo 30° to suru.

10. Hitotuno Syamen no ueni Buttai A (Omosa w_1) to Buttai B (Omosa w_2) to ga atte, Ito de tunaide aru. A no Masatu-keisû ga μ_1 , B no Masatu-keisû ga μ_2 ($\mu_1 > \mu_2$) de aru naraba, Syamen no Katamuki wo sidukani masu tokini donna Koto ga okoru ka? Tadasî, Ito wa saidaino Katamuki no Hôkô ni aru.

15th March
S.M.

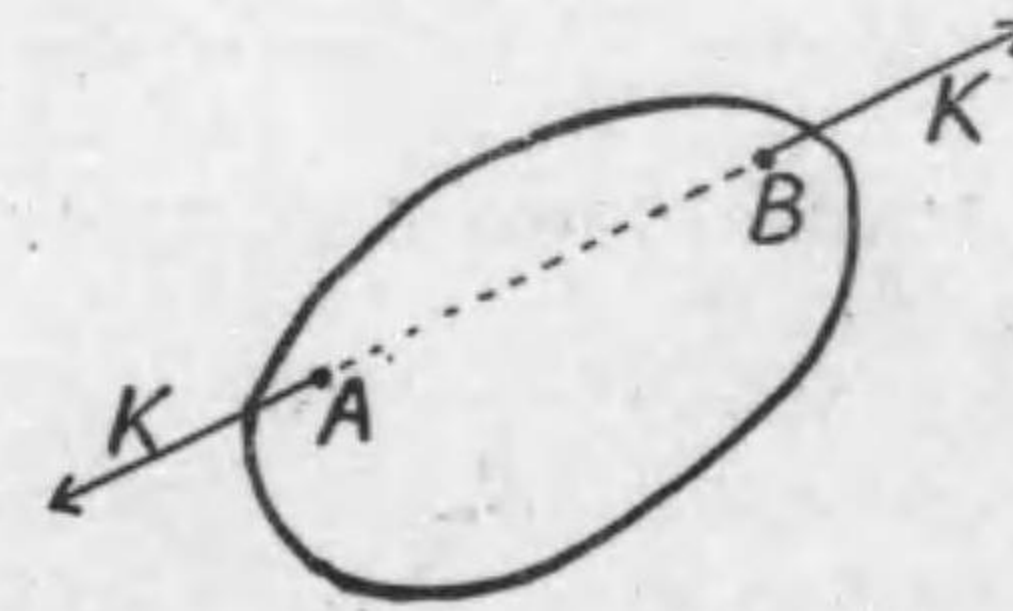
$T \sin \alpha = \dots$
 Du

SYOO II.

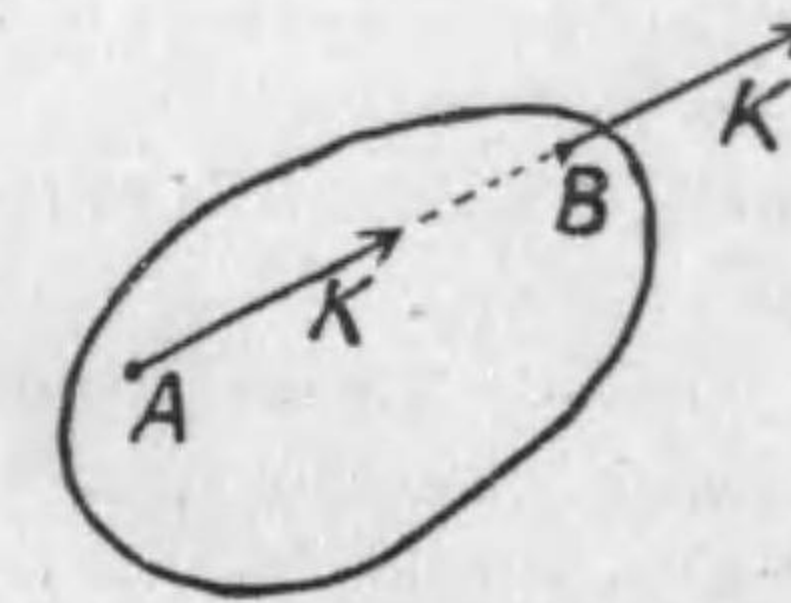
Gôtai no Turiaî.

31. Gôtai. Hoka kara Tikara ga hataraitemo, Ooisa mo Katati mo kawaranai Buttai wo "Gôtai" to tonaeru.

32. Sayôsen no Hôsoku. Gôtai no utino hutatuno Ten A, B ni, sorera wo musubu Tyokusen ni sôte, Ooisa no hitosii Tikara ga hantaino Hôkô ni hataraku tokiniwa (Du 31), korerano hutatuno Tikara wa turiatte iru. Kore wa wareware ga Keiken



Du 31.



Du 32.

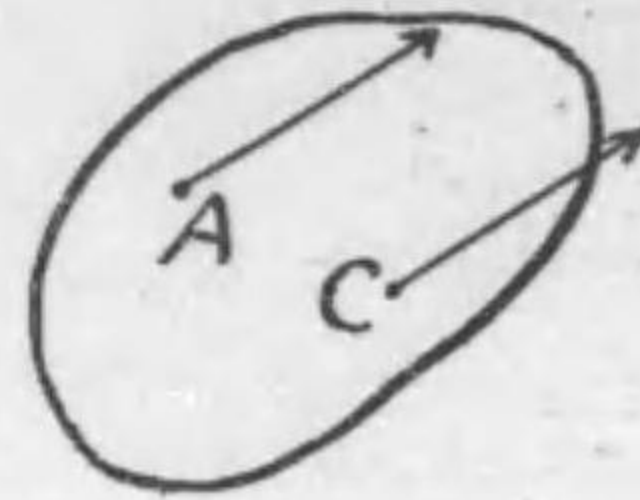
karamo Zikken karamo sitte iru Koto de aru.

Kono Zizitu kara tugino Koto ga wakarû:—

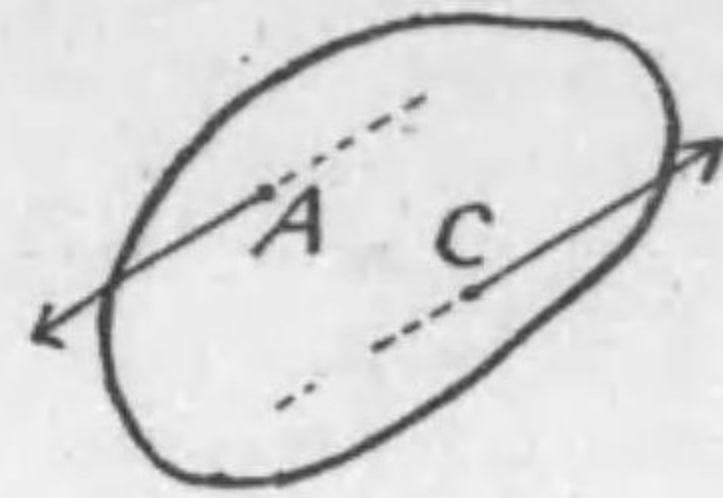
Ataerareta Hôkô oyobi Ooisa wo motte, ataerareta Sayôsen ni sôte hataraku Tikara wa, Sayôten ga tigatte itemo, subete dôto de aru.

Tatoeba, Du 32 no A ni hataraku Tikara K to B ni hataraku K to wa dôto de aru.

33. Hôkô to Ooisa ga onazi de attemo, Sayôsen ga tigau Tikara (tatoeba Du 33 no C ni okeru K to A ni okeru K no yôna mono) wa dôto de nai koto wa, katakata wo hantaini totta Baai (Du 34) wo kangaereba wakarû. Kono Baai niwa,



Du 33.



Du 34.

hutûno Keiken karamo wakarû tôri, Gôtai ga tomatte inaide, (Du no Baai naraba hidari-mawarini) mawaru; sunawati, Du 34 no yôna hutatuno Tikara wa tagaini turiawanai. Sitagatte, C to A to ni oite *onasi* Hôkô ni totta hitosii Tikara K wa tagaini dôto dewa nai.

34. Tikara no Moment. Sayôsen ga tigau tameni, Tikara no Sayô no tigau koto wa "Moment" to tonaeru Ryô de arawasareru.

Madu, Tikara ga hitotuno kimatta Heimen ni aru Baai dake ni tuite noberu⁽¹⁾.

"Hitotuno Tikara K no, aru Ten O no mawarino Moment", motto kuwasiku ieba, "O wo tôsite Tikara no Sayôsen to O to wo hukumu Heimen ni suitokuni hiita Tyokusen (Diku) no mawarino, Tikara K no Moment" wa, Tikara no Ooisa to, Ten O kara Tikara no Sayôsen ni itaru Kyori to no Zyôseki de aru.

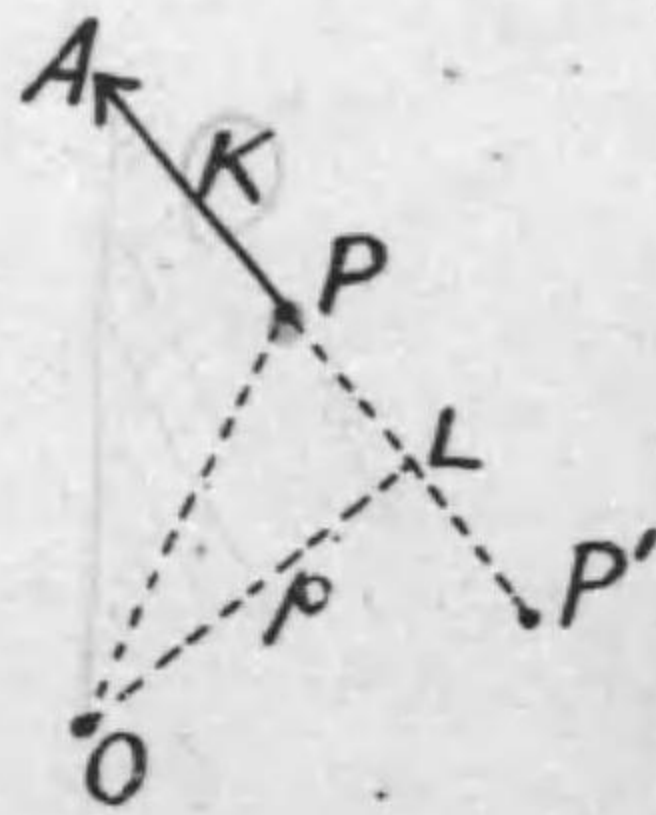
Du 35 de, Tikara K ga Ten P ni hataraku to sureba, O kara Tikara no Sayôsen ni otosita Suisen-kyori wo $OL=p$ to site, Tikara K no, Ten O no mawarino Moment wa

$$G = K \times p \dots\dots\dots(1).$$

p wo "Tikara K no Ude no Nagasa" to iu.

Mata, Tikara no Daihyôsen wo PA to toreba,

⁽¹⁾ Motto hiroi Baai, sunawati Tikara no Sayôsen ga Diku ni suitokoku de nai Baai no Moment no Teigi wa § 68 ni aru.



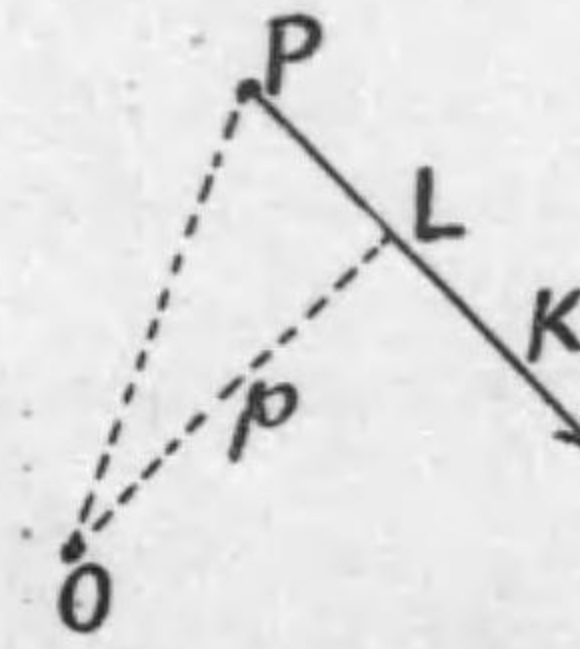
Du 35.

$$\text{Moment} = 2(\Delta OPA \text{ no Menseki}) \dots\dots\dots(2)$$

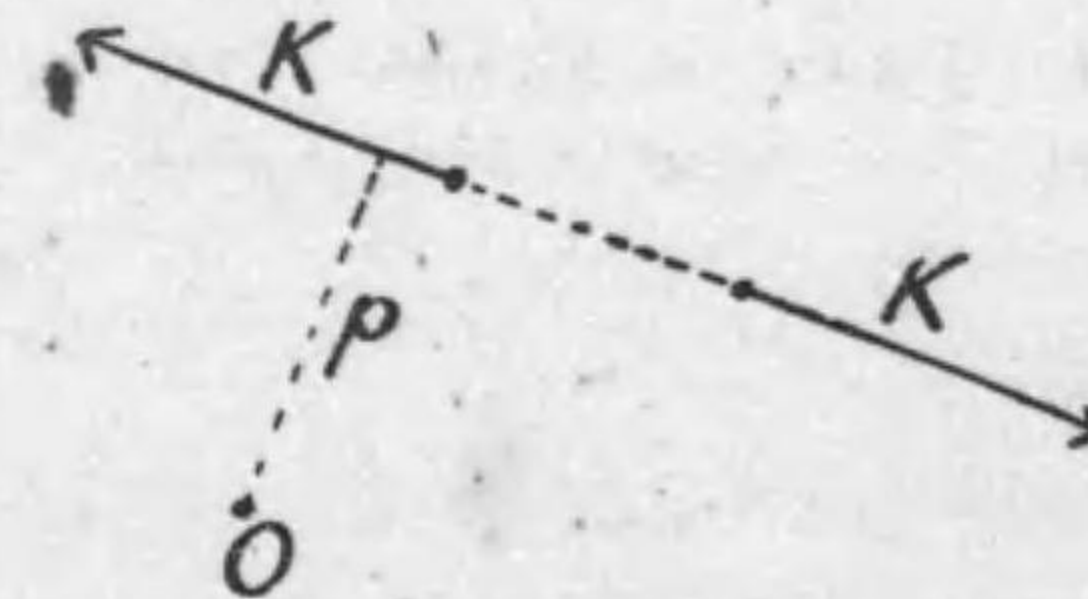
no Kwankei ga aru.

Tyûi. Tikara no Hôkô, Ooisa, Sayôsen ga kimatte oreba, Sayôten P ga doko ni attemo Moment ni Kawari ga nai. Tatoeba, Du 35 no Baai ni Tikara K ga P ni hataraku no to P' ni hataraku no to Moment ni Tigai ga nai.

35. Moment niwa Hugô wo soete toriatukau. Tûzyô O kara mite hidari-mawasino (sunawati Tokei no Hari to hantaino) mono wo *sei* (+) to si, migi-mawasino mono wo *hu* (-) to suru. Tatoeba, Du 35 no Baai niwa Tikara K no O no mawarino Moment ga $+Kp$ de ari, Du 36 no Baai niwa, sore ga $-Kp$ de aru.



Du 36.



Du 37.

Tyûi. Hitotuno Sayôsen ni sôte hitosii Ooisa K no Tikara ga hutatuno hantaino Muki ni hataraku tokiniwa (Du 37), korerano Tikara ga tagaini turiau (§ 32) to dôzini, sorera no Moment no dai-sûtekino Wa ga $(+Kp) + (-Kp) = 0$ de aru.

36. Du 38 de P ni hataraku Tikara K no O no mawarino Moment wa,

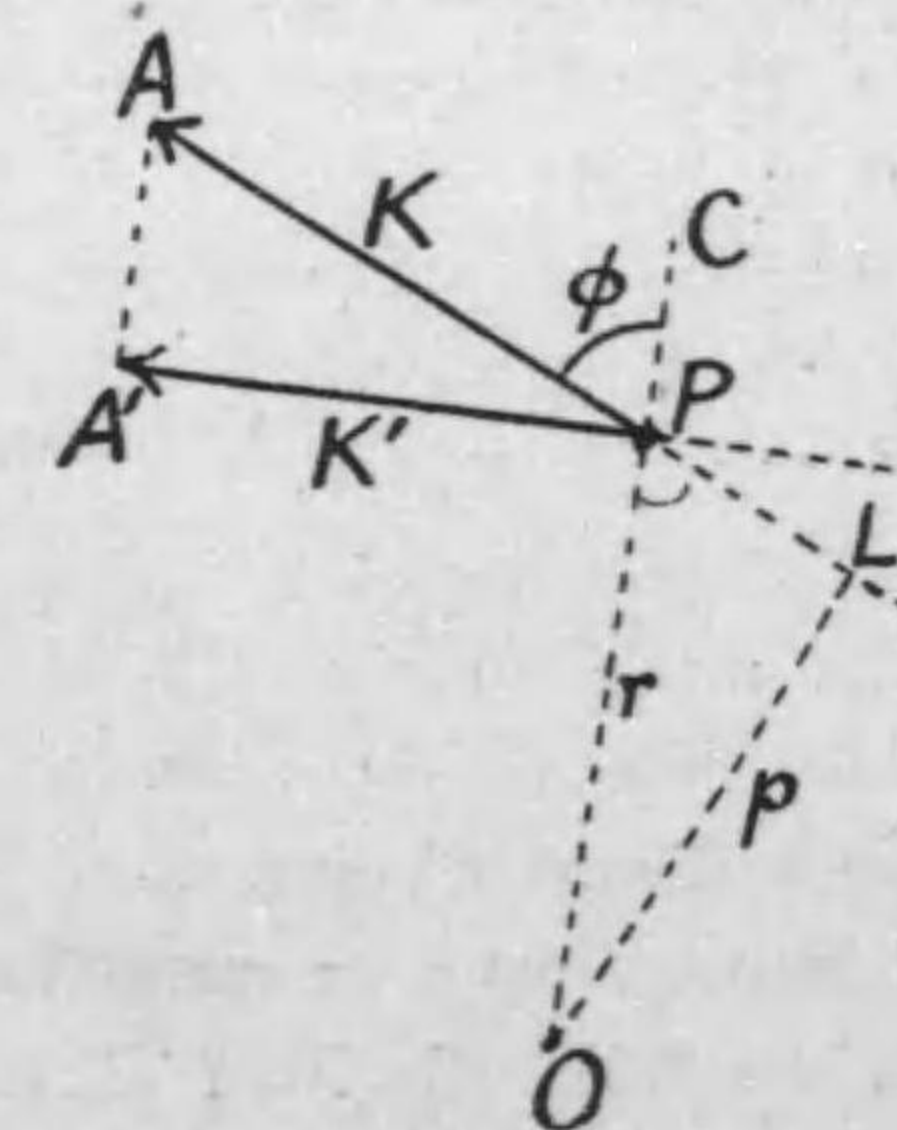
$$OP = r,$$

Kaku (OP, Tikara no Hôkô)

$$= \angle CPA = \varphi$$

to toreba,

$$\text{Moment} = Kr \sin \varphi \dots\dots(3)$$



Du 38.

to kaku koto mo dekiru.

Mata, Tikara no OP ni suitiyokuna Tyokkaku-seibun wo K' to sureba,

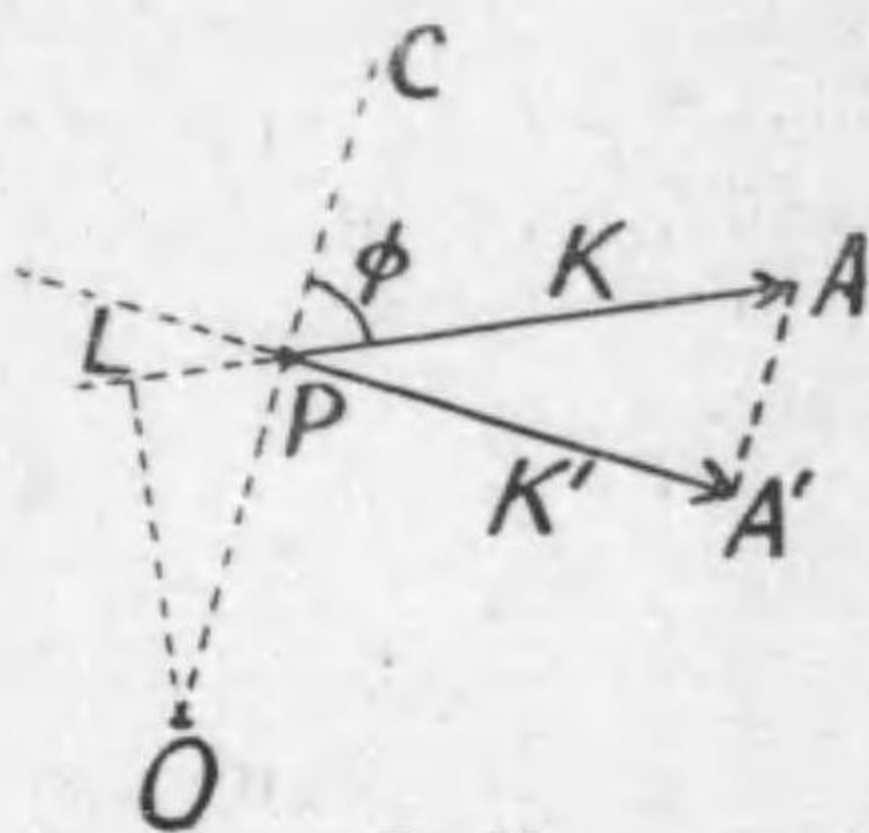
$$\text{Moment} = Kr \sin \phi = K'r \dots \dots \dots (4)$$

to kaku koto mo dekiru.

Korerano Siki (3) to (4) wa, ϕ to K' to ni Kigô wo hukumasete tukaeba, Moment ga hu de aru Baai nimo, sonomama tadasii. Sunawati, O kara P ni mukatte miru Hito no Hidarite ni mukau ϕ oyobi K' wo (+), Migite ni mukau ϕ oyobi K' wo (-) (Du 39) to toreba, — K .wa itumo (+) ni toru to kimete—

$$\text{Moment} = Kr \sin \phi = K'r$$

wa Kigô ni oitemo, Ooisa ni oitemo itumo tadasii.



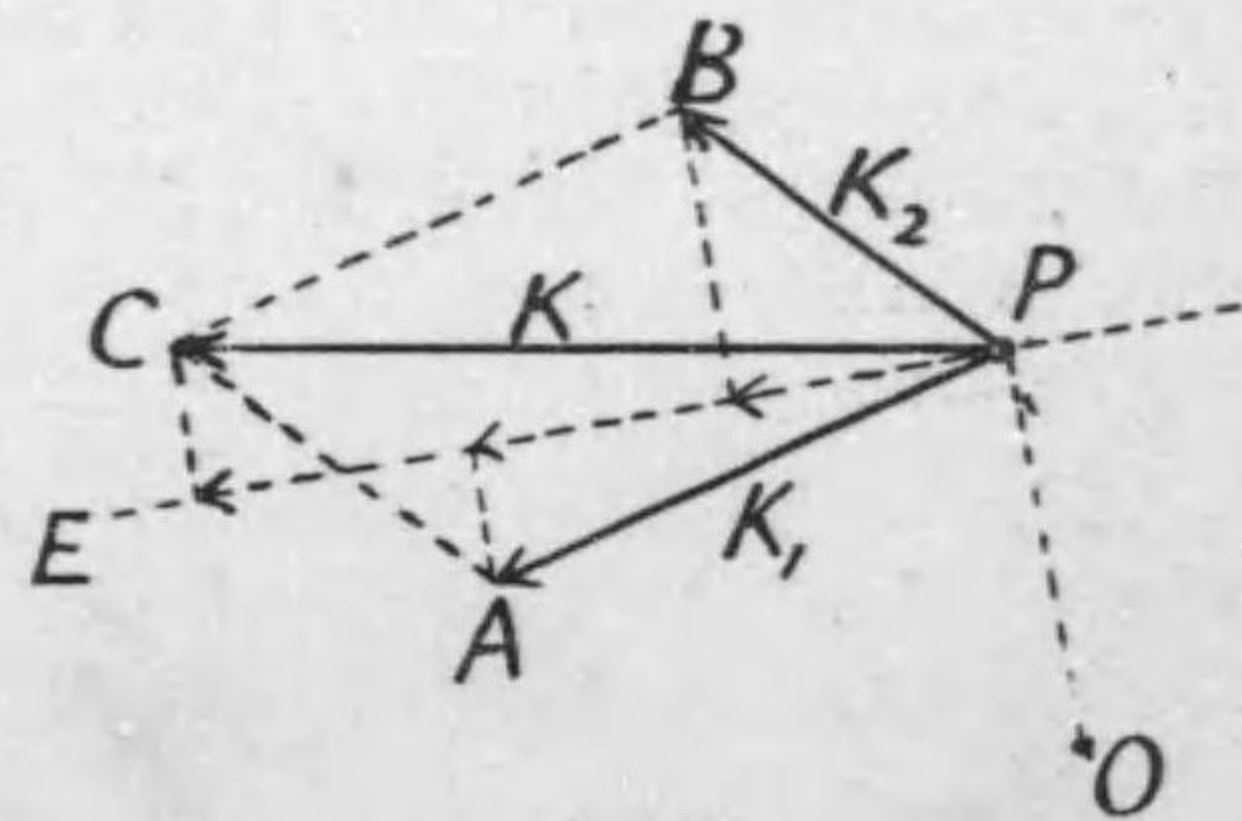
Du 39.

37. Moment no Teiri. Hitotuno Ten P ni hataraku ikutu kano Tikara no, hokano Ten O no mawarino Moment no Wa wa, onazi Ten P ni okeru Gôryoku no, Ten O no mawarino Moment ni hitosii.

Madu hutatuno Tikara ni tuite syômeisuru.

Tikara K_1, K_2 ga, Ten P (Du 40) ni hataraku mono to site, Gôryoku wo K to suru. Subete Ten O no mawari-

ni Moment wo toru mono to si, PE wo OP ni suitiyokuni hiku. PE no Hôkô ni okeru Tikara no Tyokkaku-seibun wo sorozore K'_1, K'_2, K' to sureba, § 15 no Teiri ni yotte,



Du 40.

$$K' = K'_1 + K'_2;$$

sitagatte, $K' \times OP = (K'_1 + K'_2) \times OP = K'_1 \times OP + K'_2 \times OP$. Sikaruni,

$$K' \times OP = K \text{ no Moment,}$$

$$K'_1 \times OP = K_1 \text{ no Moment,}$$

$$K'_2 \times OP = K_2 \text{ no Moment;}$$

yueni,

Gôryoku K no Moment

$$= \text{Bunryoku } K_1, K_2 \text{ no Moment no Wa.}$$

Tikara ga hutatu yorimo ôi Baai nimo, ueno Syômeisikata ga okonawareru koto wa akiraka de aru.

38. Moment no kaiseikitekino Siki. Tikara K no x, y -Seibun wo X, Y to si (Du 41), sore no Sayôten P no Zahyô wo x, y to site, Zahyô-genten no mawarini Moment wo toreba,

$$X \text{ no Moment} = -y X,$$

$$Y \dots \dots \dots = +x Y;$$

yueni, ueno Teiri ni yotte, K no Genten no mawarino

$$\text{Moment} = xY - yX. \dots (1)$$

Gôtai no iroirona Ten ni Tikara ga ikutu mo hataraite iru Baai niwa, sore wo

$$(x_1, y_1) \text{ ni okeru } (X_1, Y_1),$$

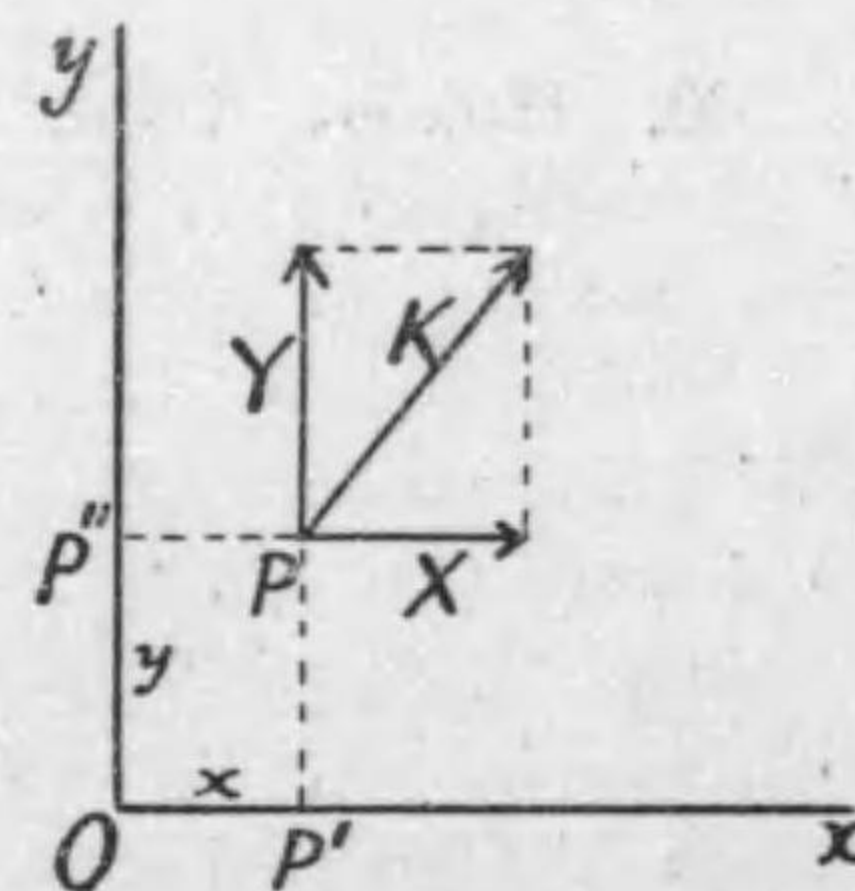
$$(x_2, y_2) \text{ ni okeru } (X_2, Y_2) \dots (2).$$

to suru tokini, Zahyô-genten no mawarini totta

$$\text{zentaino Moment} = G = \sum_i (x_i Y_i - y_i X_i) \dots \dots (2).$$

39. Hitotuno Heimen ni atte, heikô de nai Tikara no Gôryoku. Gôtai ni hataraku hutatuno Tikara ga hitotuno Heimen ni hataraite, Sayôsen ga heikô de nai Baai wo siraberu.

Tikara ga P_1 (Du 42) ni hataraku K_1 to P_2 ni hataraku K_2 to de aru to suru. Hutatuno Sayôsen no Kiriaiten Q wo



Du 41.

motomete, K_1, K_2 ga tomoni Q ni hataraku yôni kangaetemo Tigai ga nai (§ 32). Sôsureba, *hitotuno Ten ni hataraku* hutatuno Tikara da kara, § 8 no Hôhō de sorera wo gôseisite, Gôryoku K wo tukuru koto ga dekuru.

Kono Gôryoku K wa, zissai ueno yôna Sakudu wo sinakutemo kimerareru.

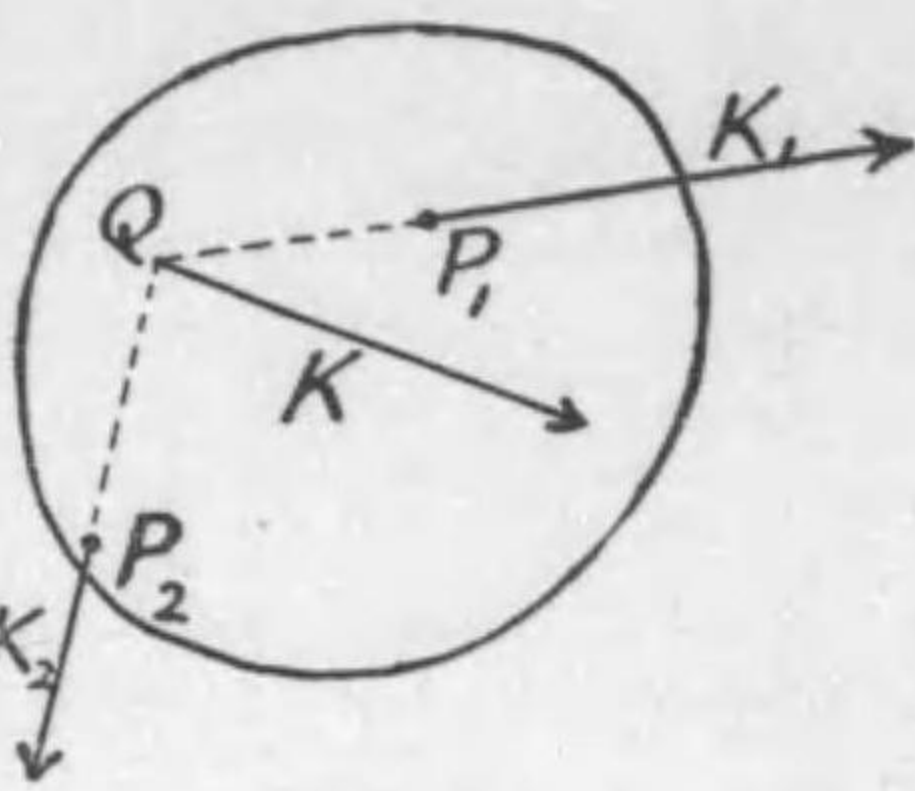
Sore no Hôkô to Ooisa wa, ueno Kangaekata de sireru tôri, ataerareta Tikara K_1, K_2 ga hitotuno Ten ni hataraku Baai no Gôryoku no to onazi de aru; mata, sore no *Sayôsen no Iti* wa, kattena Ten no mawarini totta sore no Moment ga (§ 34 no Tyûi to § 37 no Teiri ni yotte) ataerareta hutatuno Tikara no Moment no (daisûtekino) Wa ni hitosii koto de kimaru.

40. Heikôna Tikara no Gôryoku. P_1 ni okeru K_1 to P_2 ni okeru K_2 to no Sayôsen ga heikô de aru Baai niwa, ueno yôna Sakudu ga dekinai.

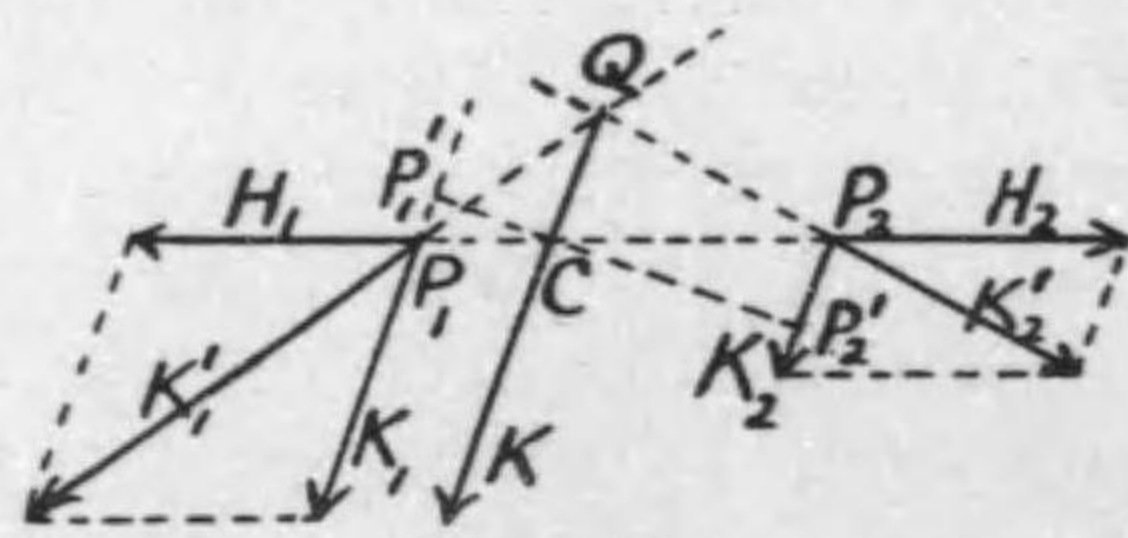
Madu, K_1 to K_2 no Muki ga onazi de aru Baai wo siraberu (Du 43).

Ima P_1, P_2 ni K_1, K_2 no hokani, P_1, P_2 wo musubu Tyokusen ni sôte,

Ooisa ga hitosikute Hôkô no hantaina Tikara H_1, H_2 ga hataraitte iru mono to sôzôsitate miru noni, korerano Tikara wa tagaini turiau kara, Undô nimo Turiai nimo Eikyô ga nai. Sitagatte, ataerareta Tikara K_1, K_2 no Kumiai wa yottuno Tikara K_1, K_2, H_1, H_2 ga hataraku no to dôto de aru. Sikaruni, P_1 ni hataraku K_1 to H_1 wa Gôryoku K_1' to dôto de ari, P_2 ni hataraku K_2 to H_2 to wa Gôryoku K_2' to dôto de atte, korerano K_1' to K_2' to wa heikô de nai kara, maeno § no Hôhō ni yotte sorera no Gôryoku— Q ni okeru K —wo eru koto ga dekuru. Tumari, kono-



Du 42.



Du 43.

yôni site erareru Q ni okeru K wa ataerareta P_1 ni okeru K_1 to, P_2 ni okeru K_2 to no Gôryoku de aru.

Kono Gôryoku wa ueno yôna Sakudu wo zissaini sinakutemo kimerareru.

Kono K no Hôkô oyobi Ooisa wa, K_1, K_2, H_1, H_2 no yottuno Tikara ga hitotuno Ten (Q) ni hataraku Baai no Gôryoku no to onazi de aru; sunawati, Hôkô wa K_1, K_2 to heikô de, Ooisa wa $K_1 + K_2$ ni hitosii. Mata sore no *Sayôsen no Iti* wa, kattena Ten no mawarini totta sore no Moment ga, ataerareta K_1 to K_2 no Moment no (daisûtekino) Wa ni hitosii koto de kimaru. Nazekanareba, K no Moment wa Q ni okeru K_1' to K_2' to no Moment no Wa ni hitosiku (§ 37); sore wa P_1 ni okeru K_1' to P_2 ni okeru K_2' to no Moment no Wa ni hitosiku; sore wa P_1 ni okeru K_1 to H_1 to, P_2 ni okeru K_2 to H_2 to no Moment no Wa ni hitosiku; sore wa — H_1 to H_2 to no Moment wa tagaini utikesu (§ 35 no Tyûi) tameni — ataerareta K_1 to K_2 to no Moment no Wa ni hitosii kara de aru.

Kotoni, K no Sayôsen to P_1P_2 Sen no Kiriaiten C no mawarini Moment wo totte miruto, K no Moment wa 0 de aru kara, K_1 to K_2 to wa C no mawarini hitosikute hantaina Moment wo motu hazu de aru. Sunawati, CP_1', CP_2' wo K_1, K_2 ni suitiyokuni hikuto,

$$K_1 \times \overline{CP_1'} = K_2 \times \overline{CP_2'},$$

sitagatte,

$$\frac{CP_1}{CP_2} = \frac{CP_1'}{CP_2'} = \frac{K_2}{K_1}.$$

Sunawati, *onazi Muki no heikôna hutatuno Tikara no Gôryoku wa, sorera to heikôna, sorera no Wa ni hitosii Tikara de atte, sore no Sayôsen wa ataerareta Tikara no Sayôten no aida wo Tikara no Ooisa ni gyakuhireisite wakeru Ten wo tôru.*

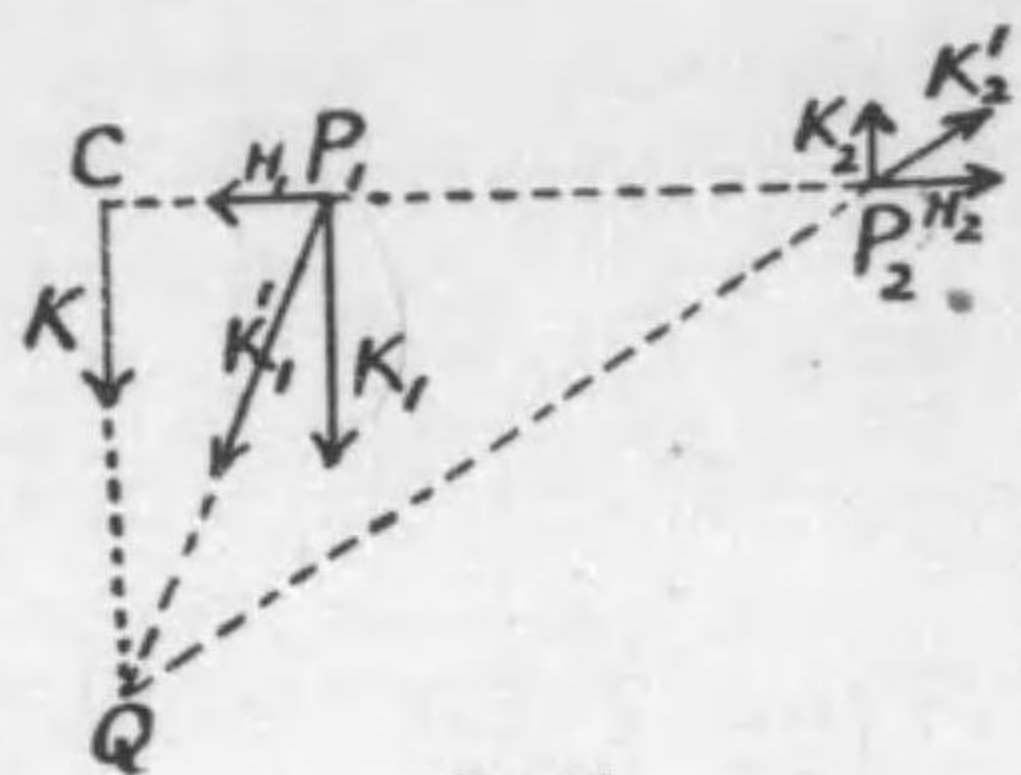
41. Hutatuno Tikara K_1, K_2 ga heikôna Sayôsen ni sôte hantaina Muki ni hataraku Baai nimo, ueno Baai to dôyôna Toriatukai wo suru koto ga dekuru (Du 44). Ima $K_1 > K_2$ to sureba, Gôryoku wa K_1 to onazi Muki no $K_1 - K_2$ dake no

Tikara de, sore no Sayôsen wa P_1P_2 Sen wo P_1 no hô e hikinobasita Sotogawa de

$$\frac{CP_1}{CP_2} = \frac{K_2}{K_1}$$

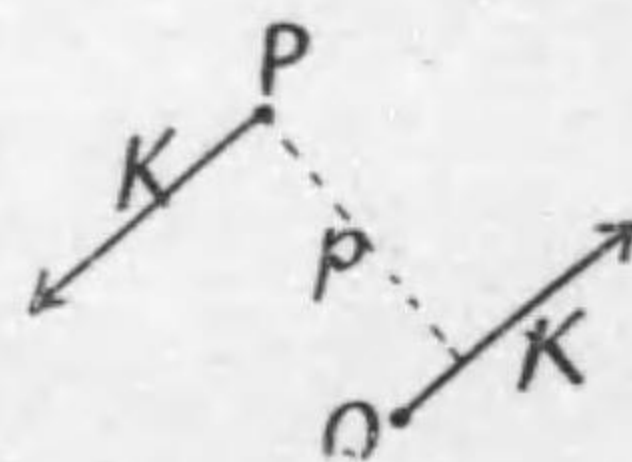
no Kwankei wo

nasu Ten C wo tôru. [P_1 to P_2 to no aidano Ten C' no mawarini Moment wo toruto, K_1 no Moment to K_2 no Moment to ga onazi Kigô wo motte, daisûtekino Wa ga o ni nari enai.]



Du 44.

42. Gûryoku. Ueno Toriatukai no dekinai Baai wa K_1, K_2 ga hitosikute Hôkô ga hantai de aru Baai de aru. Konoyôni, Gôtai ni hataraku hutatuno Tikara K_1, K_2 ga hitosikute, Hôkô ga hantai de, sikamo Sayôsen ga tigau Baai (Du 45) ni, korerano hutatuno Tikara no Kumiai wo Gûryoku to tonaeru. Gûryoku wo tukuru onônono Tikara no Ooisa K ni, sorera no Sayôsen no aidano Suisen-kyori ("Ude") p wo kaketa Ryô Kp wo "Gûryoku no Moment" to tonaeru.



Du 45.

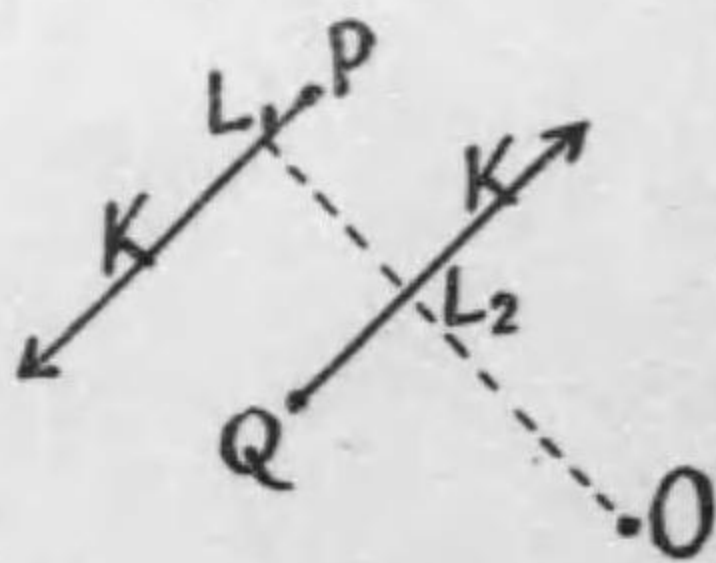
Gûryoku no Moment ni tuitewa, sore ga Gôtai wo mawasô to suru Mawasikata no Muki (Hidarimawasi to Migimawasi) wo kubetusuru.

43. Gûryoku no Sayôsen no aru Heimen no kattena Ten O no mawarini Tikara KK no Moment wo toruto, O no mawarino KK no Moment

$$= K \times OL_1 - K \times OL_2$$

$$= K \times L_1L_2$$

= "Gûryoku no Moment."



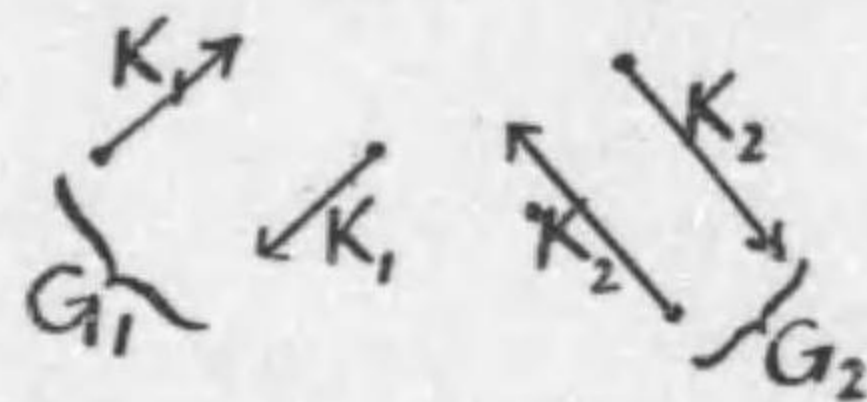
Du 46.

Sunawati, Gûryoku wo kumitatete iru Tikara ni tuite kattena Ten O no mawarini totta sentaino Moment wa, O no Iti ni kakawarazu, sono Gûryoku no Moment ni hitosii.

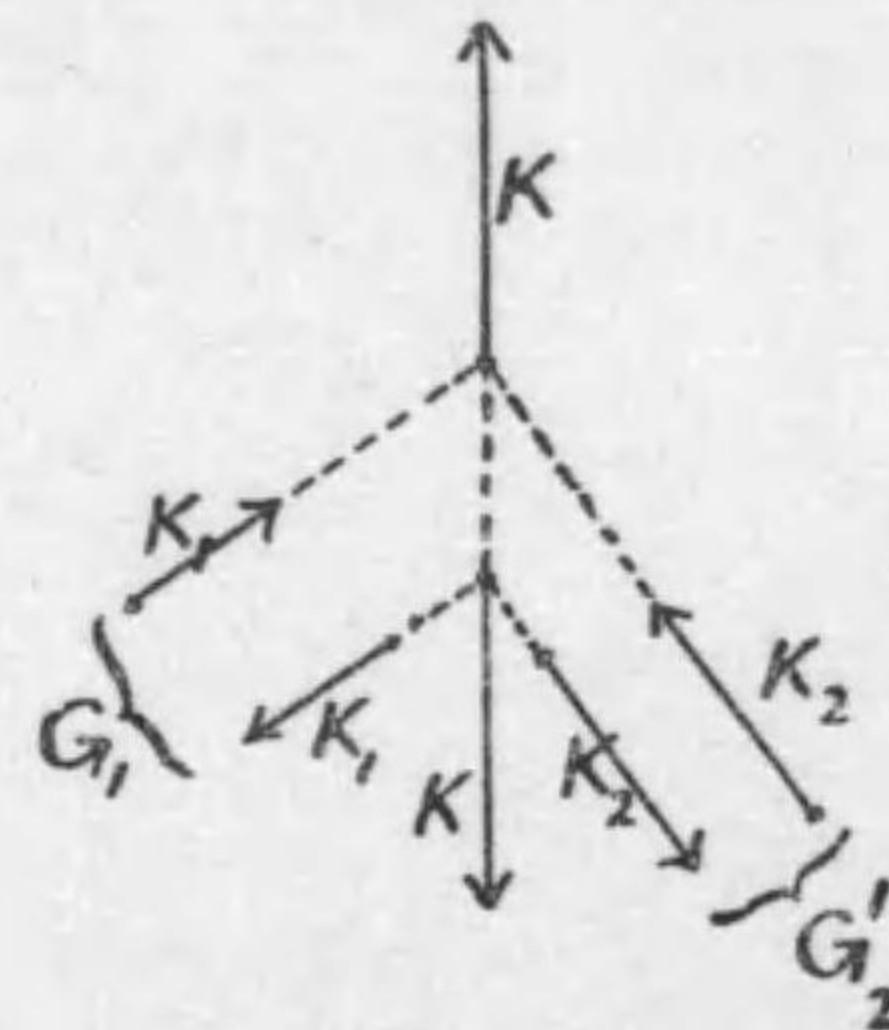
44. Gûryoku ni tuitewa tugino Teiri ga aru :—

Teiri. Onazi Heimen matawa heikôna Heimen ni atte, onazi (kwaitentekino) Muki ni, hitosii Moment wo motu Gûryoku wa, Sayôten no Iti, Tikara no Ooisa oyobi Hôkô ni kakawarazu, subete dôto de aru.

(a) Madu, hutatuno Gûryoku G_1, G_2 ga hitotuno Heimen ni atte, onazi Muki ni hitosii Moment wo motte iru Baai (Du 47)



Du 47.



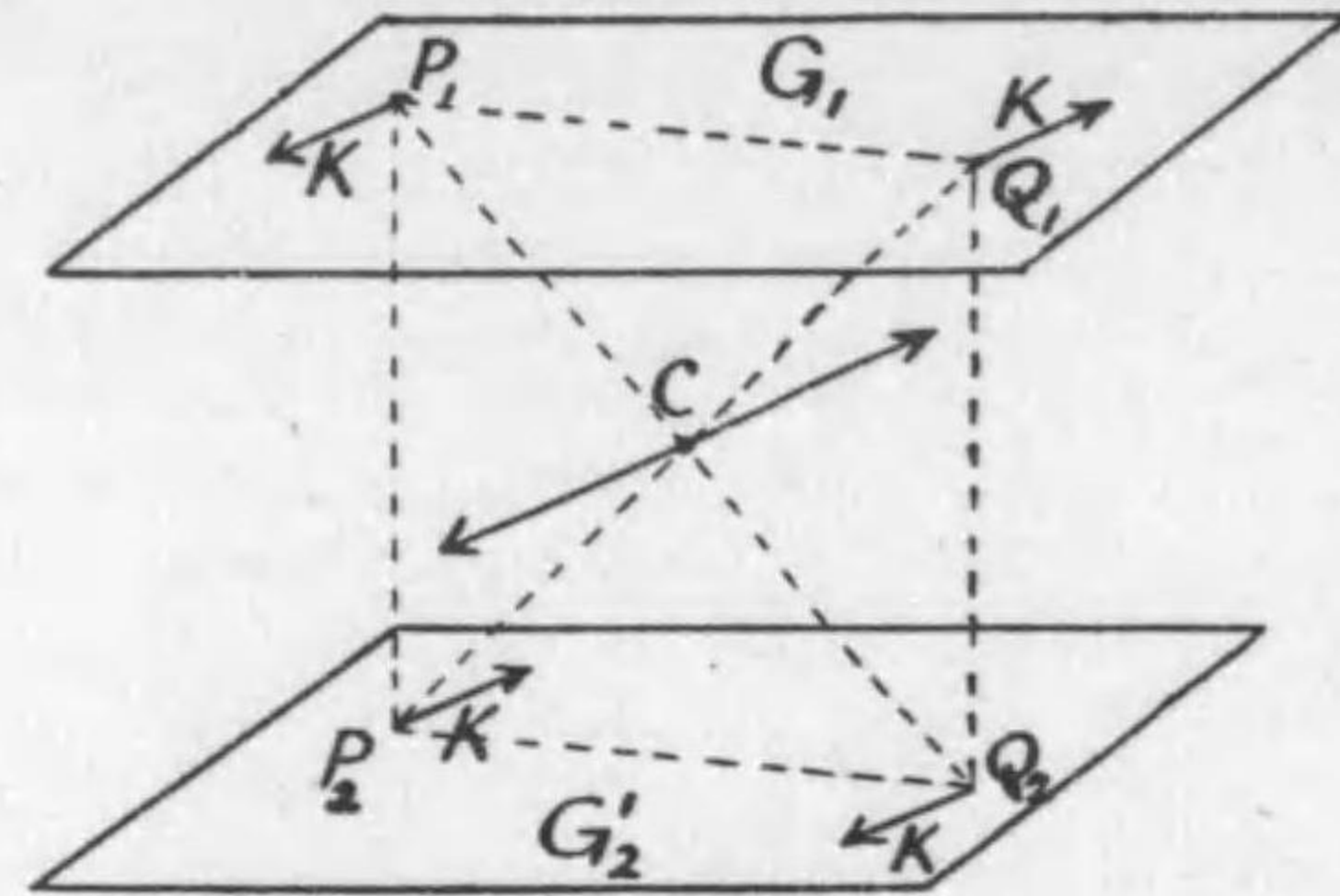
Du 48.

wo siraberu. G_1 to G_2 ga dôto de aru koto wo syômeisuru niwa, katakata G_2 wo gyakuni totta Gûryoku G_2' to G_1 (Du 48) to ga tyôdo turiau koto wo syômeisureba yoi. G_1 no hitotuno Tikara K_1 to G_2' no hitotuno Tikara K_2 to no Gûryoku to, nokorino K_1, K_2 no Gûryoku to wa tyôdo hantaino Hôkô ni atte, Ooisa ga hitosii koto wa akiraka de aru, ippôno Gôsei-no-Du wo 180° mawaseba, sonomama ippôno Gôsei-no-Du ni naru kara.

Sitagatte, G_1 to G_2' to wa hitotuno Gûryoku KK wo tukurû. Kono Gûryoku no Moment wa, kattena Ten O no mawarini totta subeteno Tikara no Moment no daisûtekino Wa ni hitosii (§ 43 oyobi § 37 no Teiri), sunawati, = G_1 no Moment + G_2' no Moment = 0. Soreyueni, KK wa, Sayôsen no aidano Kyori ga o, sunawati onazi Sayôsen no ueno hitosikute hantaina Tikara de aru kara, tyôdo tagaini turiau Kumiai wo nasite iru.

Soreyueni, Du 47 no G_1 to G_2 to wa dôto de aru.

(b) Tugini heikôna Heimen ni aru G_1, G_2 ni tuitewa, (a) no Bubun ga sudeni syômeisareta kara, G_2 wo kumitatete iru Tikara no Hôkô to Ooisa to Sayôsen no Kyori to ga G_1 no



Du 49.

Tikara no sorera to onazi de aru Baai dake wo sirabereba zyûbun de aru. Du 49 wa konoyôna Baai ni tuite, ippô G_2 wo gyakuni totta G_2' to G_1 to wo arawasita mono de, Sayôten P_1, Q_1, P_2, Q_2 wa subeteno Sayôsen wo sorera ni suitiyokuna Heimen de kitta Ten ni totte aru. Sitagatte, $P_1 Q_1$ to $P_2 Q_2$ to wa heikô de katu hitosii kara, $P_1 Q_1 Q_2 P_2$ wa Heikô-sihenkei de, sore no Taikakusen $P_1 Q_2$ to $Q_1 P_2$ to wa Kiriaiten C de tóbunsarete iru. Konoyôni site miruto, P_1 to Q_2 to ni hataraku Tikara wa onazi Hôkô no hitosii Tikara de, sorera no Gôryoku wa $P_1 Q_2$ no mannakano Ten C ni aru $2K$ no Tikara de aru. Mata, Q_1 to P_2 ni hataraku Tikara mo dôyô de, sorera no Gôryoku wa yahari C ni aru hantaina Hôkô no $2K$ de aru. Soreyueni, yottuno Tikara wa zentai de turiatte iru.

Konoyôni Gûryoku G_1 to G_2' to ga turiau kara, G_1 to G_2 to wa dôto de aru.

45. Hitotuno Heimen ni aru ikutu kano Tikara no Gôryoku. Gôtai ni hataraku ikutu mono Tikara ga mina hitotuno Heimen de hataraku Baai niwa, sorera no utino hutatu dutu wo totte, § 39-41 no Hôhō de gôscisite yukuto, ippanno Baai tosite, hitotuno Gôryoku ni gôscisuru koto ga dekuru.

Kono Hôhō de Gôryoku wo erarenai Baai wa, saigoni hutatuno hitosikute hantaina Tikara wo eru Baai, sunawati atarareta Tikara no Kumiai zentai ga hitotuno Gûryoku ni naru Baai de aru. Soreyueni,

Hitotuno Heimen de Gôtai ni hataraku Tikara no Kumiai wa tada hitotuno Tikara matawa hitotuno Gûryoku to dôto de aru.

46. Hutatu dutu ni tuite Tekazu wo kurikaesu kawarini, tugino yôna Toriatukai wo sitemo yoi:—

Gôryoku K no Hôkô to Ooisa wa, subeteno Tikara ga hitotuno Ten ni hataraku Baai no to onazi de aru kara, § 14 to dôyôni,

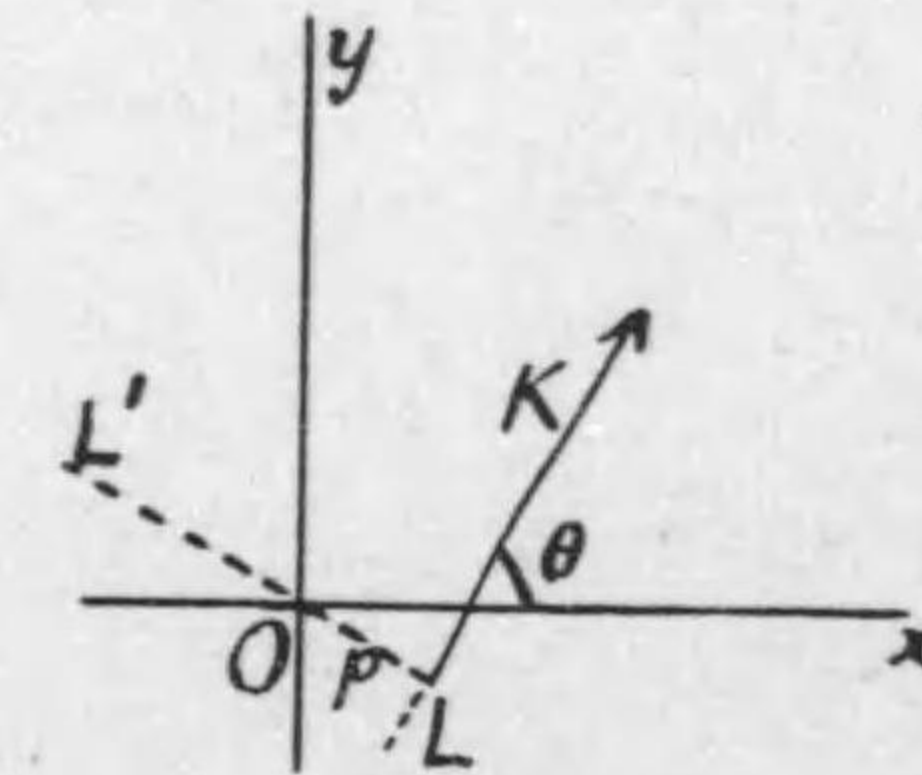
$$K = \sqrt{(\sum X_i)^2 + (\sum Y_i)^2} \quad \tan \theta = \frac{\sum Y_i}{\sum X_i} \dots (1)$$

de sireru. Mata sore no Sayôsen wa, Zahyô-genten kara sore ni itaru Kyori p ga, (§ 38 no (2) ni yotte),

$$Kp = \text{zertaino Moment} \\ = G = \sum(x_i Y_i - y_i X_i)$$

wo mitasu koto kara sireru. Sunawati,

$$p = \frac{G}{K} = \frac{\sum(x_i Y_i - y_i X_i)}{\sqrt{(\sum X_i)^2 + (\sum Y_i)^2}} \dots (2)$$



Du 50.

Tadasi, kono p wo, O wo tôsite K ni suitiyokuna Sen no ue de Dotiragawa ni toru ka—Du 50 de OL no hô ni toru ka OL' no hô ni toru ka—wa G no sei de aru ka hu de aru ka wo mite, Kp no Moment ga sore to onazi Hugô wo motu yôni kimereba yoi.

Tikara no Kumiai ga hitotuno Gûryoku ni naru no wa

$$\sum X_i = 0, \quad \sum Y_i = 0, \quad \sum(x_i Y_i - y_i X_i) = G \neq 0$$

no Baai de aru. Kono Baai ni, atarareta Kumiai to dôtona Gûryoku no Moment wa, § 43 ni yotte,

$$G = \sum(x_i Y_i - y_i X_i) \dots \dots \dots (3)$$

de ataerareru.

Tyûi. Kono owarino Baai — $\sum X_i = 0, \sum Y_i = 0, \sum(x_i Y_i - y_i X_i) \neq 0$ no Baai — ni, (1) (2) no Siki wo tukatte hitotuno Gôryoku ni siyô to suruto, $K=0, p=\infty$ ni naru, sunawati, kagirinaku tôi Tokoro ni aru Ooisa o no Tikara ni naru. Kore wa zissai-zyôno Imi wo motanai kara,

Gûryoku wa hitotuno Tikara to dôto de aru koto ga dekinai; sitagatte mata,

Gûryoku to hitotuno Tikara to ga turiau koto wa dekinai.

47. Ikutu mono heikôna Tikara no Gôryoku. Gôtai ni hataraku (mittu izyôno) Tikara ga mina heikôna Sayôsen wo motte ite, sikamo sorera ga hitotuno Heimen ni nai Baai demo, hutatu dutu wo totte gôseisuru koto wa § 40, 41 no Hôhó ni yotte dekuru. Tatoeba, Du

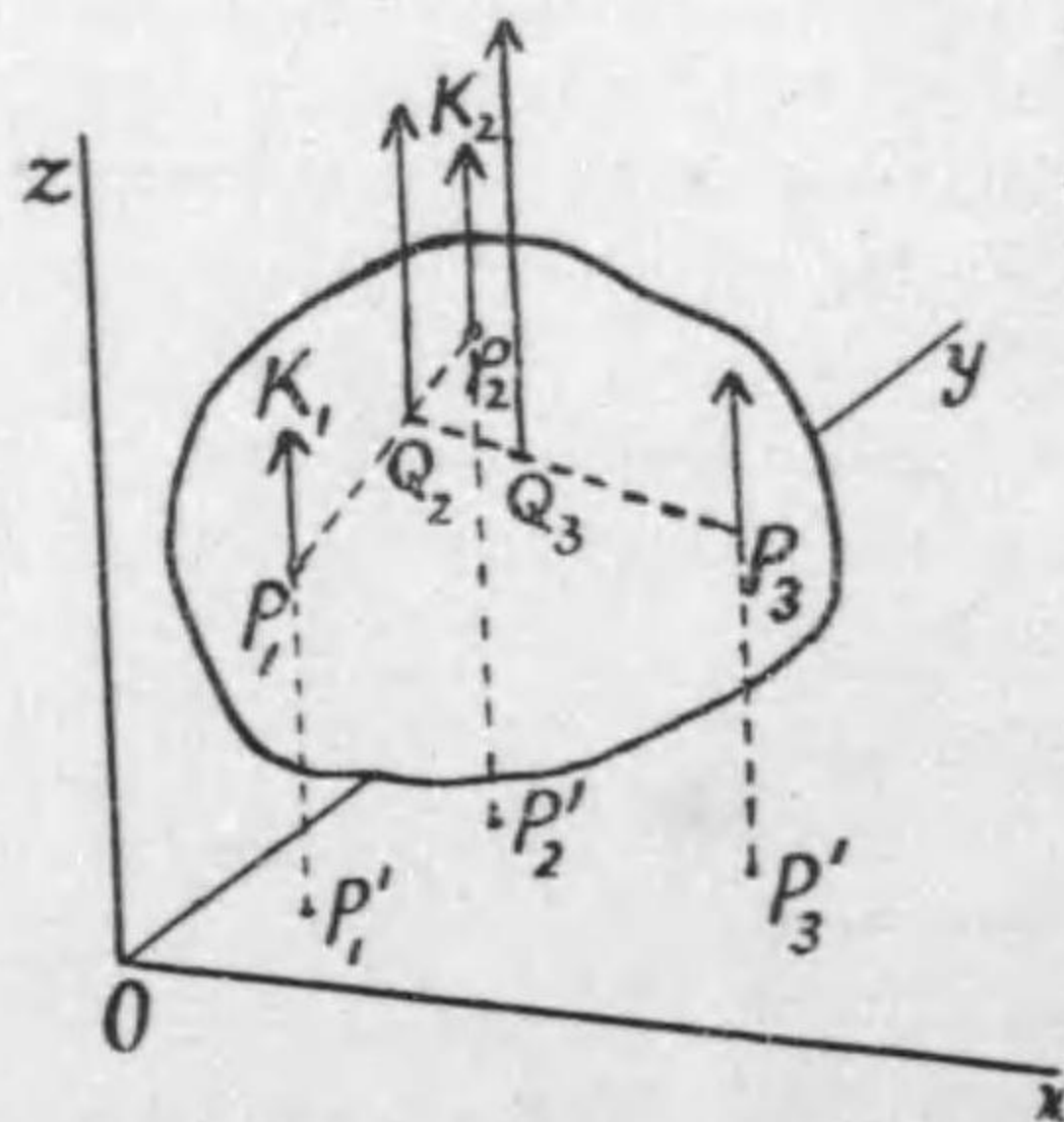
51 de P_1 ni okeru K_1 to P_2 ni okeru K_2 to wa Q_2 ni okeru $K_1 + K_2$ ni naru; sore to P_3 ni okeru K_3 to wo gôseisureba, Q_3 ni okeru $K_1 + K_2 + K_3$ ni naru to iu yôni. Kono Hôhó no Kekkwa ga — Tikara no Muki ni yotte (+) (—) no Hugô wo soeru Torikime no motoni — tugino yôni naru koto wa yôini sireru:—

$\sum K_i \neq 0$ naru ippanno Baai niwa, zentai ga hitotuno Tikara ($=\sum K_i$) ni naru;

$\sum K_i = 0$ naru tokubetuna Baai niwa, zentai ga hitotuno Gûryoku ni naru.

Kore ga donna Tikara matawa Gûryoku de aru ka wa, zissai hutatu dutu gôseisite yukeba wakaru.

48. Hutatu dutu gôseisuru Tekazu wo kurikaesanaide, itidokini Gôsei no Kekkwa wo siru niwa, Tikara no Hôkô ni suityokuna



Du 51.

Heimen wo xy -Zahyômen ni tori, x -Diku to y -Diku no mawarino Moment wo siraberu ga yoi.

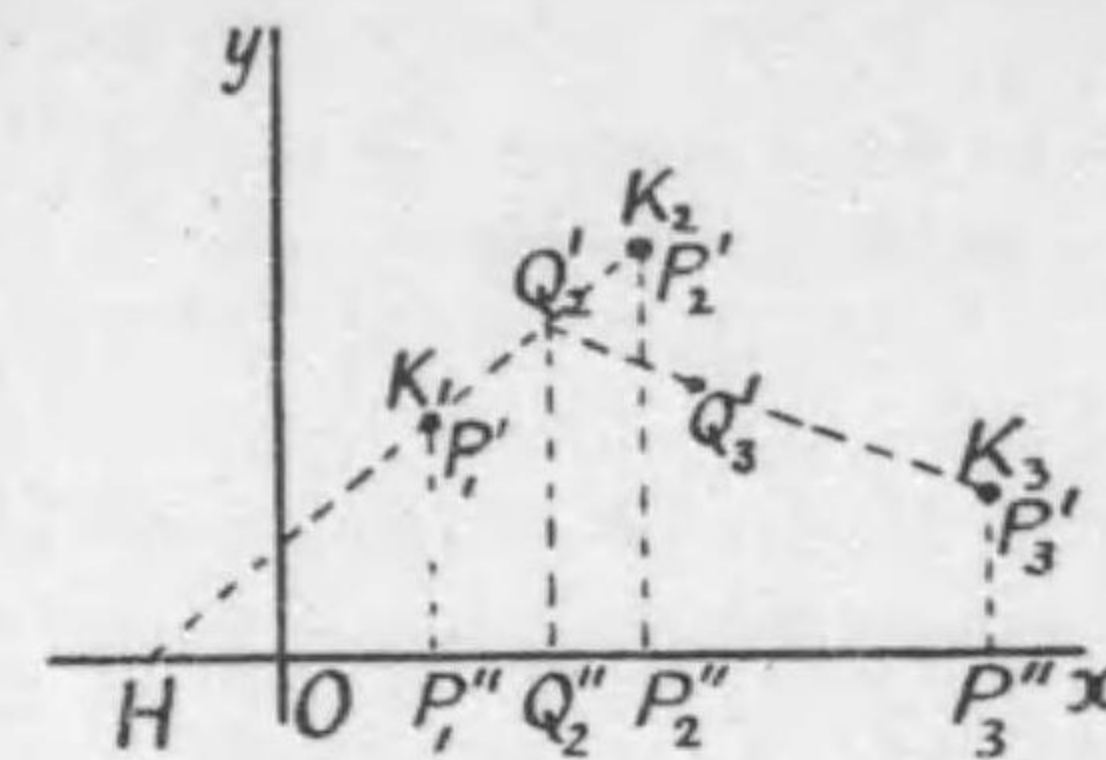
Tikara ga mina s -Diku ni heikô de,

$P_1(x_1, y_1, z_1)$ ni okeru K_1 ,

$P_2(x_2, y_2, z_2)$ ni okeru K_2

nado de aru to suru.

Du 52 wa Du 51 no Sama wo $+s$ no hô kara mita Du de, P_1', P_2', \dots wa $K_1, K_2 \dots$ no Sayôsen ga xy -Men wo turanuku



Du 52.

Ten, Q_2' wa K_1 to K_2 to no Gôryoku no Sayôsen ga xy -Men no turanuku Ten de aru. Mata $P_1'', P_2'', Q_2'' \dots$ wa $P_1', P_2', Q_2' \dots$ kara y -Diku ni heikôni hiita Tyokusen ga sorezore x -Diku wo kiru Ten de aru.

Du de sireru tôri, x -Diku no mawarini totta, P_1 ni okeru K_1 no Moment $= K_1 \times P_1' P_1'' = K_1 y_1$; P_2 ni okeru K_2 no Moment $= K_2 \times P_2' P_2'' = K_2 y_2$; hoka mo dôyô de aru.

Konoyôna, x -Diku no mawarino Moment ni tuitemo, “ K_1 no Moment to K_2 no Moment no (daisûtekino) Wa wa Gôryoku no Moment ni hitosii” to iu Teiri ga naritatu. Nazekanareba, maeni (§ 40) sitte iru Koto ni yotte, K_1 to K_2 to no Sayôsen wo hukumu Heimen no ueno hitotuno Ten H no mawarini totta Moment ni tuite,

$$K_1 \times HP_1' + K_2 \times HP_2' = (K_1 + K_2) \times HQ_2'$$

Kore ni sin ($P_1' Hx$) wo kakeruto,

$$K_1 \times P_1' P_1'' + K_2 \times P_2' P_2'' = (K_1 + K_2) \times Q_2' Q_2'';$$

sunawati,

K_1 no Moment + K_2 no Moment = Gôryoku no Moment wo eru kara. Tikara wo ikutu gôseisitemo onazikoto de aru.

49. Soreyueni,

(a) $\sum K_i \neq 0$ naru ippanno Baai ni, zentai no Gôryoku $\sum K_i$ no Sayôsen ga (x_a, y_a) wo tôsite hataraku to sureba,

$$(\sum K_i) \times y_G = \sum K_i y_i,$$

sitagatte,

$$y_G = \frac{\sum K_i y_i}{\sum K_i} \dots \dots \dots (1).$$

y -Diku no mawarini Moment wo kangaetemo dōyōna Kekwa ni naru koto wa akiraka de aru kara,

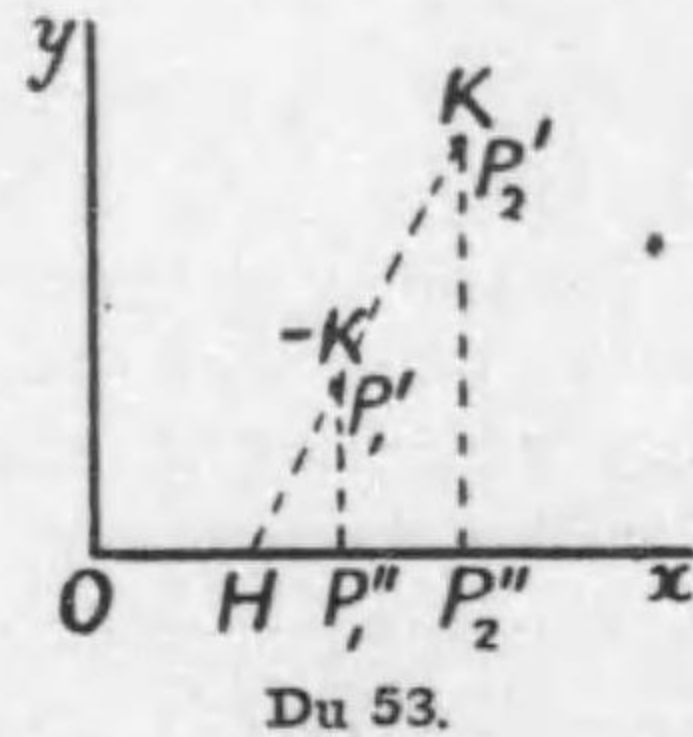
$$x_G = \frac{\sum K_i x_i}{\sum K_i} \dots \dots \dots (2).$$

(1) (2) de Gōryoku no Sayōsen no Iti ga kimaru.

(b) $\sum K_i = 0$ naru tokubetuna Baai.

Kono Baai ni, saigoni eru Gūryoku ga, xy -Men no P_1' (Du 53) ni okeru $-K$ to P_2' ni okeru $+K$ de aru to suruto, x -Diku no mawarino Moment wa

$$\begin{aligned} & K \times P_2' P_2'' - K \times P_1' P_1'' \\ &= (K \times P_2' H - K \times P_1' H) \sin (P_1' Hx) \\ &= (K \times P_1' P_2') \sin (P_1' Hx) \\ &= (\text{Gūryoku no Moment}) \times \sin (P_1' Hx). \end{aligned}$$



Soreyueni, (Gūryoku no Moment) $\sin (P_1' Hx) = \sum K_i y_i$.
Dōyōni,

$$(\text{Gūryoku no Moment}) \cos (P_1' Hx) = \sum K_i x_i.$$

Korera kara tugino Kekwa wo eru—

$$\left. \begin{aligned} \text{Gūryoku no Moment} &= \sqrt{(\sum K_i x_i)^2 + (\sum K_i y_i)^2}, \\ \tan (P_1' Hx) &= \frac{\sum K_i y_i}{\sum K_i x_i} \end{aligned} \right\} \dots \dots (3).$$

Kono Kaku $P_1' Hx$ de Gūryoku no hataraku Heimen no Hōkō ga kimaru.

50. Dyūsīn. Buttai ni hataraku Dyūryoku wa sore no subeteno tiisai Bubun, sunawati (x_1, y_1, z_1) ni aru Situryō m_1 , (x_2, y_2, z_2) ni aru Situryō $m_2 \dots$ ni hataraku no de aru ga, mina heikōna Tikara da kara, sorera no zentaino Gōryoku wa § 48 no Teiri ni yotte keisansareru. Kono Gōryoku ni tuitewa tugino Teiri ga okonawareru :—

Buttai no Katati ga kimatte iru Baai ni, kono Gōryoku no Sayōsen wa, Buttai wo oku Muki ni kakawarazu, Buttai no nakano (matawa Buttai ni taisite) kimatta Ten wo tōru; sosite, kono Ten no Zahyō (x_G, y_G, z_G) wa

$$x_G = \frac{\sum m_i x_i}{\sum m_i}, \quad y_G = \frac{\sum m_i y_i}{\sum m_i}, \quad z_G = \frac{\sum m_i z_i}{\sum m_i} \dots \dots (1)$$

de ataerareru. Kono Ten wo “Dyūsīn” matawa “Situryō no Tyūsīn” to tonaeru.

Syōmei. Madu, ueno Siki de kimaru Ten G ga Zahyōdiku no Iti ya Muki ni kakawarazu, Buttai ni taisite kimatta Iti ni aru koto wo syōmeisuru.

Hitotuno Zahyōdiku $(xyz$ -Diku) ni tuite ueno Siki de Ten G wo kime, kattena hokano Zahyōdiku $(x'y'z'$ -Diku) ni taisuru sono Ten G no Zahyō x'_G wo siraberu.

Ippanni, x' -Zahyō wa

$$x' = Ax + By + Cz + D$$

de ataerareru kara⁽¹⁾,

$$\begin{aligned} x'_G &= Ax_G + By_G + Cz_G + D \\ &= A \frac{\sum m_i x_i}{\sum m_i} + B \frac{\sum m_i y_i}{\sum m_i} + C \frac{\sum m_i z_i}{\sum m_i} + D \\ &= \frac{\sum m_i (Ax_i + By_i + Cz_i + D)}{\sum m_i} = \frac{\sum m_i x'_i}{\sum m_i}. \end{aligned}$$

y'_G, z'_G ni tuitemo dōyō de aru.

Soreyueni, xyz -Diku ni taisite (1) no Siki de kimaru Ten wa, $x'y'z'$ -Diku ni taisite dōyōna Siki de kimaru Ten to *onazi* Ten de aru.

Tugini, Buttai ga kattena Iti ni aru Baai ni, *tugōyoku* Zahyōdiku wo erande, Gōryoku ga ueno Ten wo tōru koto wo syōmeisureba zyūbun de aru.

⁽¹⁾ $x' = Ax + By + Cz + D$ ga Tyokkaku-zahyō no ippanno Kakikae wo arawasu koto wa, Kikagaku de siru Koto de aru ga, Heimen-Kaisekikika no Kakikae wo nido ($x' = x \cos \alpha + y \sin \alpha + a$, $y' = -x \sin \alpha + y \cos \alpha + b$, $z' = z$) to ($x'' = x'$, $y'' = y' \cos \beta + z' \sin \beta + a'$, $z'' = -y' \sin \beta + z' \cos \beta + b'$) to wo tudukete okonau koto ni yottemo sireru.

Sore niwa, z -Diku wo entyokuni, x -, y -Diku wo suiheini totte § 49 (a) no Teiri wo atehamereba yoi. Buttai no tiisai Bubun m_i ni hataraku Tikara ga Dyûryoku-tan'i de m_i de aru kara, macno K_i wa imano Baai ni m_i de aru. Sitagatte, Gôryoku no Sayôsen wa, xy -Men wo

$$x_G = \frac{\sum m_i x_i}{\sum m_i}, \quad y_G = \frac{\sum m_i y_i}{\sum m_i}$$

de turanuku entyokuna Sen de, sore wa (1) de ataerareru Ten wo tôru koto wa iu mademo nai⁽¹⁾.

Hutûno Buttai dewa Bussitu ga hikituduite hirogatte iro kara, ueno Siki (1) wo Sekibun no Katati de kaku no ga hutû de aru:—

$$x_G = \frac{\int x dm}{m}, \quad y_G = \frac{\int y dm}{m}, \quad z_G = \frac{\int z dm}{m} \dots \dots (2);$$

tadasi x, y, z wa Situryô-element dm no aru Ten no Zahyô, m wa zentaino Situryô.

51. Mosimo Dyûsin wo Zahyô-genten ni totte areba, $x_G = y_G = z_G = 0$. Yueni, (1) no Siki kara tugino Teiri ga sireru:—

Teiri. *Zahyô-genten wo Dyûsin ni toru Baai niwa,*

$$\sum m_i x_i = 0, \quad \sum m_i y_i = 0, \quad \sum m_i z_i = 0$$

kono Kwankei ga okonawareru.

52. *Taiseki no Dyûsin to Heimen-menseki no Dyûsin.* Taiseki wa Bussitu dewa nai keredomo, sore no Dyûsin wo toriatukau koto ga aru. Sore wa, Taiseki-element wo dV , zentaino Taiseki wo V to kaku tokini, (2) to dôyôni,

⁽¹⁾ Ueno Teiri wo syômeisuru no ni, tugino yôni sitemo yoi. Madu Buttai wo tiisai Bubun— P_1 ni aru m_1 , P_2 ni aru m_2 ... ni waketa to kangae, sorera ni hataraku Dyûryoku wo § 40 no yôna Hôhó de hitotu dutu gôseisuru. Sô sureba, P_1, P_2 ni hataraku Dyûryoku no Gôryoku wa, *Buttai no Mukikata sumawati Tikara no kyôtina Hôkô ni kakawarazu*, Q_2 ni okeru $m_1 + m_2$ de ari, sore to P_3 ni okeru m_3 to no Gôryoku wa, *Buttai no Mukikata ni kakawarazu*, Q_3 ni okeru $m_1 + m_2 + m_3$ de aru to iu yôni, zentai no Gôryoku ga, *Buttai no Mukikata ni kakawarazu*, *Buttai ni taisite kimatta hitotuno Ten G* ni okeru $\sum m_i$ de aru koto ga ieru. Kono Ten G no Zahyô wo kimeru niwa, *Buttai ni koteisita Zahyôdiku* no z -Diku wo entyokuni sita Baai ni § 49 (a) no Teiri wo atehamete x_G, y_G wo siri, x -Diku wo entyokuni sita Baai ni onazi Teiri wo atehamete y_G, z_G wo sireba yoi. Sore no Kekwa wa ueno (1) no tôri.

$$x_G = \frac{\int x dV}{V}, \quad y_G = \frac{\int y dV}{V}, \quad z_G = \frac{\int z dV}{V}$$

de kimaru Ten de aru.

Dôyôni, Heimen-menseki ni tuite, sono Heimen ni xy -Diku wo tori, Menseki-element wo dS , zentaino Menseki wo S to suru tokini,

$$x_G = \frac{\int x dS}{S}, \quad y_G = \frac{\int y dS}{S}$$

de kimaru Ten wo, sono Menseki no Dyûsin to iu.

53. *Tokubetuna Baai.*

(a) Mitudo ga itiyôna (hutû tanni "itiyôna" to iu) *Kyû, Heikô-rokumentai, Daentai, Marubasira* nado no Dyûsin wa sorera no kikagakutekino Tyûsin ni aru. Mata, Mitudo to Atusa ga itiyô de, Katati ga *En, Daen, Heikôsihenkei, Seitahenkei* nado de aru heimenno Ita mo dôyô de aru.

(b) Mitudo to Atusa no itiyôna sankakuno Ita no Dyûsin wa Tyûsen no Kiriaiten no Tokoro de Atumi no Mannaka ni aru. [Kono Teiri wa, hitotuno Hen ni heikôna musûna Sen de Ita wo waketa to kangaruto, onônono hosoi Bubun no Dyûsin ga mina hitotuno Tyûsen no ueni aru koto kara wakaru.]



Dv 54.

(c) Itiyôna Suitai no Dyûsin wa, Tyôten O wo Soko no Dyûsin C ni musubu Tyokusen no ue de, Tyôten kara $\frac{3}{4}$ no Tokoro ni aru. [Soko ni heikôna Heimen de OC wo musûno hitosii Nagasa ds ni wakeruto, Suitai ga musûno Ita ni naru. Sorerano Ita no Dyûsin wa mina OC no ueni atte, O kara Kyori s ni aru Ita no Situryô ga s^2 ni hireisuru kara, sore wo $ks^2 ds$ to kakuto,



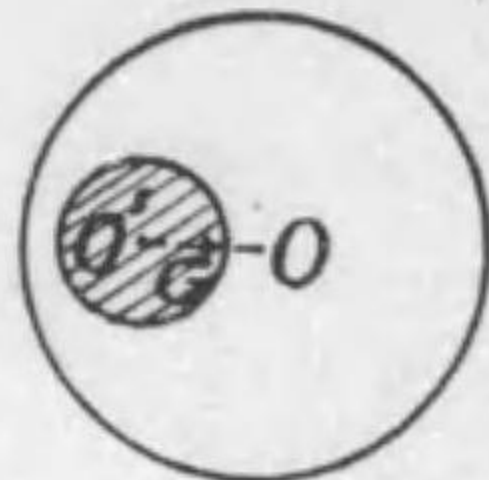
Du 55.

$$s_G = \int_0^{OC} s \cdot ks^2 ds / \int_0^{OC} ks^2 ds = \frac{3}{4} OC.]$$

Mondai. Atusa mo Mitudo mo itiyôna marui kino Ita no Sin wo hadurete, marui Ana wo kiritotte, Namari ga tumete aru. Dyûsin wa doko ka?

[Kino Ita no Hankei= a , Namari no Hankei= b , hutatuno Tyûsin no Kyôri $OO'=c$ ($c < a-b$) nareba, Namari no Mitudo wo n , Ki no Mitudo wo k to site,

Kotae. $OG = \frac{cb^2(n-k)}{a^2k + b^2(n-k)}$.]



Du 56.

54. Hitotuno Heimen ni aru Tikara no Turiai. Hitotuno Heimen ni aru Tikara wo gôseisureba, § 45, 46 ni yotte, hitotuno Tikara (Seibun ga $\Sigma X_i, \Sigma Y_i$) matawa hitotuno Gûryoku (Moment ga $\Sigma(x_i Y_i - y_i X_i)$) ni naru. Sorerano Tikara ga turiau tamenizwa,

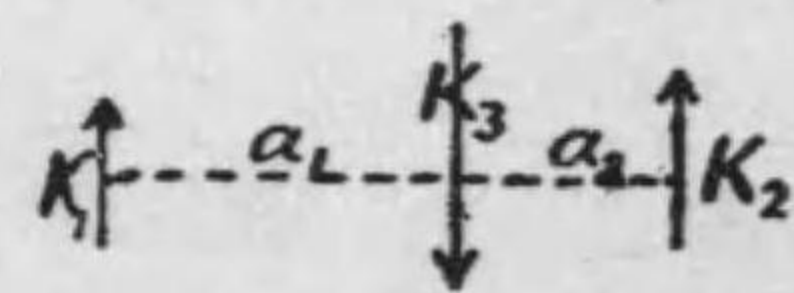
$$\Sigma X_i = 0, \Sigma Y_i = 0, \Sigma(x_i Y_i - y_i X_i) = 0 \dots (1)$$

korerano mittuno Dyôken ga hituyô de katu zyûbun de aru.

Hituyô da to iu Riyû wa, $\Sigma X_i = 0, \Sigma Y_i = 0$ de nakereba, sorerano Tikara no Kumiai ga hitotuno (o dewa nai) Tikara to dôtoni naru si, $\Sigma X_i = 0, \Sigma Y_i = 0$ de $\Sigma(x_i Y_i - y_i X_i) \neq 0$ de areba sono Kumiai ga hitotuno (Moment ga o de nai) Gûryoku to dôtoni naru kara de aru. Tugini, zyûbun da to iu Riyû wa, (1) no Kwankei ga naritateba, sono Kumiai ga Moment ga o no Gûryoku to dôtoni naru ga, Moment ga o no Gûryoku wa onazi Sayôsen ni sôte hantaino Hôkô ni hataraku hitosii Tikara de, sore wa Turiai no Kumiai de aru koto wa maeni (§ 7) nobeta tôri de aru kara de aru.

55. Mittuno Tikara no Turiai. Mittuno Tikara ga hitotuno Heimen ni atte turiau no niwa, hutatuno Baai ga aru.

(a) Mittu tomoni heikôna Sayôsen wo motte iru Baai. Konotoki Ryôwaki ni hataraite iru Tikara no Gôryoku ga nakano Tikara to Sayôsen ga onazi de, hantaino Muki ni hitosii Ooisa wo motanakereba naranai kara, § 40 ni yotte,



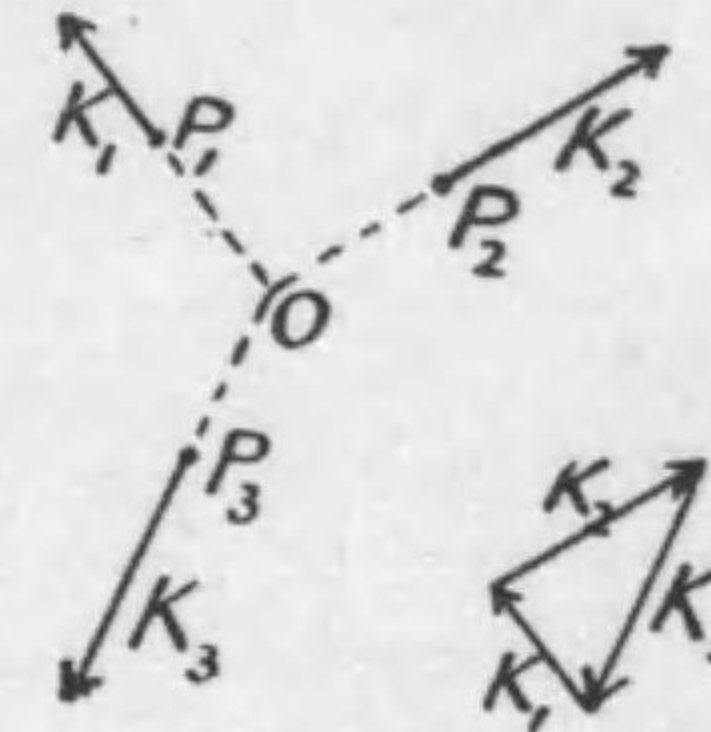
Du 57.

Muki ga Du 57 no yôna Kwankei ni natte, Sayôsen no Kyori to Tikara no Ooisa to ga

$$K_1 a_1 = K_2 a_2$$

no Kwankei wo nasu koto wo yôsuru.

(b) Hutatuno Tikara K_1, K_2 (Du 58) no Sayôsen ga heikô de nakute Ten O de kiriau to sureba, sorera ga O wo tôru hitotuno Tikara to dôtoni naru kara, nokorino Tikara K_3 no Sayôsen ga kanarazu O wo tôranakereba naranai; sosite, Tikara no Kwankei ga, hitotuno Ten ni hataraku mittuno Tikara no Baai to onazini naru. Soreyueni,



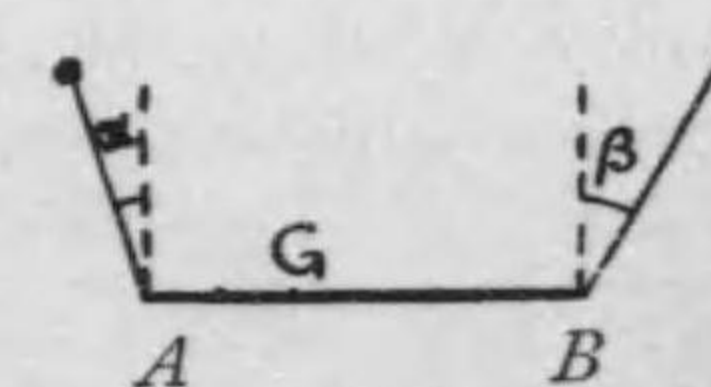
Du 58.

Mittuno Tikara no Sayôsen ga hitotuno Ten de kiriai, katu K_1, K_2, K_3 de tukutta Tikara no Tahenkei ga todiru koto wo yôsuru.

Tyûi. Mittuno Tikara ga Gôtai ni hataraite turiau no wa uéno hutatuno Baai ni kagiru (sunawati, mittuno Tikara ga hitotuno Heimen ni nakute turiau koto wa dekinai) no de aru ga, sore no Syômei wa p. 44 no Susogaki ni aru.

56. Hutatuno Tikara no Turiai. Gôtai ni Tikara ga hutatu hataraite turiau Baai wa, ueno Baai no mittuno Tikara no uti hitotu ga o de aru Baai de aru kara, hutatuno Tikara ga onazi Sayôsen ni sôte hantaino Muki ni hataraite, Ooisa ga hitosii Baai ni kagiru. Sitagatte, sorerano Tikara wa, sorera no Sayôten wo musubu Tyokusen ni sôte hataraku koto wo yôsuru.

Mondai (i). Dyûsin G ga katayotte iru Bô AB wo, Ryôhazi ni torituketa Ito de suiheina Iti ni tamotu tokini nihonno Ito no Entyokusen ni taisuru Katamuki wo sorezore α, β to sureba, tugino Kwankei



Du 59.

$$\frac{\tan \alpha}{\tan \beta} = \frac{AG}{BG}$$

ga aru koto wo syômeisei!

(ii) Namerakana entyokuna Kabe OB to arai Yuka OA to ni sasaerarete, itiyôna Bô AB ga Entyokusen to Kaku α wo nasite tomatte iru tokini, Yuka no Masatu-keisû μ ni tuite donna Koto ga ieru ka?

[Kotae. $\mu \geq \frac{1}{2} \tan \alpha$.]

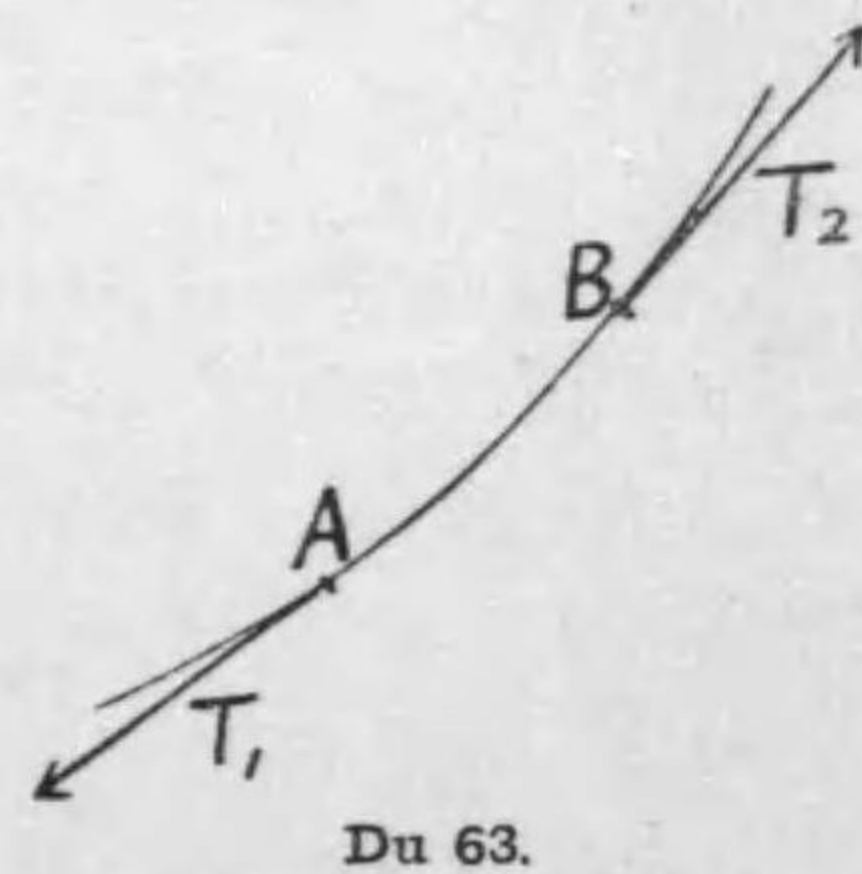
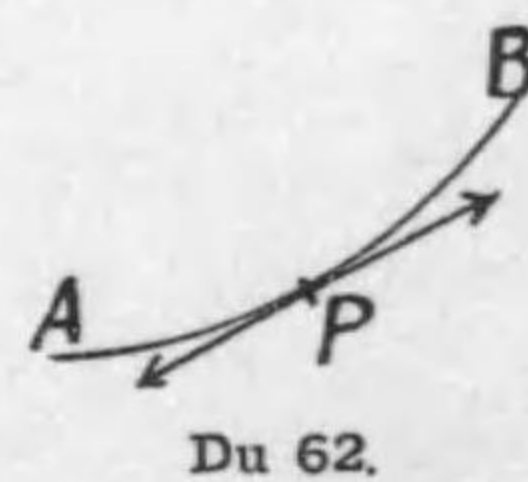
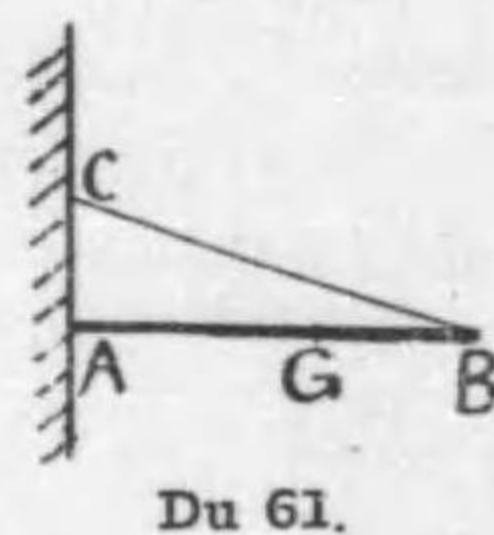
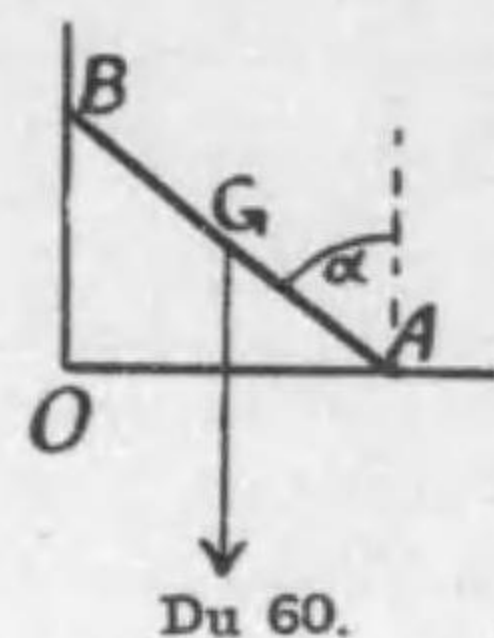
(iii) Omoi Bô AB wo Ito BC to A -Teni ni okeru Kabe no Masaturyoku dake de suiheini sasaeru niwa, Ito no Hôkô wo dô toreba yo ka?

57. Magariyasui Ito no Turiai. "Magariyasui" Ito to iu no wa, zibun no Nagasa no Hôkô ni hipparu Tikara wo sasaeru dake de, suityokuna Hôkô ni hataraku Tikara wo sasaeru koto no dekinai Ito de aru. Sita-gatte, Ito no kattena Ten P (Du 62) de, sore no Ryôgawa no Bubun, PA to PB to ga tagaini oyobosu Tikara wa, P ni oite Ito ni hiita Sessen no Hôkô ni oite hikiau Tikara ni kagiru. Kono Tikara wo Ito no Hari matawa Tyôryoku to iu.

Magariyasui Ito no koto wo hutûniwa tanni "Ito" to yonde iru.

58. Kotonî, karui Ito, sunawati Tyôryoku ni kurabete sore zisin no Omosa wo sutete kangaete yoi yôna Ito ga turiau Baai niwa, sore no kattena Bubun AB (Du 63) ga Ryôhazi ni hataraku hutatuno Tyôryoku T_1, T_2 dake de turiau kara, § 56 ni yotte⁽¹⁾, A, B

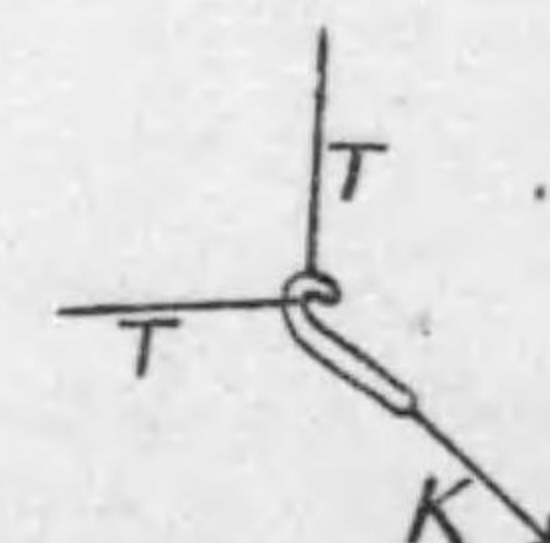
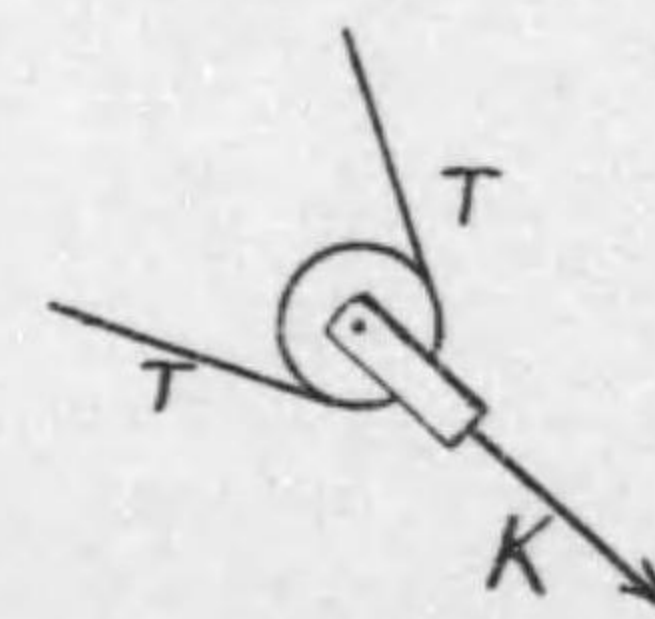
⁽¹⁾ Ito wa Gôtai de nai keredomo, genzai turiatte iru Baai niwa, sore ga sonomamano Katati de kataku natta to sitemo, Turiai ga kuruu hazu ga nai kara, sukunakutomo Gôtai to onazi Turiai no Dyôken wo mitasanakereba naranai.



hutatuno Ten ni okeru Sessen ga onazi Tyokusen de atte, katu $T_1 = T_2$ de nakereba ikenai. Sunawati, Ito no subeteno Ten ni okeru Sessen ga onazi Tyokusen de aru koto wo yôsuru node, Ito zisin ga Tyokusen no Katati ni hararete katu Tyôryoku ga doko demo onazi Atai wo motu.

59. Mottomo, kore wa ipponno Ito no uti, hoka kara Tikara wo ukenai Bubun hitotu ni tuite iu Koto de aru. Tatoba, ipponno Ito $ABCD$ (tugino Pêzi, Du 66), no Ryôhazi ga tomete atte, B to C to ni hoka kara K_1, K_2 no Tikara ga hataraite oreba, AB, BC, CD no mittuno Bubun ga betubetuni ueno Seisitu wo motu. Sunawati, AB, BC, CD wa onôno Tyokusen de, AB no Ito ga A wo hiku Tikara to B wo hiku Tikara to ga hitosiku T_1 , BC no Ito ga B to C to wo hiku Tikara ga hitosiku T_2 , CD no Ito ni tuitemo dôyô de atte, ippanno Baai ni T_1, T_2, T_3 wa betubetuno Atai wo motte iru.

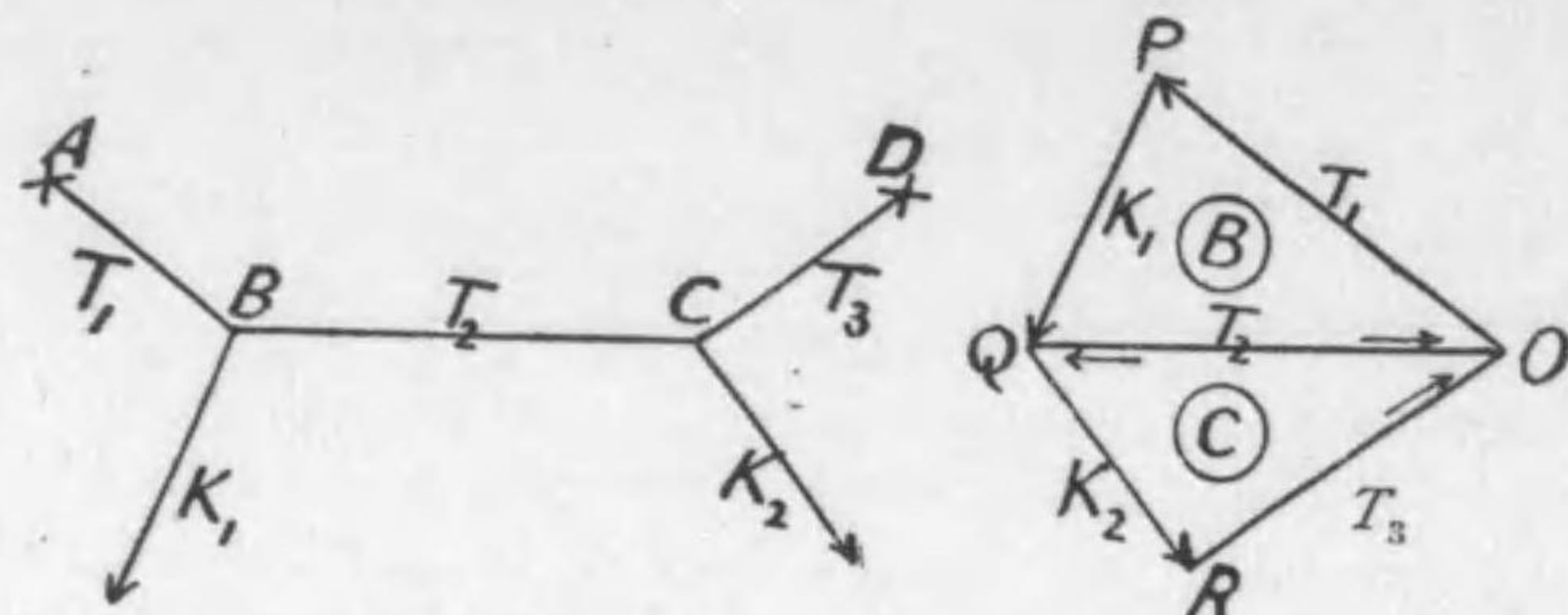
Tadasi, B, C no yôna Tokoro de Ito ga namerakana Kuruma matawa Kagi ni kakatte iru Baai (Du 64, 65) niwa, soko no Ryôgawa no Tyôryoku ga hitosii; mosimo ippôno Tyôryoku ga tuyokereba, Ito ga sono Hôkô e hippatte yukareru hazu, sunawati sonomama dewa turiatte inai hazu de aru⁽¹⁾.



60. Ito no Tahenkei. Du 66 no yôni, ipponno Ito no ikutu kano Ten ni Tikara ga hataraite sore ga tukurû Katati wo "Ito no Tahenkei" to iu.

Ito no Tahenkei no iroirona Bubun no Tyôryoku T_1, T_2, \dots to sotono Tikara K_1, K_2, \dots to no Kwankei wo, *du-sikino Hôhō* ni yotte, "Tikara no Tahenkei" de siru koto ga dekiru.

⁽¹⁾ Maeni Du 2 no Sôti ni tuite P. 5 no Susogaki ni tada zikkenzyôno Zizitu tositate kaita Koto wa kore no hitotuno Baai de aru.

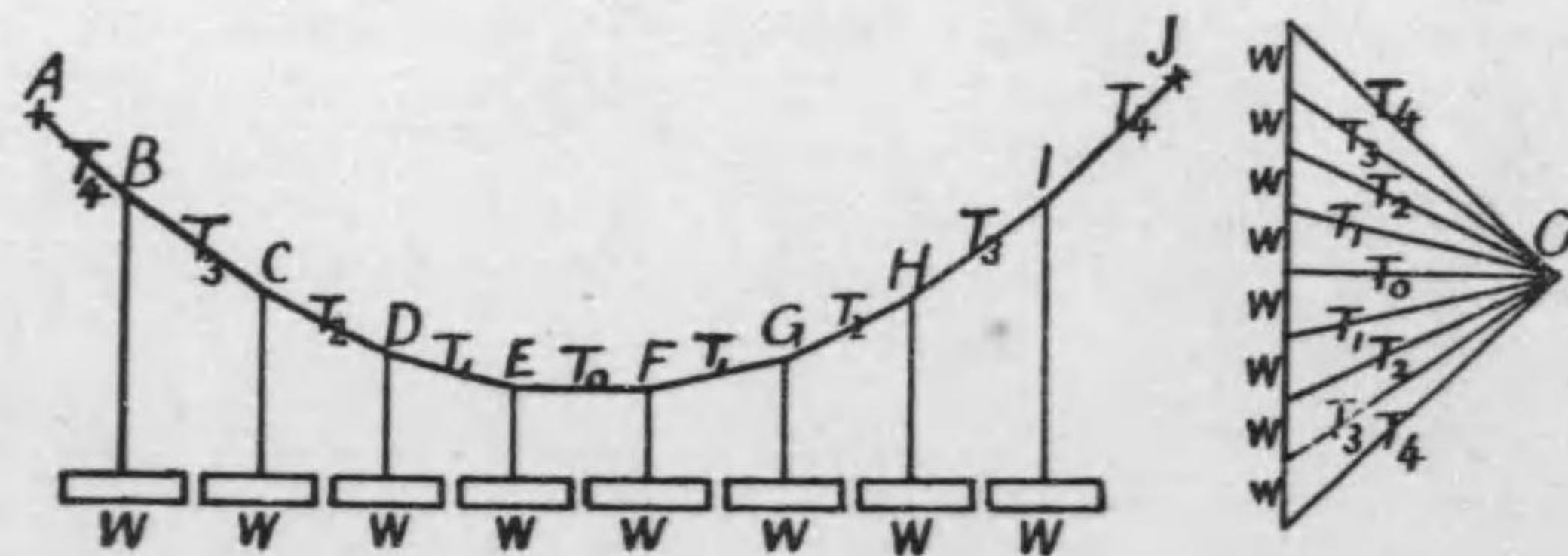


Du 66.

Du 67.

B-Ten no Turiai no Dyôken wa T_1, T_2, K_1 mittuno Tikara ga todita Sankakukei wo tukuru koto de aru kara, $K_1 : T_1 : T_2$ no Hi wa, Tikara ni heikôna Hen de tukutta Sankaku PQO (Du 67) no Hen no Hi de sireru. Dôyôni *C*-Ten no Turiai wo kangaete, $K_2 : T_2 : T_3$ no Hi ga Sankaku QRO no Hen no Hi de sireru. Kotonî, Du 67 no yôni, *B* ni hataraku T_2 to *C* ni hataraku T_2 to wo kyôtûna Hen QO de arawasu tameni, subeteno Tikara ga *onazi Sunpô* de Tikara no Tahenkei ni arawareru koto ni naru.

Mondai. Sotono Tikara ga yattuno hitosii Omori no Omosa *W* de aru. Sorerano Omori wo *onazi Takasa* ni katu hitosii Hedatari ni okitai tokini, Ito no iroirona Bubun oyobi Omori wo turisageru Ito no Nagasa wo dô toreba yoi ka? Tadasî Ito no mannakano Bubun (*EF*) wo suiheini suru.

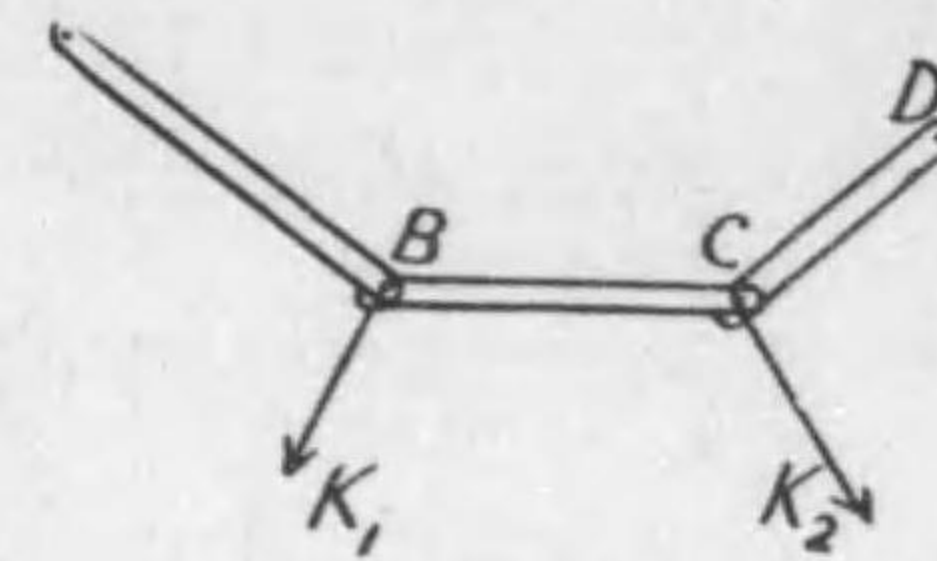


Du 68.

Du 69.

61. Namerakana Tugime wo sonaeta Bô. Du 70 no *AB*,

BC, CD ga iduremo Bô no Katati wo sita Gôtai de, sore no Ryôhazi ni tikai Tokoro ni, Tikara no hataraku Heimen ni suitiyokuna entyûkeino Ana wo motte ite, Bô *AB* no *B*-Hazi no Ana to Bô *BC* no *B*-Hazi no Ana to ni kyôtûna namerakana Marubô (Sinbô) ga hamatte iru to suru. *C* demo dôyô. Mata, *A* to *D* no Ana wa koteisita namerakana Sinbô ni hamatte iru to suru.



Du 70.

Kokoni *A, B, C, D* ni aru yôna Bô no Tugime wo namerakana Tugime to iu.

Namerakana Tugime de Bô ga Sinbô kara ukeru Tikara wa entyûkeino Ana no Tyûsinsen (Entyû no Diku ni ataru Sen) wo tôsite hataraku. Nazekanareba, Sinbô ga uturona Entyû-men no ue de, doko ni atatte iru to sitemo, sono Hureai ga nameraka de aru tameni, Hankôryoku wa Hureai no Men ni suitiyokuna Sen sunawati Entyû no Tyûsinsen wo tôru Sen ni sôte hataraku kara.



Du 71.

62. Mosimo turiatte iru Bô *AB* ni hataraku Tikara ga sore no Ryôhazi *A* to *B* ni okeru namerakana Tugime kara kuru Tikara *dake* de aru Baai (sitagatte, Bô no Omosa mo kangaenai Baai) niwa, sono Bô wa tada hutatuno Tikara wo ukete turiatte iru no da kara, sorerano Tikara wa Tyokusen *AB* (kuwasiku ieba, hutatuno entyûkeino Ana no Tyûsinsen wo turaneru Sen) ni sôte hataraitte iru.

Soreyueni, Du 70 no yôna Kumiai de, sotono Tikara K_1, K_2 ga namerakana Tugime *B, C* no Sinbô ni hataraitte iru to sureba, kono Kumiai ni okeru Tikara no Hatarakikata wa Du 66 no Ito no Baai to mattaku dôyô de aru. Tada, konoyôna Bô no Kumiai to Ito no Baai to de tigau Koto wa, Bô dewa *osu Tikara* no hataraki eru ni taisite, Ito dewa *hiku Tikara* nomi ga hataraku koto de aru. Tatoeba, Du 70 de K_1 to K_2 no

Hôkô wo gyakuni sureba, subeteno Bô ni Osi no Tikara ga okotte, motono Iti de sonomama turiatte iru ga, Du 66 no Ito dewa, K_1, K_2 no Hôkô wo gyakuni sureba Ito ga tarunde simau.

63. Ueno yôna Sikake de, Bô zisin no Omosa matawa sonohokano Tikara ga Bô ni hataraku Baai niwa, Tugime ni okeru Tikara wa Hôkô mo Ooisa mo zibun dake de kimattewa inakute, ippanno Gôtai ni okeru to onazi Turiai no Dyôken kara kimaru no ga hutû de aru.

64. Reidai. Hitosii Omosa (W), hitosii Nagasa $AB=BC=CD=a$ no itiyôna Bô ga Du no yôna Iti ni, onazi Takasa no A to D ni okeru namerakana Kugi ni kakatte iru ($AD=2a$). Tugime C oyobi Kugi D ni okeru Tikara wo dase!

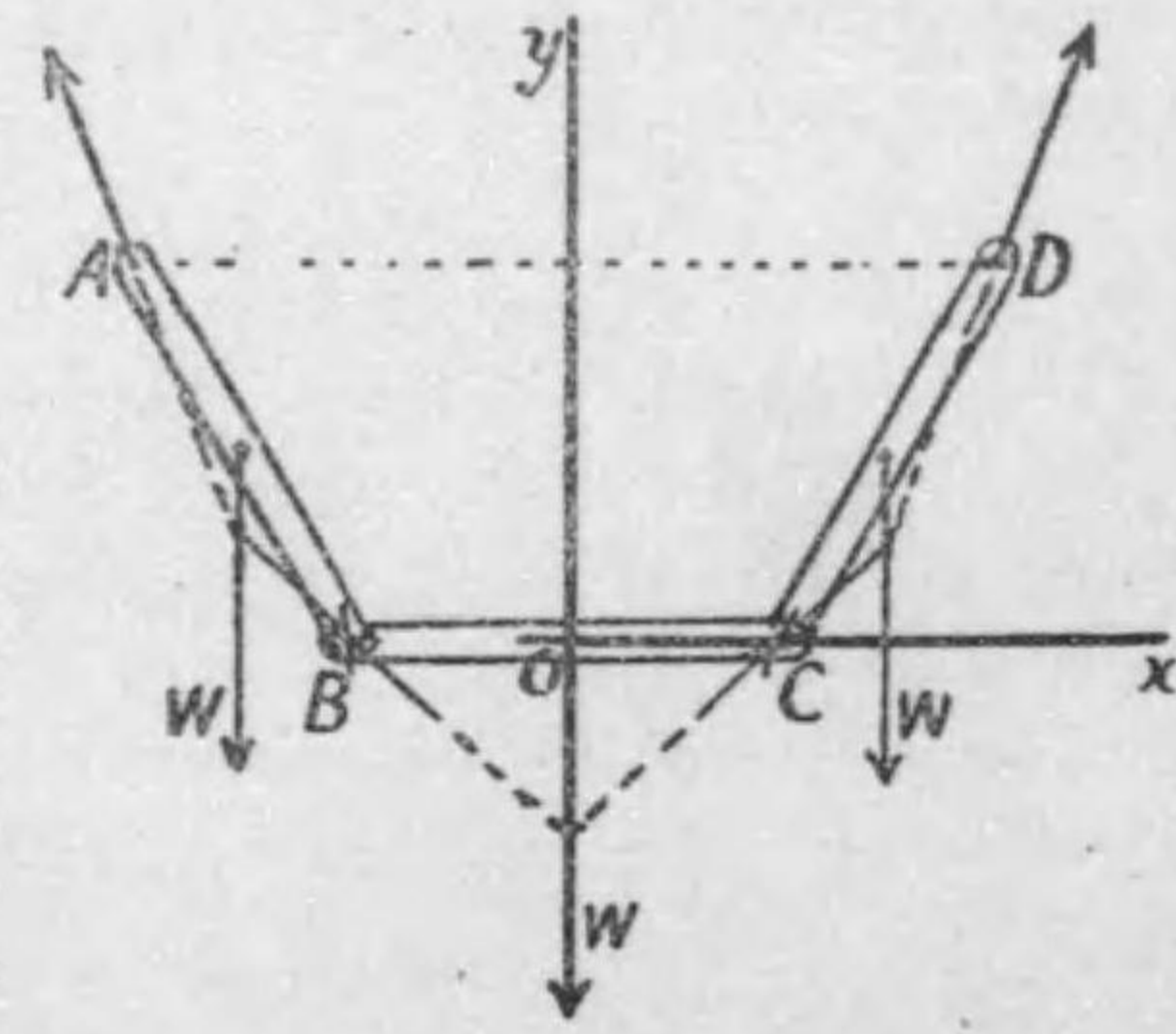
Kono Baai niwa, onônono Bô ni hataraku Tikara ga mittu da kara, § 55 (b) no Teiri ni yotte kangactemo yoi ga, ima § 54 no kaisekitekinô Siki de siraberu.

Subeteno Kotogara ga mihi-hidari taisyôni natte iru kara, BC wa suihei de aru. BC no Mannaka ni Zahyô-genten wo totte, suiheini x -Diku, ueni y -Diku wo toru. A, B, C, D yottuno Ten no Zahyô wa—

$$A(-a, \frac{\sqrt{3}a}{2}), B(-\frac{a}{2}, 0), C(\frac{a}{2}, 0), D(a, \frac{\sqrt{3}a}{2}).$$

Bô BC ga C de ukeru Tikara no Seibun wo X, Y ; Bô CD ga D de ukeru Tikara no Seibun wo X', Y' to sureba, Taisyô no Kwankei kara,

$$\begin{aligned} CD \text{ ga } C \text{ de ukeru Tikara wa } & -X, -Y; \\ BC \text{ ga } B \dots\dots\dots & -X, Y; \\ AB \text{ ga } B \dots\dots\dots & X, -Y; \\ AB \text{ ga } A \dots\dots\dots & -X', Y'. \end{aligned}$$



Du 72.

Sitagatte, BC no Turiai no tameniwa, tugino mittuno Kwankei ga hituyô de aru:—

$$\Sigma X = X - X = 0 \dots\dots\dots(1),$$

$$\Sigma Y = 2Y - W = 0 \dots\dots\dots(2),$$

$$\Sigma(xY - yX) = \frac{a}{2}Y - \frac{a}{2}Y - 0 \cdot W - 0 \cdot X - 0 \cdot (-X) = 0 \dots\dots(3).$$

Mata, CD no Turiai no tameniwa,

$$\Sigma X = -X + X' = 0 \dots\dots\dots(4),$$

$$\Sigma Y = -Y + Y' - W = 0 \dots\dots\dots(5),$$

$$\Sigma(xY - yX) = \frac{a}{2}(-Y) + aY' - \frac{3a}{4}W - 0(-X) - \frac{\sqrt{3}a}{2}X' = 0 \dots\dots(6).$$

(1) to (3) to wa sizenni mitasareru; sosite nokorino yottuno Hôteisiki wa X, X', Y, Y' wo tugino yôni kimeru:—

$$Y = \frac{W}{2}, Y' = W + Y = \frac{3}{2}W,$$

$$X' = X = \frac{2}{\sqrt{3}} \left\{ Y' - \frac{1}{2}Y - \frac{3}{4}W \right\} = \frac{1}{\sqrt{3}}W.$$

Mata, $Y : X = \frac{\sqrt{3}}{2}, Y' : X' = \frac{3\sqrt{3}}{2}$ kara C to D ni okeru Tikara no Hôkô ga wakarû.

65. Koteisita Diku wo motu Gôtai no Turiai. Tikara ga Diku ni suitoyokuna hitotuno Heimen ni hataraku Baai. Gôtai ga “koteisita Diku” wo motte iru to iu no wa, sore no utino hitotuno Tyokusen (Diku) ga tekitôna Hôhô de sasaerarete ugoki enai yôna Arisama ni natte iru koto wo imisuru; sunawati, Diku wo osu yôna Tikara ga hatarakuto, Diku no Sasae ga sore wo sasaeru yôna Tikara sunawati “Hankôryoku” wo okosu. Kono Hankôryoku wa, Hôkô ya Ooisa wa Baai ni yotte iroiro de arô keredomo, Sayôsen ga Diku wo tôru tameni, Diku no mavarino Moment wa o to kimatte iru.

Gôtai ga Diku ni suitoyokuna hitotuno Heimen ni hataraku Tikara wo ukete turiatte oru tokiniwa, sorerano Tikara ni Diku no Hankôryoku wo kuwaeta zentai ni tuite § 54 no mittuno Dyôken ga okonawarete iru. Sononakade, $\Sigma X = 0, \Sigma Y = 0$ niwa Hankôryoku wo hukunde iru ga, Moment no Siki niwa Hankôryoku wa hukumarete inai (Hankôryoku no Moment ga o da kara). Soreyueni ataerareta Tikara dake ni tuite,

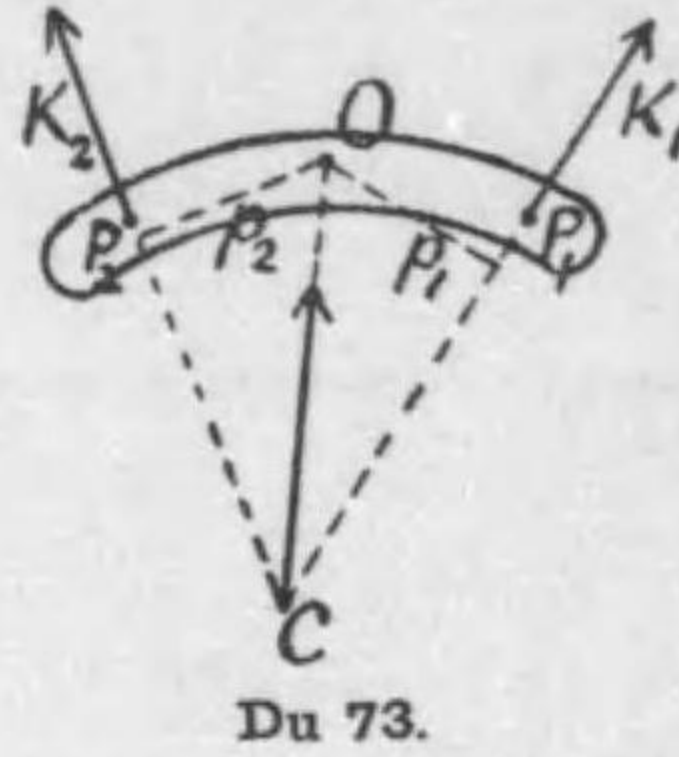
$$\left. \begin{aligned} & \text{Diku no mawarino Moment no daisûtekino } Wa=0, \\ & \text{kaisekitekini kakeba, Diku wo } s\text{-Diku ni totte,} \\ & \qquad \qquad \qquad \Sigma(x_i Y_i - y_i X_i) = 0 \end{aligned} \right\} \dots (1).$$

Kore ga Turiai no Dyôken de aru.

Tatoeba, O ni Koteidiku wo motu Gôtai ni Du 73 no yôni K_1, K_2 no Tikara ga hataraite turiau to sureba,

$$K_1 p_1 = K_2 p_2$$

no Kwankei ga aru. Konotoki, K_1, K_2 no Gôryoku wa, hutatuno Sayôsen no Kiriaiten C wo O ni musubu Tyokusen CO ni sôte Diku wo osite iru no de aru.

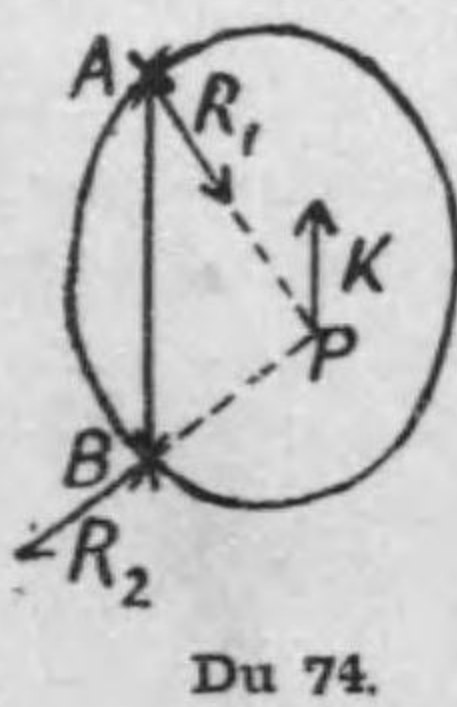


66. Koteisita Diku wo motu Gôtai no Turiai. Ippanno Baai. Tugini, Tikara no Sayôsen ga Diku ni katamuite iru Baai oyobi tigau Heimen ni aru Baai wo siraberu.

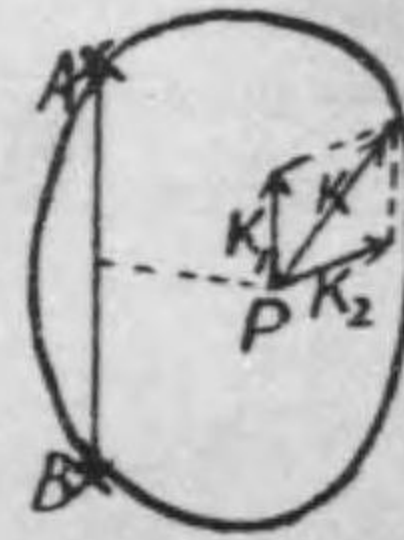
Diku wo sasaeru niwa sore no ueno sukunakumo hutatuno Ten wo sasaeru koto ga hituyô de aru kara, hutatuno Ten A, B ga sasaerarete aru mono to suru. Sitagatte, Hankôryoku wa korerano Ten A, B ni hataraku wake de aru.

67. Zyunbino Teiri (i). Gôtai ga A, B hutatuno Ten de sasate aru tokini, Du 74 no yôni, AB Sen ni heikôna Tikara K ga sore ni hataraku Baai niwa,

A to B to ni Du no R_1, R_2 no yôna Hankôryoku ga tekitôna Hôkô oyobi tekitôna Ooisa ni hataraite sore to turiau. Soreyueni, kattena Ten P (Du 75) ni kattena Hôkô no Tikara K ga hataraku tokiniwa, sore wo Diku ni heikôni waketa Bunryoku K_1 wa Hankôryoku ni sasaerarete, Gôtai no Turiai ni mukwankeini naru; sosite, K no Sayô wa mattaku, Diku ni suityokuna Heimen ni okeru Bunryoku K_2 dake no Sayô to onazi de aru.



Du 74.

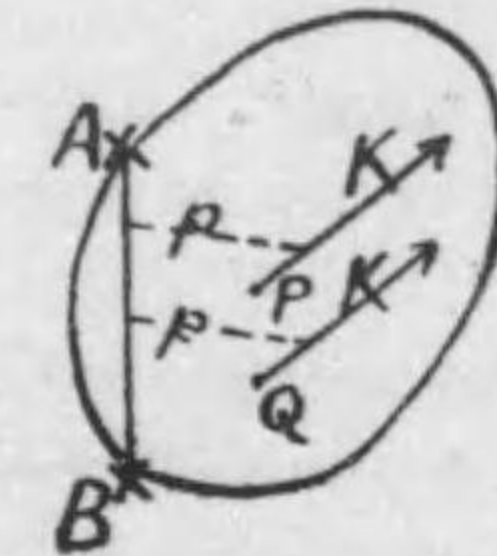


Du 75.

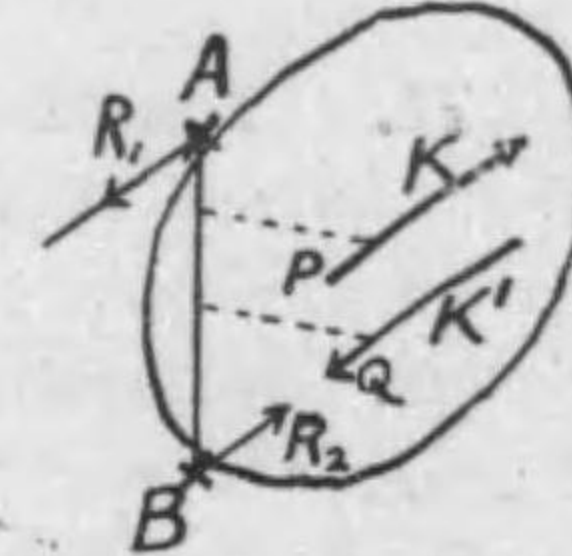
68. "Aru Tyokusen (Diku) no mawarino Tikara no Moment" wa, Tikara no Hôkô ga Diku ni suityoku de nai Baai niwa, Diku ni suityokuna Heimen ni okeru sore no Bunryoku no Moment to onazimono wo imisuru. Sunawati, Du 75 no Baai niwa, AB Sen no mawarino Tikara K no Moment wa K_2 no Moment to onazimono de aru.

69. Zyunbino Teiri (ii). Diku AB ni suityokuna hutatuno Heimen de, Hôkô mo Ooisa mo onazi Tikara ga hitosii. Ude wo motte hataraite iru no wa dôto de aru.

Tatoeba, Du 76 de, P ni okeru K to Q ni okeru K to ga, Hôkô mo Ooisa mo onazi de, Ude p ga hitosii naraba, sorera no Sayô wa dôto de aru. Nazekanareba, Q ni okeru K wo sonomama gyakuni



Du 76.



Du 77.

totte K' to sita Baai (Du 77) wo kangaeruto, K, K' wa Diku ni heikôna Heimen ni okeru Gûryoku wo katatidukuru tameni, sore wa Sasae no Ten A, B ni okeru Hankôryoku R_1, R_2 no Gûryoku de sasaerarete Sayô wo arawasanaï kara.

70. Turiai no Dyôken. Koteisita Diku AB wo motu Gôtai ni kattenni Tikara ga hataraite turiatte iru Baai niwa, Diku ni suityokuna hitotuno Heimen ni Tikara no hataraku Baai (§ 65) to onazi Teiri ga okonawareru; sunawati,

$$\left. \begin{aligned} & \text{Diku no mawarino Moment no } Wa=0, \\ & \text{mata, Diku wo } s\text{-Diku ni totte,} \\ & \qquad \qquad \qquad \Sigma(x_i Y_i - y_i X_i) = 0 \end{aligned} \right\} \dots (1).$$

Nazekanareba, Tikara no Diku ni heikôna Seibun (Z_i) mo, Sayôten no s -Zahyô mo, § 67, 69 no Teiri ni yotte, Eikyô ga nai kara, Tikara no Sayô wa, subeteno Tikara ga Diku ni suityokuna hitotuno Heimen ni oite, sorezore ataerareta tôrino x -Seibun to y -Seibun to narabini Sayôten no x, y -Zahyô wo motte, hataraite iru Baai to onazi de aru; soreyueni, Turiai no Dyôken wa § 65 no tôri de aru. Sonoue, ataerareta Tikara no

“Moment” to iu Ryô ga, § 68 ni yotte, sore no Diku ni suitiyokuna Seibun dake no Moment to onazi de aru kara, ippanno Baai no Turiai no Dyôken ga, Kotoba mademo mattaku maeno Baai no Dyôken (§ 65 no (1)) to onazini naru no de aru.

Tyûi. Donna Gôtai demo, sore ga turiatte iru Baai niwa, sore no utino kattena Tyokusen wo sono Iti ni sasaeru yôna Sikake ga aru to sôzôsitemo, Turiai wa sonomama naritatu koto wa iu mademo nai. Soreyueni, *turiatte iru Gôtai ni hataraku subeteno Tikara no Moment wo kattena Tyokusen no mawarini toreba, sore no Daisûwa wa rei de aru*⁽¹⁾.

71. “Kantanna Kikai”. Mokuteki no Buttai (matawa Buttai no Bubun) ni Tikara wo kuwaeru no ni, tyokusetuni Tikara wo kuwaeru kawarini, aidani *Teko, Kwassya, Rindiku, Syamen, Kusabi, Nedi* nado no Sikake wo Nakadati ni tukau koto ga aru. Korera wo “kantanna Kikai” to tonaeru.

Kantanna Kikai wo tugino hutatuno Syurui ni wakeru koto ga dekiru:—

(i) Koteisita Diku wo sonaeta mono; *Teko, Kwassya, Rindiku.*

(ii) Koteisita Diku wo motanai mono; *Syamen, Kusabi, Nedi.*

Teko wa Syurui (i) no Daihyôzya de, Syamen wa Syurui (ii) no Daihyôzya to mite yoi.

⁽¹⁾ Kono Teiri wo ôyôsute, § 55 no Owari ni nobeta Teiri, sunawati mittuno Tikara K_1, K_2, K_3 ga Gôtai ni hataraitte turiau tokini, sorera no Sayôsen S_1, S_2, S_3 ga kanarazu hitotuno Heimen ni aru koto wo syômeisuru koto ga dekiru. Tikara K_1 no Sayôsen S_1 ni kattena hutatuno Ten A, A', K_2 no Sayôsen S_2 ni kattena hutatuno Ten B, B' , wo tori, Tyokusen AB no mawarini Moment wo toreba, K_1 to K_2 no Moment ga o de aru kara, K_3 no Moment mo o de nakereba naranai; sunawati, K_3 no Sayôsen S_3 ga AB -Sen ni kirawaneba naranai. [Gûzen sore ga AB ni heikô de aru koto mo ari eru ga, sono Baai niwa B no Iti wo sukosi kaete toreba yoi.] Onazi Riyû de, S_3 wa AB' mo kuru kara, S_3 wa A -Ten to S_2 to wo hukumu Heimen ni aru. Sunawati, S_2 to S_3 to ga hitotuno Heimen H ni atte, A -Ten ga sore no ueni aru koto wo yôsuru, A' -Ten ni tuite onaziyôni kangacuto, A' mo onazi Heimen H no ueni aru koto wo yôsuru. Soreyueni, AA' sunawati Sayôsen S_1 mo Heimen H no ueni aru. Sunawati, mittuno Sayôsen S_1, S_2, S_3 ga mina onazi Heimen H ni aru.

Kuwaeru Tikara wo tada *Tikara*, sore ni yotte ugokasareru Buttai no okonau Tikara wo *Teikôryoku* to iu no ga hutû de aru.

Korerano Kikai no zissaino Tukaimiti dewa, Hito ga kuwaeru Tikara ni yotte Teikô-buttai ga ugokidasu no de aru kara, sorerano Kikai ga turiatte oru no dewa nai. Sikasi, Tikara ga Teikôryoku ni taisite turiaubeki Atai yorimo *kiwamete sukosi demo* ôkii tokiniwa, motomerareru yôni Buttai ga ugoku — Hayasa wa Mondai ni sinai — kara, wareware wa *Tikara to Teikôryoku to ga turiau Kwankei wo sireba*, Buttai wo ugokasu no ni hituyôna Tikara ga wakaruru no de aru.

72. Teko no Teiri. Teko no Sasaeten wa koteisita Diku to mirareru node, sore ni hataraku Tikara to Teikôryoku to no Kwankei wa § 65 no Teiri sunawati koteisita Diku wo motu Gôtai no Turiai ni okeru Kwankei to onazi de aru. Tûzyô hitotuno Tikara de hitotuno Teikôryoku wo osinokeru kara,

Sasaeten no mawarino Tikara no Moment to Teikôryoku no Moment to ga hitosikute, hantaini hataraku tokini Teko ga turiau.

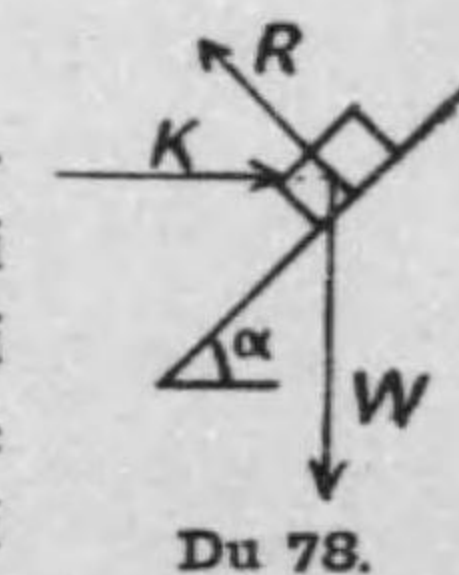
Kore ga “Teko no Teiri” de aru.

Rindiku wa motiron, *Kwassya* no iroirona Baai (Sinbô ga koteisite aru Baai, sore ga ugoki uru Baai) mo mina Teko no Riron de syobunsareru.

73. Syamen to Kusabi. Koteisita namerakana Syamen ni omoi Buttai ga aru tokini (Teikôryoku ga kono Buttai no Omosa), sore ni Tikara wo kuwaete osiageru koto wo § 24 de sirabeta. *Suiheina* Tikara wo kuwaeru Baai (Du 78) ni, Tikara K wa

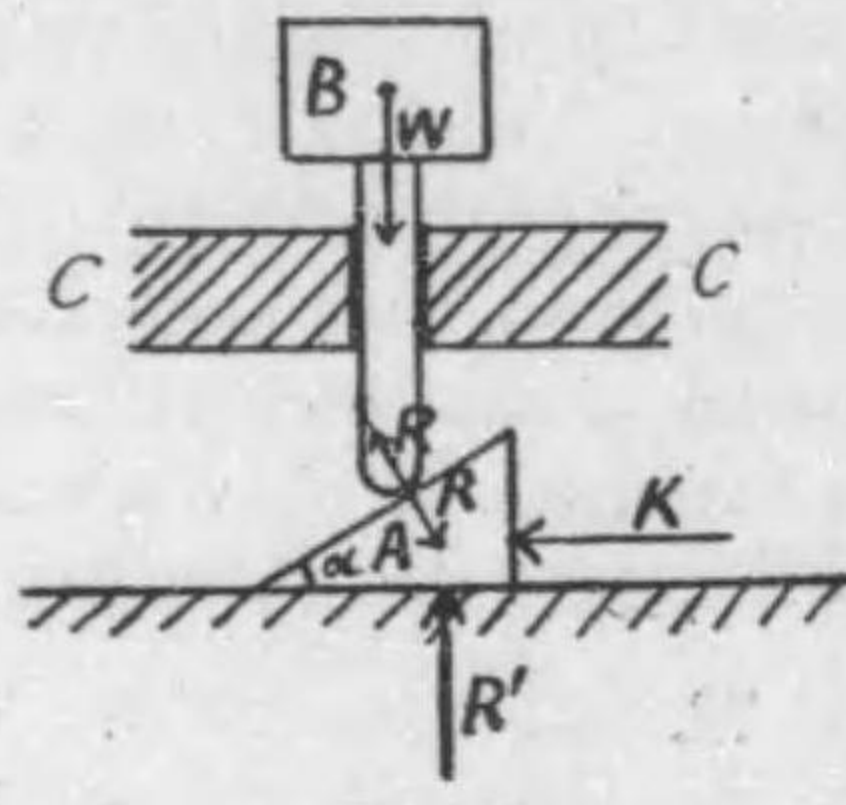
$$K = W \tan \alpha.$$

Kore to onazi Kwankei wa, Du 79 no yôni ue-sitani dake ugoki uru Buttai B no sitani Kusabi A wo osikonde sore wo ageru Baai ni, Kusabi wo osu Tikara K to Buttai B no Omosa W to ni okonawareru. Tadasî, Kusabi no notte iru Men wa suihei de, katu subeteno Hureai ga nameraka da to suru. Nazekanareba,



Du 78.

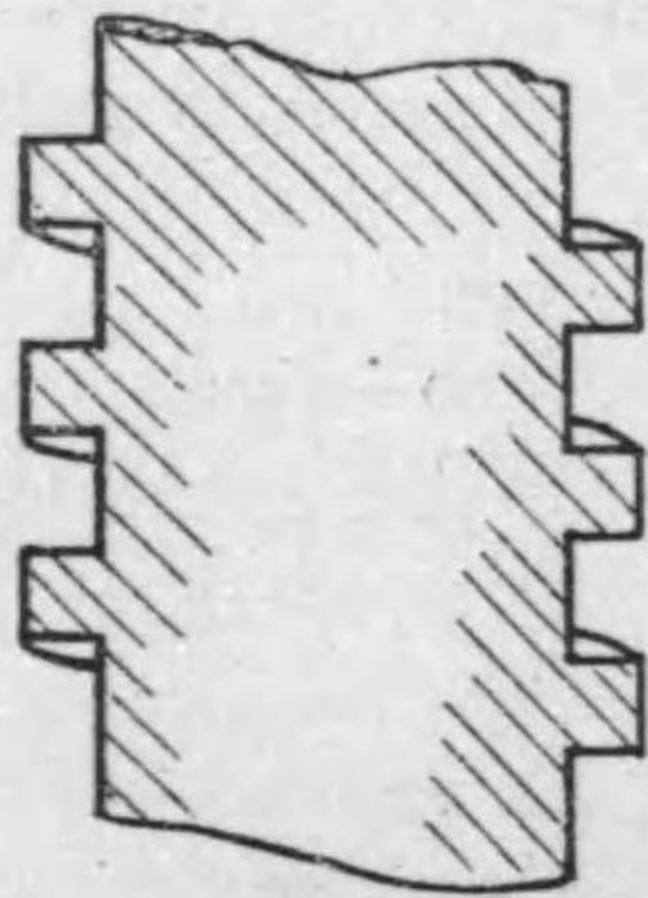
Buttai no suiheina Undô wo tomeru (CC ga okonau suiheina) Tikara wo X ,
 Buttai to Kusabi to ga osiau (Kusabi no Syamen ni suityo-kuna) Tikara wo R ,
 Kusabi no notte iru Men no (entyokuna) Hankôryoku wo R' to sureba, Buttai no Turiai kara
 $W=R \cos \alpha$, $X=R \sin \alpha$;
 Kusabi no Turiai kara
 $R'=R \cos \alpha$, $K=R \sin \alpha$;
 sitagatte, $K=W \tan \alpha$.



Du 79.

[Toi. CC ga okonau Tikara X no Hatarakikata wa dô ka?]

74. *Nedi.* Nedi (Du 80 wa tateni kitta Du) wa Syamen wo nagaku site Hasira ni makituketa Sikake to miru koto ga dekiru.



Du 80.



Du 81.

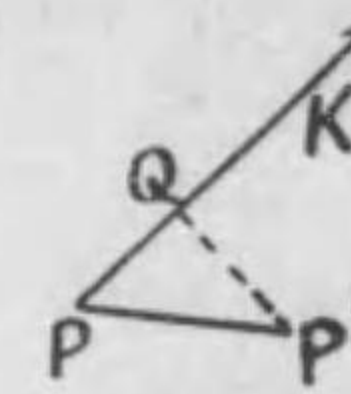
Tadasi, Nedi-yama no Katati ga Du 81 no yôna mono dewa, Noborizaka no Men ga Migi-hidari ni katamuite iru to onaziyôna Kwankei ni — mata Sakamiti wo Saidai-keisya no Hôkô ni taisite aru. Kakudo wo nasu Hôkô ni Mono wo osiageru no to onaziyôna Kwankei ni — natte iru kara, Tikara no Hatarakikata ga huku-zatuni naru ga, sikasi notini siru Teiri (§ 80) ni yottemo sireru tôri, Tikara no Kwankei wa Du 80 no Baai to tigawanai.

75. *Sigoto.* Buttai no hitotuno Ten P (Du 82) ga Tikara

K wo ukete oru aidani, P kara P' made ugoku tokini, "Tikara K ga (matawa sore wo okonatte iru Buttai ga)

$$W = K \cdot \overline{PP'} \cdot \cos (K, PP')$$

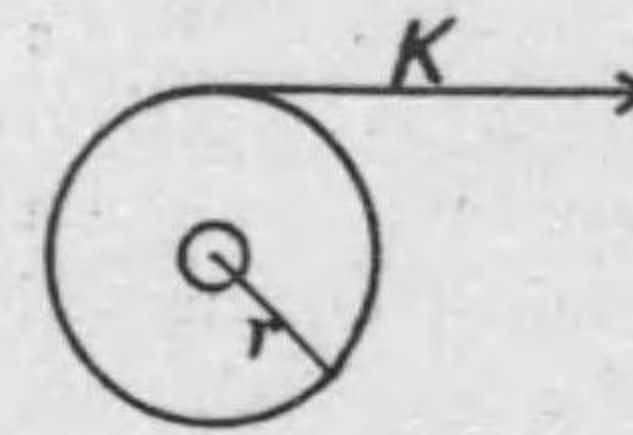
dakeno *Sigoto* wo sita to iu. $PP' \cos (K, PP') = PQ$ wa, PP' wo Tikara no Hôkô ni syaeisita



Du 82.

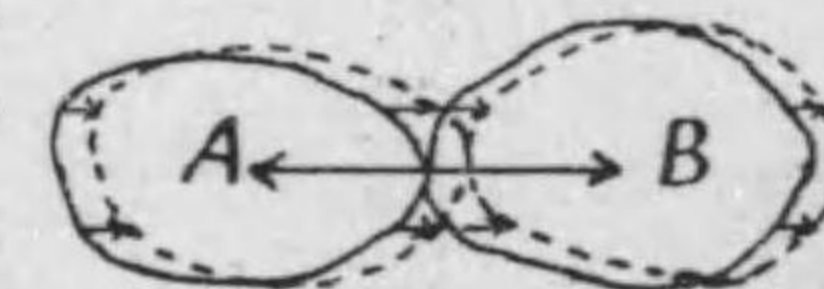
Nagasa, sunawati "Tikara no Hôkô ni sore no Sayôten no ugoita Kyori" de aru kara, "Sigoto wa Tikara to, sore no Sayôten ga sore no Hôkô ni ugoita Kyori to no Zyôseki de aru" tomo iwareru. Kaku (K, PP') ga Tyokkaku yorimo ôkii Baai niwa, Tikara K no nasita Sigoto wa hu de aru. Kono Sigoto no Keisan wa, Ten P no Undô ga Tikara K no tameni okotta Undô de aru-nai niwa kwankeisina no de, kotoni sôzôzyôno Iti no Kawari ni taisitemo Sigoto wo keisansuru koto ga dekiru.

Tatoeba, Hankei r no Kuruma (Du 83) ni zurenai yôni makitukete aru Ito wo K dake no Tikara de hiki tutu, Kuruma ga hitomawari-sureba, kono Tikara ga $K \cdot 2\pi r$ dake no Sigoto wo sita no de aru.



Du 83.

Mata, Buttai A to B (Du 84) to ga tagaini Tikara wo oyobosite (tatoeba osiatte) iru aidani, Hureaiten ga B no hô e ugokeba, A no nasu Sigoto wa (+), B no nasu Sigoto wa (-) de, hutatu ga Ookisa ga hitosii.

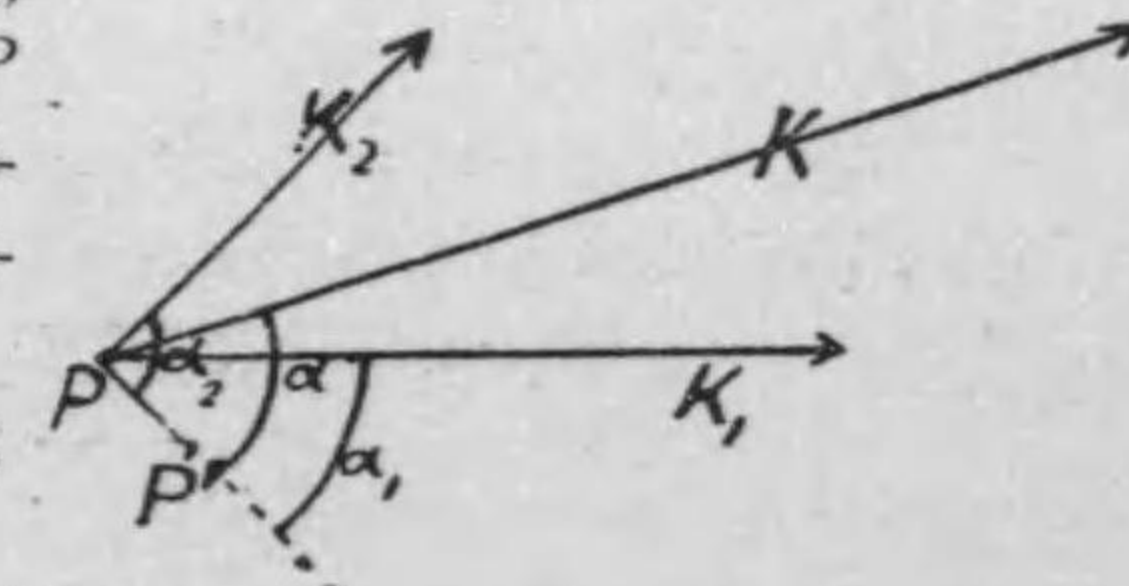


Du 84.

76. *Sigoto no Keisan ni kwansuru Teiri I.* Onazi Ten P (Du 85) ni hutatuno Tikara K_1 , K_2 ga hataraite iru aidani, P ga P' ni ugokeba, hutatuno Tikara ga nasita Sigoto no zentaino Ryô =

$$(K_1 \cos \alpha_1 + K_2 \cos \alpha_2) \times \overline{PP'};$$

tadasi,
 $\alpha_1 = (K_1, PP')$,
 $\alpha_2 = (K_2, PP')$.



Du 85.

§ 15 no Teiri de, K_1, K_2 no Gôryoku wo $K, (K, PP') = \alpha$ to sureba,

$$K_1 \cos \alpha_1 + K_2 \cos \alpha_2 = K \cos \alpha.$$

Yueni, ueno Ryô = $K \cos \alpha. PP'$

$$= \text{Gôryoku no Sigoto.}$$

Sunawati, hitotuno Ten ni hataraku ikutu kano Tikara ni tuite betubetuni keisansita Sigoto no Wa wa Gôryoku ni tuite keisansita Sigoto ni hitosii.

77. II. Gôtai ni hataraku Tikara ga sore no Sayôsen no ueno hitotuno Ten P_1 ni hataraku to suru no to, hokano Ten P_2 ni hataraku to suru no to de, Sigoto no Ryô ni Tigai ga aru ka nai ka wo siraberu.

Gôtai no Hen'i (Iti no Kawari) ga Kwaiten wo hukumanai Baai niwa, P_1 to P_2 no Hen'i ga onazi de aru kara, Sigoto no Keisan ni Tigai no nai no wa akiraka de aru. Soreyueni, wareware wa tada Kwaiten no aru Baai dake wo sirabereba yoi.

Gôtai ga Ten O (Du 86) wo Tyûsin to site tiisai Kaku θ dake mawatta to si, O kara Sayôsen ni itaru Suisen-kyori wo p to suru.

Kono Kwaiten de, P_1 ga P_1' ni, P_2 ga P_2' ni kuru to sureba,

$$P_1 P_1' \perp OP_1, \overline{P_1 P_1'} = \overline{OP_1} \cdot \theta;$$

$$P_2 P_2' \perp OP_2, \overline{P_2 P_2'} = \overline{OP_2} \cdot \theta.$$

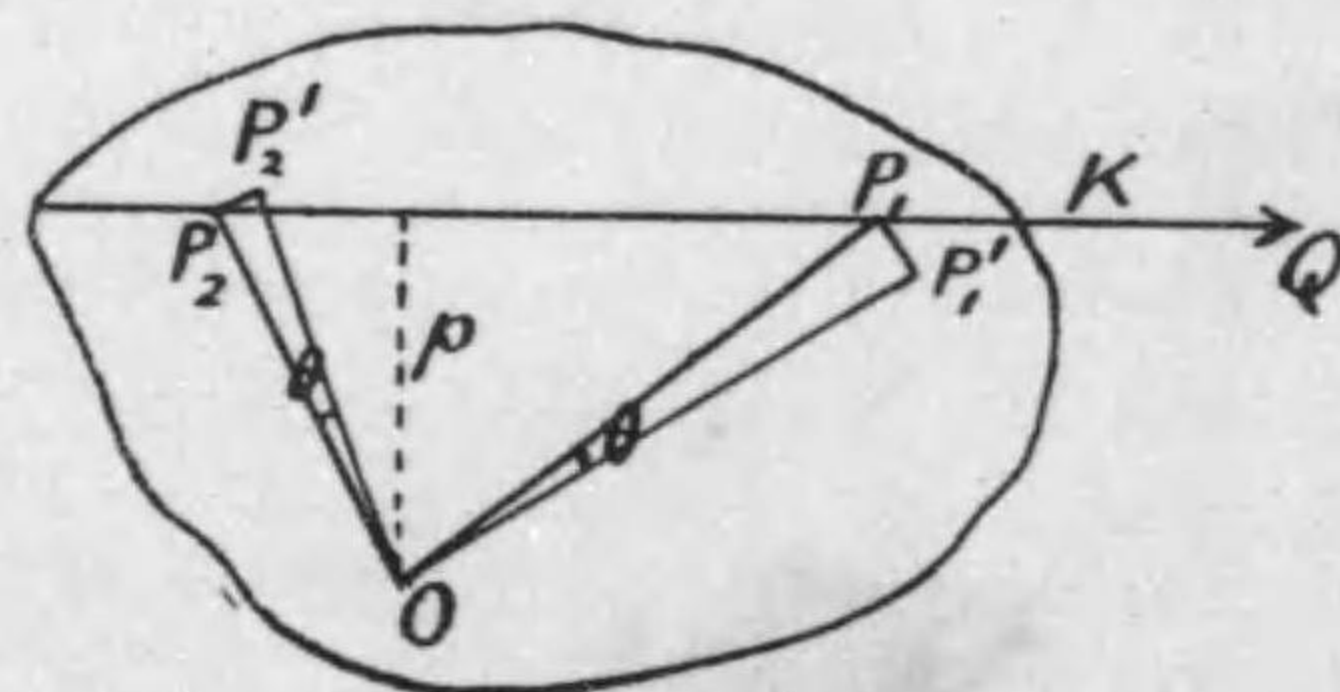
K ga P_1 ni hataraku to sureba,

$$\text{Sigoto} = K \cdot \overline{P_1 P_1'} \cdot \cos (P_1' P_1 Q)$$

$$= K \cdot \overline{OP_1} \cdot \theta \cdot \sin (OP_1 Q)$$

$$= K \cdot p \cdot \theta.$$

K ga P_2 ni hataraku to sitemo, dôyôni



Du 85.

$$\text{Sigoto} = K \cdot \overline{P_2 P_2'} \cdot \cos (P_2' P_2 Q) = K \cdot p \cdot \theta.$$

Soreyueni,

Sigoto no Ryô wa, Sayôsen no ueno dono Ten ni Tikara ga sayôsuru to sitemo Tigai ga nai.

78. III. § 39-41, 45-49 de nobeta Gôtai ni hataraku Tikara no Gôsei wa, hitotuno Ten ni hataraku Tikara no Gôsei to Sayôsen no Teiri to wo Dodai ni site okonawarete iru. Sikaruni, korerano hutatuno Kwankei de dôto to mitomerareru Tikara wa, ueno Teiri (I), (II) ni yotte, Sigoto no Ryô ni oitemo dôto de aru. Soreyueni,

Gôtai ni hataraku Tikara ga sore no kattena Hen'i ni taisite nasu Sigoto wa, Tikara zisin ni tuite betubetuni keisansite kuwaetemo, sorera no Gôryoku ni tuite keisansitemo Tigai ga nai.

79. IV. Ueni § 77 de eta kwaitensuru Gôtai ni taisite nasareru Sigoto no Ryô no Siki $Kp\theta$ de, Kp wa Tikara no Moment de aru. Yueni,

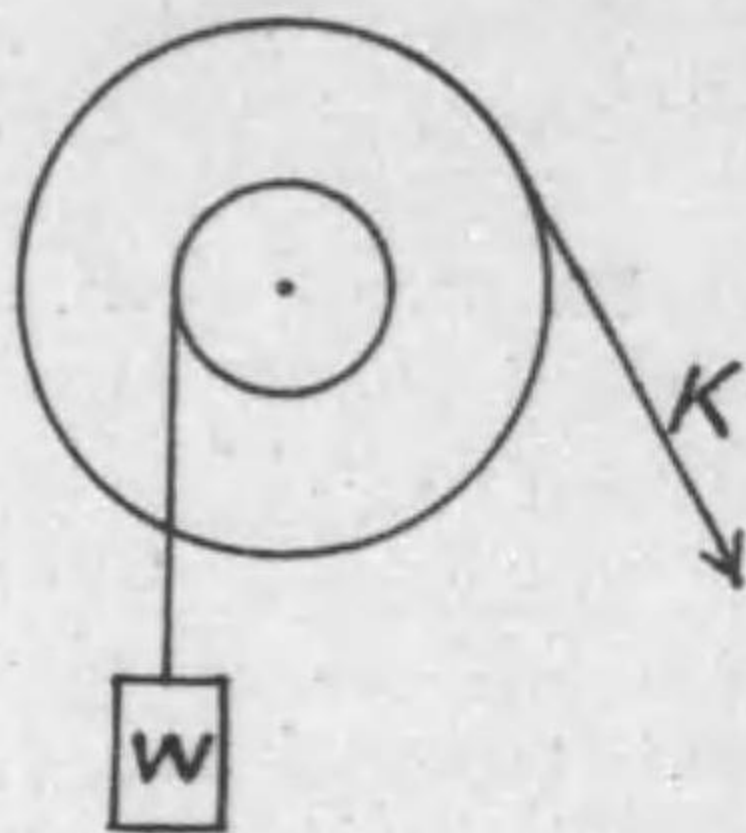
Kwaitensuru Gôtai ni nasareru Sigoto

$$= \text{Tikara no Moment} \times \text{Kwaitenkaku (Radian de hakatta).}$$

80. Turiau Tikara no Kumiaini kwansuru "karino Sigoto" no Genri. Ueno Teiri no tokubetuna Baai tosite, Tikara ga turiau Baai niwa, Gôryoku ga o de aru kara, donna tiisai Iti-no-kawari sunawati Hen'i wo Gôtai ni ataeru to sitemo, sore ni taisuru Sigoto no Ryô wo, onônono Tikara ni tuite betubetuni keisansite kuwaeta tokini, tyôdo o ni naru. Sôiu Sigoto wa tada sôzôzyôno mono de, zissaini nasareru Sigoto de nai kara, kore wo "karino Sigoto" to tonae, kono Teiri wo "karino Sigoto no Genri" to nadukeru. Kono Genri wa, Gôtai bakari de naku, motto hiroku subeteno Buttai oyobi Buttai-kumiai ni okonawareru Genri de, tugino yôni iiarawasareru:—

Turiatte iru Buttai matawa Buttai-kumiai ni hataraitte iru subeteno Tikara ga kattena karino Hen'i ni taisite nasu Sigoto no zentaino Wa wa rei de aru.

81. Kantanna Kikai (tatoeba, Du 87 no Rindiku) ga Tikara K to Teikôryoku W to wo ukete turiatte iru tokini, sono Kikai wo Tikara no Hôkô ni sukosi susu-meta to kangaeruto, Tikara K ga S dake no Sigoto wo suru toki, Teikô-buttai ga $-S$ dakeno Sigoto wo suru, sunawati Kikai ga Teikô-buttai ni taisite S dakeno Sigoto wo suru. Kono Sigoto wa tumari Tikara ga nasita Sigoto to onazimono de aru. Sunawati,



Du 87.

Tikara ga nasu Sigoto wa tyokusetuni zibun no Sayôten ni tuite keisansitemo, Teikô-buttai ni sessuru Tokoro de keisansitemo Tigai ga nai; iikaereba, Kikai wo tukau koto ni yotte, Tikara ni oite donna Rieki ga attemo, Sigoto ni oitewa Rieki mo Sonsitu mo nai.

Mottomo, Kwaitendiku no Sinbô ya Syamen nado ni Masaturyoku ga aru to sureba, zissai okoru Undô ni taisitewa, sore ga itumo Undô no Hôkô ni hantaini hataraku tameni, sore no nasu Sigoto wa $(-)$ de, sitagatte, Teikôryoku (W) ni tuite keisansita Sigoto no hô ga itumo Tikara (K) ni tuite keisansita mono yorimo tiisai; sunawati, Sigoto ni oite kanarazu Sonsitu ga aru.

82. Kôba nado no "Hataraki." Iroirona Kôba de ugoite iru Kikai wa iroiro aru ga, sorerano Kikai wa hotondo mina ueni dasita "kantanna Kikai" wo kumiawaseta mono matawa sonohokano Gôtai no Kumiwase de atte, sorera wa Gendôki kara Tikara wo ukete ugoki, Mokuteki — katai Sinamono wo kiru toka, omoi Buttai wo hikiageru toka — no Tokoro de Teikôryoku ni utikatte Sigoto wo suru.

Kono Baai ni Totyû ni donna Sikake ga attemo, *Sigoto no Bunryô ni oitewa* môkeru koto ga dekinai. Soreyueni, Gendôki ga aru Zikan ni nasu Sigoto wa, — Totyû no Kikai ni okeru Masatu wo sasioite ieba — sonomama Teikô-buttai ni nasareru.

Kono Sigoto no Ryô wo Tan'i-zikan ni tuite hakatta mono, sunawati Sigoto wo suru Hayasa wo "Hataraki" (matawa *Kôritu*) to tonae, *iku-bariki* matawa *iku-kirowatto* to site sore wo hakaru.

1 bariki wa iti-byô ni 550 pondo no Omosa wo 1 foot ageru Wariai de Sigoto wo suru Hataraki de aru. 1 kirowatto wa 1.34 bariki ni hitosii.

83. *Seiryoku.* Sigoto wo suru Nôryoku wo *Seiryoku* matawa *Enerugii* to iu. Gendôki zisin wa, tûzyô hoka kara *Seiryoku* wo ukete soledakeno Sigoto wo Kikai ni taisite suru, sunawati, Kikai wo tôsite Teikô-buttai ni suru mono de aru.

Gendôki ni kyôkyûsareru *Seiryoku* wa tûzyô takai Tokoro ni aru Midu ga motte iru *Iti-seiryoku*, matawa Sekitan sonohokano Nenryô ga Kûki no nakano Sanso to kumiau koto ni yotte motte iru *kwagakutekino Seiryoku* de aru.

Rensyû-Mondai II.

1. Gôtai ni hataraku mittuno Tikara ga Sei-sankaku no Hen ni sôte, subete migimawarini hataraita iru. Sorera no Ooisa ga 3, 3, 4 de areba, sorera no Gôryoku wa nani ka?

2. Gôtai ni hataraku mittuno Tikara ga Sei-sankaku no Hen ni sôte, subete migimawarini hataraita iru. Sorera no Ooisa ga 2, 3, 4 de areba, sorera no Gôryoku wa nani ka?

3. Gôtai ni hataraku Tikara ga kattena Tahenkei no Hen ni sôte, subete migimawarini hataraita iru. Sorera no Ooisa ga sozoreno Hen no Nagasa ni hireisuru tokini, sorera no Gôryoku wa nani ka?

4. Gôtai ni hataraku Tikara ga Seihôkei $ABCD$ no yottuno Kado ni, sore no Heimen ni suityokuna Hôkô ni hataraita iru. Tugitugino Kado ni hataraku Tikara no Ooisa (to Muki) ga (a) 1, 2, 5, 3 kg., (b) 2, 3, -5, 4 kg. to ataerareru naraba, Gôryoku wa sozore doko ni atte, dôiu Ooisa wo motu ka?

5. Hankei 5 cm., Omosa 1 kg. no itiyôna Kyû ni, Nagasa

50 cm. Omosa 8 kg. no itiyôna Bô ga, sore no Hikinobasi ga Kyû no Tyûsin wo tôru yôna Hôkô ni toritukete aru. Dyûsin no Iti ga, Bô no "ziyûna" (sunawati nani mo tuite inai hôno) Hazi kara ikura no Kyori ni aru ka?

6. Nagasa 50 cm. no itiyôna massuguna Harigane wo, 20 cm. to 30 cm. ni wakeru Ten de tyokkakuni mage, Orime wo Hasudi (Eigo no, knife-edge) ni nosete sasae, sore ga seisisuru tokini, 30 cm. no Bubun ga Entyokusen ni taisite ikura no Kakujo wo nasu ka?

7. Tyokkei 1 cm. no Tetubô wo, Hen no Nagasa 25 cm. no Seihôkei ni orimageta Waku ga 600 g. no Omosa wo motte iru. Sore no hitotuno Hen no Nakahodo wo nimaino entyokuna heikôna Ita ni hasande, Waku wo suiheina Iti ni motiageyô to sureba, nimaino Ita wo tagaini ositukeru Tikara ga ikura izyô de aru koto wo yôsuru ka? Tadasî, Tetubô to Ita to no Masatu-keisû wo $\frac{2}{3}$ to suru.

8. Ueno Mondai de, hasamu Ita wo suiheini sureba, ositukeru Tikara ga ikura izyô de aru koto wo yôsuru ka?

9. Itiyôna Bô AB (Nagasa a , Omosa W) wo, namerakana entyokuna Kabe ni Hazi A wo atete, Kabe ni suityokuna Iti ni sasaeru tameni, sore no Ryôhazi ni Ito wo tukete, A kara b dake ueno Ten C ni aru Kugi ni musubitukeru. Nihonno Ito no Tyôryoku wa ikura ka?

10. Itiyôna Bô AB (Omosa W) no Hazi A wa suiheina Yuka ni, Hazi B wa entyokuna Kabe ni sasaerarete iru. Kabe mo Yuka mo nameraka de aru tokini, Hazi A ni torituketa Ito wo Kabe no Humoto ni koteisite, Bô no suberi-otiru koto wo husegu to sureba, kono Ito no Tyôryoku wa ikura ka? Tadasî, Bô no Kabe ni taisuru Katamuki wo α to suru.

11. Mondai 9 de, Kabe ga arai tokini, AC no Ito wo torisari, B ni Omori wo sagete, Bô wo Kabe ni suityokuni sasaeru niwa, Omori no Omosa wo dô toreba yoi ka? Tadasî, Kabe no Masatu-keisû $= \frac{1}{10}$, $a = 30$ cm., $b = 15$ cm. to suru.

12. Mondai 10 de, Yuka to Kabe ga arai (Masatu-keisû iduremo μ) tokini, A ni Ito wo tukenaide Bô ga turiau tameniwa, Bô no Katamuki α ga dô de areba yoi ka?

13. Itiyôna Bô (Nagasa a , Omosa W) ga, sore no hitotuno Hazi A ni tuketa Ito de turisagete aru. Bô no, Hazi A kara c dake sitano Ten ni suiheina Tikara K ga hataraku tokini, Turiai no Arisama de Ito oyobi Bô ga Entyokusen ni taisite nasu Kaku α , β wo keisansei!

14. Itiyôna seihôkeino Ita (Omosa W) no ittuino Hen wo entyokuni si, ueno Hen no Ryôhazi ni hitosii Nagasa no Ito wo tukete, sorera ga heikôni naru yôni Kugi ni kakete aru. Entyokuna hitotuno Hen no Mannaka ni, Ita no Heimen ni oite suiheina Tikara wo kuwaeta kekkwa, Ito ga Entyokusen kara 30° kata-muite turiatte iru. Nihonno Ito no Tyôryoku wa ikura ka?

15. Itiyôna Tyoku-rokumentai wo arai Ita ni nosete, Ita wo dandan katamukeru tokini, Buttai ga suberu ka korogaru ka wa donoyôna Dyôken ni yotte kimaru ka? Tadasî, Tyoku-rokumentai no hitokumino Hen wo suiheini site oku.

16. Itiyôna Tyoku-rokumentai ga suiheina arai Yuka ni tatte iru. Hitotuno yokono Men no Tyûsin ni, suiheina Tikara wo kuwae, sore wo sidaini tuyoku osu tokini, Tyoku-rokumentai ga suberidasu ka korogaru ka wa nani ni yotte kimaru ka?

17. Dimen ni yokotawaru Hasigo (Nagasa l , Omosa W) wo tateru no ni, sitano Hazi wo tekigina Sasae ni ate, ueno Hazi wo 5 syaku agete kara noti, itumo Dimen kara 5 syaku no Ten ni (mottomo yûkôna Hôkô ni) Tikara wo kuwaeru to sureba, kono Tikara wa Hasigo no Dimen ni taisuru Katamuki to tomoni dô kawaru ka?

18. Itiyôna semai Ita (Nagasa l , Omosa W) ga, koteisita arai Kyû (Hankei $= R$, Masatu-keisû $= \tan \epsilon$) no ueni, Ita no Tyûsin ga Kyû no itiban takai Ten ni hureru yôna Iti ni oite aru. Ita no hitotuno Hazi ni Omosa P no Omori wo toritukeru tokini, P no Ooisa ikura madewa Ita ga suberi-otinai ka? Mata sonotokini Ita wa donna Katamuki wo nasu ka?

19. Koteisita suiheina Marubô (Hankei a) ni turanukarete, sore ni suityokuni, omoi Maruita (Hankei R , Omosa W), ga hamatte iru. Maruita no Dyûsin ga Marubô no Tyûsin ni atte, sikamo hutatuno Mono no aidaniwa kiwamete sukosino Sukima ga aru to suru. Maruita no Huti ni Ito ga suberanai yôni makitukete atte, sore no hitotuno Hazi ga taresagatte, sore ni Omori (Omosa P) ga sagatte iru. Marubô to Maruita to ga doko de osiatte iru

ka? Mata sorera no aidano Masatu-keisû ga ataete aru tokini, P ga ikura izyô nareba Maruita ga mawaru ka?

20. Mattaku katai Dimen ni aru Kuruma ni, Omosa W no Nimotu ga notte iru. Sore wo suiheini hataraku Tikara K de mae e hiku tokini, Sinbô no Hureai ga donnani arakutemo, aidani Yutori sae areba, $W \frac{r}{\sqrt{K^2 - r^2}}$ yoriwa tiisai Tikara K de Kuruma ga ugokidasu koto wo syômecisei! Tadasî, r wa Sinbô no, R wa Wa no Hankei⁽¹⁾.

21. Saobakari no Torio kara Sara no Sasaeten madeno Hedatari ga 5 cm., Memori no O made ga 2 cm., 1-guramu no Me no Nagasa ga 1 mm., Omori wo torisatta Bubun (Sao, Torio, Sara) no Dyûsin no Iti ga Torio kara Sara no hô e 1 cm. de areba, Omori no Mekata to hokano Bubun no Mekata wa ikura ka?

22. Daibakari wa, Dai no ueno dono Bubun ni Sinamono wo oitemo, sore no Mekata wo tadasiku simesu. Kore wa donoyôna Teko no Kumiwase ni yotte dekiru ka?

23. "Semi (Huku-kwassya)" ni oite, ipponno Tuna ga Sinbô no ugokanai Kwassya mittu to, Teikô-buttai ni torituketa Kwassya mittu to wo hitotu-okini hete, hitotuno Hazi ga ugokanai Ten ni tomete aru. Tuna no subeteno Bubun ga heikôni natte iru to sureba, nokorino Hazi wo hiku Tikara no nanbaino Tikara wo Teikô-buttai ga ukeru ka?

24. Rindiku no Wa ga Hankei 40 cm., Diku ga Hankei 5 cm. to Hankei 4 cm. to no hutatuno Bubun de dekite iru. Teikô-buttai (tatoeba Omori) ni Kwassya no Waku ga toritukete atte, sono Kwassya ni kakatte iru Tuna ga, ippô dewa 5 cm. no Diku ni, ippô dewa 4 cm. no Diku ni, hantaino Muki ni suberanai yôni makitukete aru. Teikô-buttai ga Wa ni kuwaeru Tikara no nanbai de hikareru ka?

⁽¹⁾ Dimen to Kuruma to no aidani Kuruma no korogaru koto wo samatageru tokorono, "Korogari no Masaturyoku" to tonaeru Gûryoku ga aru ga, sore no Sayô wa tiisai kara kangaenai to suru.

Dainino Oowake.

SITTEN NO UNDÔ.

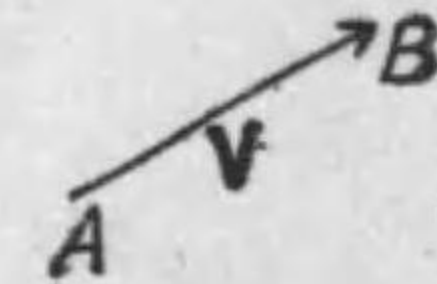
SYOO III.

Sokudo oyobi Kasokudo.

91. **Vektor.** Ippanni, Hôkô to Ooisa to wo motte iru Ryô wo *Vektor* to tonaeru. Vektor ni taisite, Ooisa (matawa Ooisa to (+) (-) no Kigô) dake wo motte iru Ryô wo *Skalar* to tonaeru.

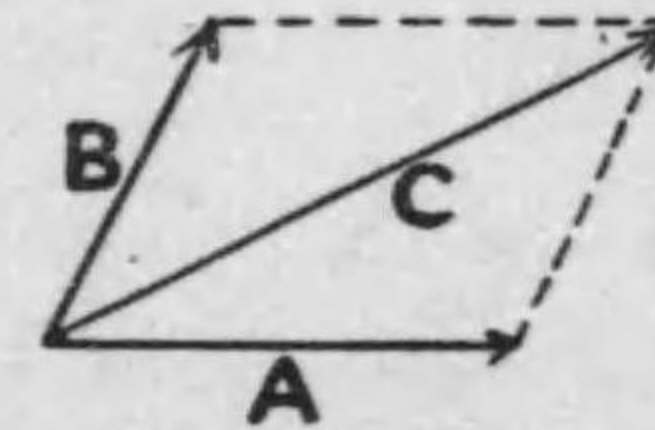
Tikara wa Vektor no hitotuno Rei de aru. Sikasi, Vektor to iu tokiniwa, Tikara no Sayôsen ni sôtôsuru Mono wo kangaenai.

Vektor wo Du ni arawasu niwa, Tikara de mita to dôyôni, sore no Hôkô ni, Ooisa ni hireisuru Nagasa no Ya wo kaite simesu (Du 95). Mata, sore wo Hugô de simesu niwa, Vektor to iu Kotoba matawa Ya no Sirusi wo soeru ka, matawa hutoi Mozi wo tukatte, *Vektor* AB , \overrightarrow{AB} , \mathbf{V} nado to kaku⁽¹⁾.

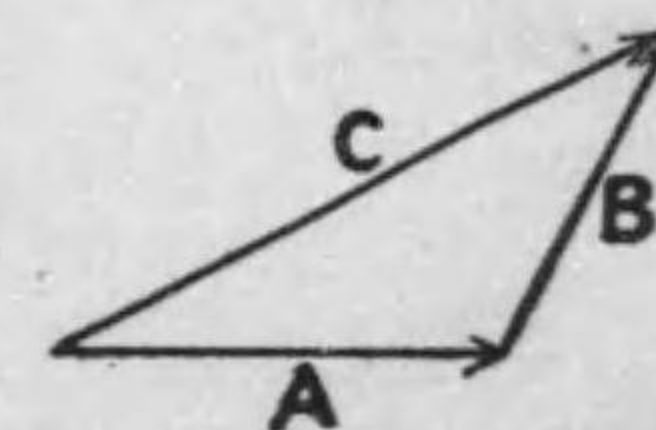


Du 95.

92. **Vektor no Gôsei to Vektor-hôteisiki.** Hutatuno Vektor \mathbf{A} to \mathbf{B} be Du 96 no yôna Heikô-sihenkei (matawa Du 97 no yôna Sankakukei) wo tukururu tokini, Du no yôna Muki ni totta Taikakusen (matawa daisanno Hen) \mathbf{C} de arawasu Vektor wo \mathbf{A} , \mathbf{B} no *Gô-vektor* to tonaeru. Sosite, \mathbf{A} to \mathbf{B} to no *Gô-vektor* wo tugino yôni kaki-arawasu :—



Du 96.



Du 97.

$$\mathbf{A} + \mathbf{B}$$

\mathbf{A} ni \mathbf{B} wo gôseisuru koto wo, " \mathbf{A} ni \mathbf{B} wo *vektortekini kuwaeru*" tomo iu.

⁽¹⁾ Vektor no Hugô ni Doitu-mozi wo tukau Hito mo aru.

Vektor **A** no Ooisa wo A de, Vektor **B** no Ooisa wo B de arawasu tokini, $\mathbf{A}+\mathbf{B}$ to iu Vektor no Ooisa wa $A+B$ dewa nakute,

$$\mathbf{A}+\mathbf{B} \text{ no Ooisa} = \sqrt{A^2+B^2+2AB \cos(\mathbf{A},\mathbf{B})}$$

de aru.

93. **C** ga **A** to **B** to no Gô-vektor de aru koto wo

$$\mathbf{C} = \mathbf{A} + \mathbf{B},$$

kôiu Hôteisiki iwayuru Vektor-hôteisiki de arawasu. Vektor-hôteisiki wa, sore no Ryôgawa ni aru hutatuno Vektor no Ooisa ga hitosii koto no hoka, sorera no Hôkô ga onazi de aru koto wo simesu mono de aru.

94. $\mathbf{A}+\mathbf{B}=\mathbf{C}$ no Kwankei ga aru tokini, **B** wo **C** to **A** de arawasu no ni,

$$\mathbf{B} = \mathbf{C} - \mathbf{A}$$

to kaku. $\mathbf{C}-\mathbf{A}$ wa "**A** ni (vektortekini) kuwaereba **C** ni naru yôna Vektor" no Imi de aru.

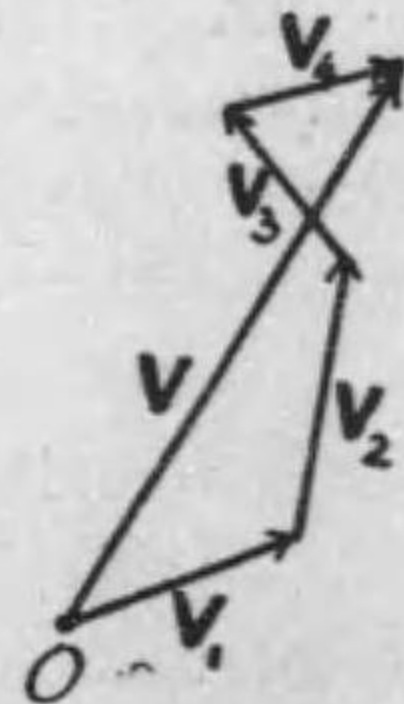
95. Vektor ga hutatu yori ôku ataete aru Baai nimo dôyô de, Du 98 no yôna Sakudu wo nasite erareru **V** wa $\mathbf{V}_1, \mathbf{V}_2, \mathbf{V}_3, \mathbf{V}_4$ no Gô-vektor de aru; sosite, kono Kwankei wo tugino yôna Hôteisiki de arawasu:—

$$\mathbf{V} = \mathbf{V}_1 + \mathbf{V}_2 + \mathbf{V}_3 + \mathbf{V}_4.$$

"Vektor no Gôsei", "Vektor no Heikô-sihenkei," "Vektor no Sankakukei," "Vektor no Tahenkei," "Vektor no Bunkai," nado no Kotoba wa Tikara no Baai to dôyôni tukawareru. Mata, Tikara no Baai no *Bunryoku* ni sôtôsuru Vektor wo *Bun-vektor* to iu.

96. Teiri. Atarareta *Bun-vektor* wo gôseisite eru Gô-vektor wa, Gôsei no Zyunzyo ni kakawarazu kimatte iru.

Nazekanareba, Vektor no Sankakukei (Du 97) de $\mathbf{A}+\mathbf{B}$ wo tukuru no to $\mathbf{B}+\mathbf{A}$ wo tukuru no to onazi **C** wo eru koto wa akiraka de aru; sosite, motto ôkuno *Bun-vektor* no Gôsei no



Du 98.

Zyunzyo wo katteni kaeru koto wa hutatu dutu no Zyunzyo wo kaeru koto wo kurikaesu koto ni yotte erareru kara.

97. Vektor no Tyokkaku-seibun. Vektor **V** ga $x-y$ -Zahyôdiku no Heimen ni atte, x -Diku to Kaku θ wo nasu tokiniwa, sore wo Zahyôdiku no Hôkô ni bunkaisita Tyokkaku-seibun wa, Tikara no Baai (§ 12) to onaziku,

$$V_y = V \cos \theta, \quad V_x = V \sin \theta;$$

tadasi V wa Vektor **V** no Ooisa wo simesu.

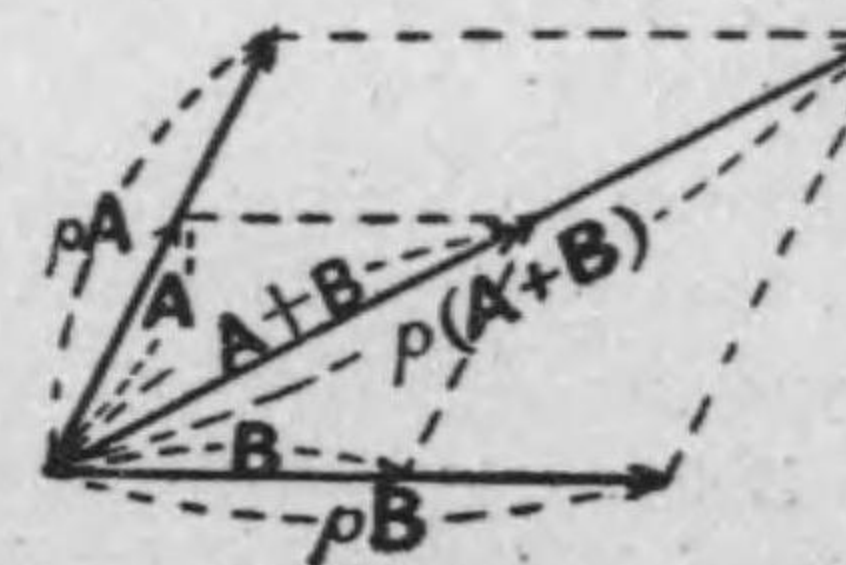
98. Skalar wo kaketa Vektor. Atarareta Vektor **V** ni taisite, kattena Skalar p wo sore ni kaketa $p\mathbf{V}$ matawa $\mathbf{V}p$ to iu Ryô wo toriatukau koto ga aru. Kore wa Hôkô wa **V** to onaziku (p ga huno Ryô de areba, Muki ga hantai de), Ooisa wa $p \times (\mathbf{V}$ no Ooisa) ni hitosii Vektor to teigisareru mono de aru. p ga 2, 3, 100 nado to iu Seisû de aru Baai niwa, ueno Teigi wa **V** wo p -ko gôscisita mono to tyôdo ittisuru.

99. Du 99 kara,

$$p(\mathbf{A}+\mathbf{B}) = p\mathbf{A} + p\mathbf{B}$$

no Kwankei ga naritatu koto ga sireru.

Nazekanareba, **A** to **B** to wo onaziku p -baini site Heikô-sihenkei wo tukureba, sore no Taikakusen wa motono (sunawati **A** to **B** to no Heikô-sihenkei no) Taikakusen to Hôkô ga ittisite, Nagasa ga p -bai de aru kara.



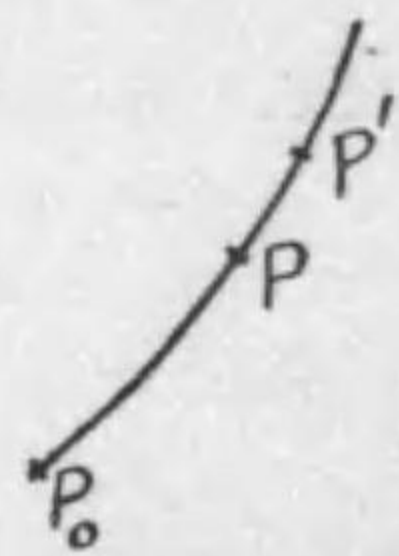
Du 99.

100. Undôsuru Ten no Hayasa. Undôsuru Mono no Hayasa wa, ippanni Tan'i-zikan (itibyô, itizikan nado) ni sore ga susumu matawa susumubeki Mitinori wo motte arawasu; tatoeba, "maibyô 10 mêturu," "maizi 40 kiromêturu" nado no yôni. Tan'i no Namae wo matomete iu niwa, "10 maibyô-mêturu", "40 maizi-

kiromêtoru" to itte, "maibyô-mêtoru" "maizi-kiromêtoru" wo Hayasa no Tan'i no Namae to subeki de aru⁽¹⁾.

101. Undôsuru Ten no Hayasa⁽²⁾ wa, hitotuno hikituduita Undô ni oitemo, Hazime kara Owari madeno aida sidaini kawaru no ga hutû de aru. Sore ga aru Basyo P wo tôru tokino Hayasa (matawa " P ni okeru Hayasa") ga ikura-ikura da to iu no wa, sono Toki no Hayasa wo sonomama tudukete yuku to sôzôsûreba, Tan'i-zikan tatoeba itibyô ni sore dakeno Mitinori wo susumu hazu de aru to iu Imi de aru.

Soreyueni, tatoeba Undôten ga P_0 (Du 100) wo dete kara, Hayasa ga masi tutu aru to sureba, P ni ita toki kara noti, aru mizikai Zikan τ byô no aidani zissai Ten no ugoita Kyori $PP' = \sigma$ wo totte, sore wo τ de wareba (tatoeba $\tau = \frac{1}{100}$ naraba, 100-



Du 100.

baini sureba), $\frac{\sigma}{\tau}$ wa P ni okeru Hayasa yorimo sukosi ôkisu-giru Atai wo eru wake de aru. Sikasi, P' ni okeru Hayasa ni kurabereba, $\frac{\sigma}{\tau}$ wa sukosi tiisa-sugiru wake de aru. Ima kono mizikai Zikan τ wo doko mademo tiisaku toruto, P' ga P ni kagirinaku tikaku natte, P ni okeru Hayasa to P' ni okeru Hayasa to no Kubetu ga naku naru; sitagatte, hutatuno Hayasa no aidano Ooisa wo motte iru hazu no σ/τ mo P ni okeru Hayasa to onazi Atai wo toru. Soreyueni, aru Tokoro (matawa aru Zikoku) ni okeru Undôten no Hayasa wa, *sore kara kiwamete mizikai Zikan τ no aidani susumu Kyori σ wo τ de watta σ/τ de ataerareru.*

Kono kiwamete tiisai hutatuno Ryô no Hi σ/τ no Keisansikata wa tugino Rei de gatensareyô.

(1) Hayasa no Tan'i no Namae wo "byô-mêtoru" "zi-kiromêtoru" nado to iu no wa seitôna ikkata dewa nai: "mai." wo habukanai yôni tyûisubeki de aru.

(2) Tadasiku ieba, koteisite iru to omotte iru Mono ni taisuru Undô no Hayasa. Ookuno zissaino Baai niwa, Dimen wo koteisite iru to miru.

Rei. Undôten no Undô ga, sore ga Ten P_0 wo dete kara (Du 100), kattena Zikan t byô tatta Zikoku ("Zikoku t " to yobu) ni, P_0 kara Miti ni sôte hakatte,

$$s = at + bt^2 \text{ cm.}$$

dakeno Iti ni aru, to iu koto ni yotte arawasareru to suru. s ga t ni hireisite inai kara, kono Undô wa Hayasa no kawaru Undô de aru. P , Zikoku t_1 byô ni Ten ga P ni aru to sureba,

$$P_0P = at_1 + bt_1^2 \text{ cm.,}$$

$t_1 + \tau$ byô ni P' ni oru to sureba,

$$P_0P' = a(t_1 + \tau) + b(t_1 + \tau)^2 \text{ cm.}$$

Yueni,

$$\begin{aligned} \widehat{PP'} &= \sigma = \widehat{P_0P'} - \widehat{P_0P} \\ &= a\tau + b(2t_1\tau + \tau^2) \text{ cm.;} \end{aligned}$$

sitagatte,

$$\frac{\sigma}{\tau} = a + 2bt_1 + b\tau \frac{\text{cm.}}{\text{byô}} \text{ (1).}$$

τ wo kiwamete tiisaku toreba,

$$\frac{\sigma}{\tau} = a + 2bt_1 \frac{\text{cm.}}{\text{byô.}}$$

to natte, kimatta Atai wo toru. Kore wa, b ga sei de areba, Toki ga tatu ni sitagatte (sunawati t_1 ga ôkiku naru ni sitagatte), dandan ôkiku naru.

102. Kono Rei de miru tôri, mosi hazime kara Zikan t no aidani tôtta Mitinori s no Atai ga subeteno t ni taisite kimatta Siki de arawasareru Baai niwa, sorerano Ryô no tagaini sôtôsuru tiisai Masidaka wo Δs , Δt de arawaseba, Hayasa wa

$$V = \frac{\Delta s}{\Delta t} \text{ no, } \Delta s, \Delta t \text{ wo tiisaku sita kyokugenno Atai;}$$

sunawati, Bibungaku no Kakikata de,

$$V = \lim \frac{\Delta s}{\Delta t} = \frac{ds}{dt}$$

de keisansareru⁽²⁾. Sunawati,

(1) $\frac{\text{cm.}}{\text{byô.}}$ wa "maibyô-sentimêtoru" no Sirusi; $\frac{\text{cm.}}{\text{s.}}$ tomo kaku.

(2) $\frac{ds}{dt}$ wo \dot{s} tomo kaku.

$$s=f(t)$$

no yôna Katati de ataerareru to sureba,

$$V=\frac{df}{dt}=f'(t)$$

de aru.

Gyakuni, Hayasa ga Toki ni taisite kimatta Siki $F(t)$ de ataerareru Baai niwa, hazime karano Mitinori wa,

$$s=\int_0^t F(t) dt$$

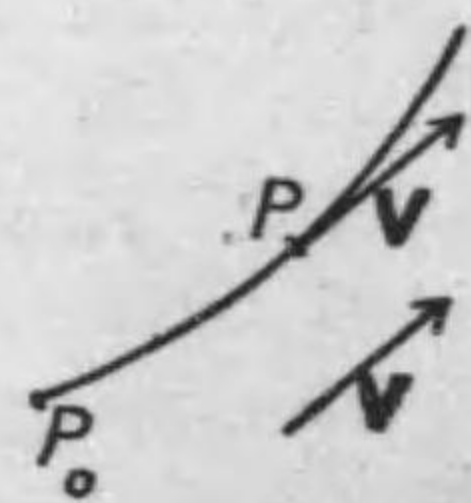
de ataerareru.

Hayasa no kawaranai Undô wo itiyôna Hayasa no Undô (matawa Tôsoku-undô) to iu.

103. Sokudo. “Undôsuru Ten no P ni okeru Sokudo” to iu no wa, sono Basyo de Mitisudi ni hiita Sessen no Hôkô wo (susumu hô e mukete) Hôkô to si, sono Ten ni okeru Hayasa wo Ooisa to suru *Vektor* \mathbf{V} de aru.

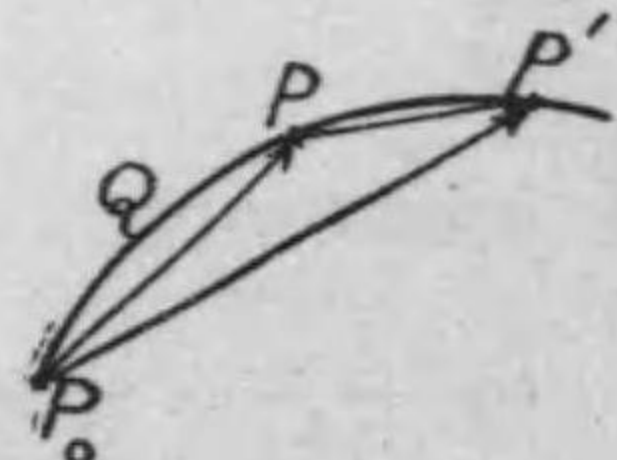
Sokudo wo Du ni kakiarawasu Baai ni, sore wo tyokusetuni P -Ten no Tokoro ni kaitemo, matawa Mitisudi wo hanareta betuno Tokoro ni kaitemo, dotira demo kamawanai.

Sokudo no kawaranai Undô, sunawati itiyôna Sokudo no Undô (Tôsokudo-undô tomo iu) wa, hitotuno Tyokusen no ue wo itiyôna Hayasa de susumu Undô de aru.



Du 101.

104. Hen'i to Sokudo. Kyokusen P_0QP no ue wo ugoku Ten ga aru to suru. Hazime ($t=0$) P_0 ni otta Ten ga, sore kara Zikan t dake tatta Zikoku—kantanni “Zikoku t ” to yobu—ni P ni kite oru tokini, P_0 to P wo Tyokusen de tunaide, “Undôten ga, hazime kara t madeni $\overrightarrow{P_0P}$ dakeno Hen'i wo sita” to iu. Sunawati, Hen'i $\overrightarrow{P_0P}$ to iu mono wa, Totyû



Du 102.

no Miti no magatte iru koto ya zissai susunde itta Mitinori niwa kakawarazu, tada *hasime to noti to no Iti no Tigai* wo iiarawasu *Vektor* de aru.

Nao Zikan τ dake sugita Zikoku (sunawati $t+\tau$ no Zikoku) ni Undôten ga P' ni kite iru to sureba, τ no aidani nasita Hen'i wa $\overrightarrow{PP'}$ de aru. Sikaruni, *Vektor* no Gôsei no Kimari ni yotte,

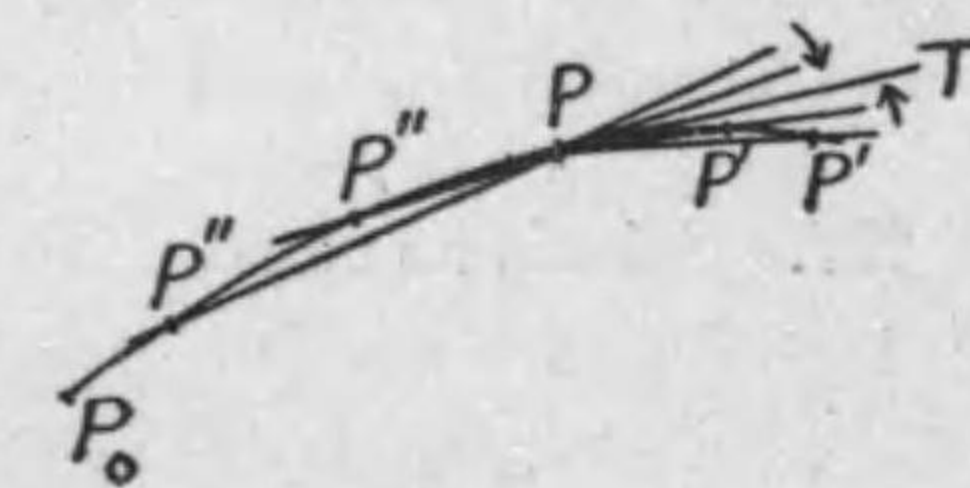
$$\overrightarrow{P_0P'}=\overrightarrow{P_0P}+\overrightarrow{PP'}$$

de aru kara, *tuduite okoru hutatuno Hen'i no Kekkwa naru Hen'i wa, sorerano hutatuno Hen'i wo vektortekini gôseisite erareru.*

Mata, Hen'i wo subete hazimeno Iti P_0 ni taisite iu mono to kimete, $\overrightarrow{PP'}$ wa “Zikan τ no aidani okotta, Hen'i no *vektortekino Masidaka* matawa *Kawaridaka*” de aru to iu.

105. Sokudo no betuno Teigi. τ wo kiwamete tiisaku toru tokini, ueno vektortekino Masidaka $\overrightarrow{PP'}$ ga dô naru ka wo sirabete miru.

Madu, sore no Hôkô wo kangaeru ni, P wo kimete oite, τ wo sidaini tiisaku toru ni sitagatte, Ten P' wa sidaini P ni tikaduite kuru (Du 103). Dôzini PP' wa sidaini, Ten P ni oite Mitisudi ni hiita Sessen PT ni tikaduku; sosite P' ga kagirinaku P ni tikadukeba, PP' wa PT ni kagirinaku tikaduku⁽¹⁾.



Du 103.

Soreyueni, $\overrightarrow{PP'}$ no kyokugenno Hôkô wa Sessen PT no Hôkô de aru. Kore ga, P ni okeru Sessen no Hôkô wo “Undô no Hôkô” to tonaeru Riyû de aru.

* Tugini, $\overrightarrow{PP'}$ no Ooisa wa, sore wo kiwamete tiisaku toreba,

(1) Kono Koto wa, P yorimo sukosi *macno* Iti P'' kara P madeno Hen'i wo kangaie, P'' wo sidaini P ni tikadukete yuku tokini $P''P$ -Sen ga hantaino Gawa kara PT ni tikaduite kuru koto wo mireba nao yoku wakaru.

Mitinori $\widehat{PP'}$ to onazimono ni naru⁽¹⁾; sunawati, Hayasa wo V to sureba, t wo tiisaku totta Kyokugen ni $PP'/\tau=V$ de aru.

Soreyueni, $\overrightarrow{PP'}/\tau$ to iu Vektor (§ 98) wa, Kyokugen ni oite, Hôkô wa Mitisudi ni hiita Sessen no Hôkô, Ooisa wa Hayasa ni hitosii Vektor, sunawati *Sokudo* to onazimono de aru.

Sokudo no Teigi wo “undôsuru Ten no (kimatta hazimeno Iti ni taisuru) Hen'i ga Zikan ni taisite kawaru Wariai” to suru koto mo aru. Kore wa ueno $\overrightarrow{PP'}/\tau$ no kyokugenno Ryô wo imisuru no de, sore ga maeni ataeta Sokudo no Teigi to onazimono wo arawasu koto wa ueni nobeta tôri de aru.

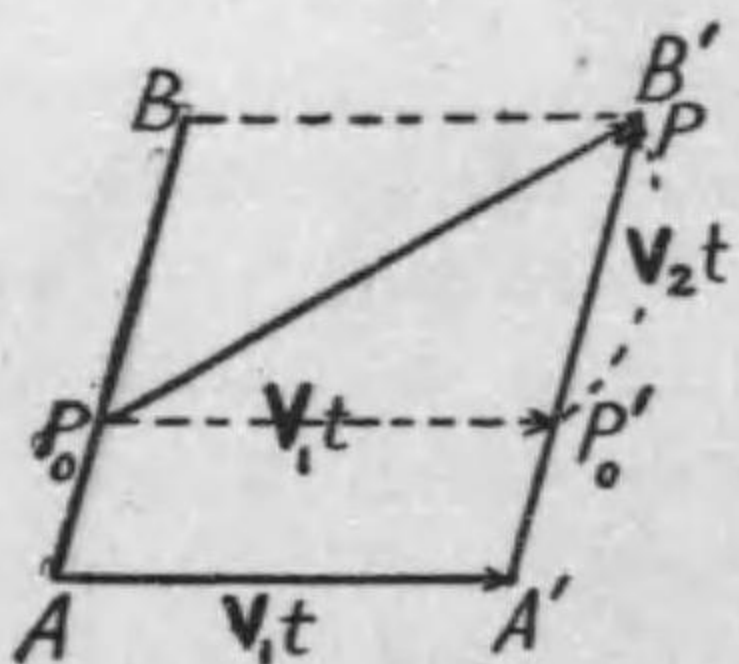
106. *Sokudo* \mathbf{V} ga kawaranai Baai ni $t=0$ ni okeru Iti P_0 ni taisuru Zikoku t no Hen'i $\overrightarrow{P_0P}$ wa tugino Vektorhôteisiki wo mitasu:—

$$\overrightarrow{P_0P} = \mathbf{V}t.$$

Nazekanareba, kore wa, ueno Teigi kara mitemo, tyokusetuni kangaetemo yôini wakaruru tôri, \mathbf{V} ni heikôna hitotuno Tyokusen no ueno kimatta Hayasa V no Undô da kara.

107. *Sokudo no Gôsei.* Tyokusen AB (Du 104) ga itiyôna Sokudo \mathbf{V}_1 de ugoite iru ue de, Undôten ga (AB ni taisite sore ni sôte) itiyôna Sokudo \mathbf{V}_2 de ugoite iru to suru. Undôten ga korerano hutatuno Sokudo ni yotte motu Sokudo sunawati *Gô-sokudo* \mathbf{V} ga, $\mathbf{V}_1, \mathbf{V}_2$ to donna Kwan kei wo nasu ka wo siraberu.

Undôten ga P_0 ni aru Toki wo Zikan no Hakari-hazime to si, Zikan t no notini, Tyokusen AB ga $A'B'$ made, P_0 ga P_0' ni kite iru to sureba,



Du 104.

⁽¹⁾ Motto hakkiri ieba, $\widehat{PP'}/PP'$ no Hi wa kagirinaku 1 ni tikaduku, $\widehat{PP'}$ no dono Rubun mo Tyokusen PP' ni taisuru Katamuki no Kaku ga 0 ni tikaduku kara.

$$\overrightarrow{AA'} = \overrightarrow{P_0P_0'} = \mathbf{V}_1t.$$

Dôzini, Undôten wa Tyokusen no ue wo

$$\overrightarrow{P_0'P} = \mathbf{V}_2t$$

de ataerareru Ten P made kite oru. Sunawati, Zikan t no aidani Sitten ga zissaini sita Hen'i wa $\overrightarrow{P_0P}$ de aru.

Du de akiraka de aru tôri,

$$\overrightarrow{P_0P} = \overrightarrow{P_0P_0'} + \overrightarrow{P_0'P}$$

sunawati,

$$\begin{aligned} \overrightarrow{P_0P} &= \mathbf{V}_1t + \mathbf{V}_2t \\ &= (\mathbf{V}_1 + \mathbf{V}_2)t \quad (\S 99). \end{aligned}$$

\mathbf{V}_1 mo \mathbf{V}_2 mo, sitagatte Vektor-wa $\mathbf{V}_1 + \mathbf{V}_2$ mo kawaranai Vektor de aru kara, kono Siki de simesareru P no Undô wa, maeno Setu ni yotte, itiyôna Sokudo $\mathbf{V}_1 + \mathbf{V}_2$ de okoru Undô de aru. Sitagatte, motomeru tokorono Gô-sokudo \mathbf{V} wa $\mathbf{V}_1 + \mathbf{V}_2$ ni hitosii.

Ueni *Tyokusen* AB ga ugoku yôni kangaeta no wa, sore ni taisuru Undôten no Undô no Hôkô ga magirenai yôni suru tame de atte, zituwa hituyô dewa nai no de aru. Sunawati, Undôten ga Ten A ni taisite Sokudo \mathbf{V}_2 wo motte ugoku to ieba, sosite sono Ten A ga \mathbf{V}_1 no Sokudo de ugoku to sureba, ueni itta tôrino Koto ga mina ieru no de aru. Soreyueni,

(Koteibutu ni taisite) Sokudo \mathbf{V}_1 de ugoite iru Ten A ni taisite Sokudo \mathbf{V}_2 de ugoite iru Ten P no (Koteibutu ni taisuru) Sokudo wa $\mathbf{V}_1 + \mathbf{V}_2$ de aru. Iikaereba, hutatuno Sokudo $\mathbf{V}_1, \mathbf{V}_2$ no Gô-sokudo wa sorera no Vektor-wa ni hitosii; mata iikaete, Sokudo wa Vektor-gôsei no Hôhô ni yotte gôscisareru.

108. Ueniwa, Ten A no Sokudo \mathbf{V}_1 mo, A ni taisuru Undôten no Sokudo \mathbf{V}_2 mo kawaranai to site kangaeta ga, korera ga katteni kawaru Baai nimo, onônono Zikoku ni ueno Teiri ga okonawareru.

Nazekanareba, aru mizikai Zikan τ ni okeru Hen'i ni tuite Du 104 to dôyôna Du wo kakeba,

$$\begin{aligned}\overrightarrow{P_0P} &= \overrightarrow{P_0P'_0} + \overrightarrow{P'_0P} \\ &= \overrightarrow{AA'} + \overrightarrow{P'_0P},\end{aligned}$$

kono Kwankei wa yahari okonawareru. Sitagatte,

$$\frac{\overrightarrow{P_0P'}}{\tau} = \frac{\overrightarrow{AA'}}{\tau} + \frac{\overrightarrow{P'_0P}}{\tau}.$$

τ wo tiisaku sita Kyokugen dewa, korerano Kô wa sorezoreno Sokudo wo arawasu kara,

$$\mathbf{V} = \mathbf{V}_1 + \mathbf{V}_2.$$

109. Hitotuno Undôten P no Undô ni tuite, “sore ga dôzini \mathbf{V}_1 to \mathbf{V}_2 no hutatuno Sokudo wo motte ugoku” to iu Kotoba wo tukau koto ga aru. Kore wa “ \mathbf{V}_1 no Undô to \mathbf{V}_2 no Undô to wo *kasaneta* Undô wo suru” to iu Imi de aru. Sunawati, karini \mathbf{V}_1 no Undô wo suru Buttai A wo sôzôsuroto, Undôten P wa sono A ni taisite \mathbf{V}_2 no Undô wo suru no de aru. Sitagatte, Kekkwa wa mattaku ueno Baai to onaziku, Gô-sokudo wa

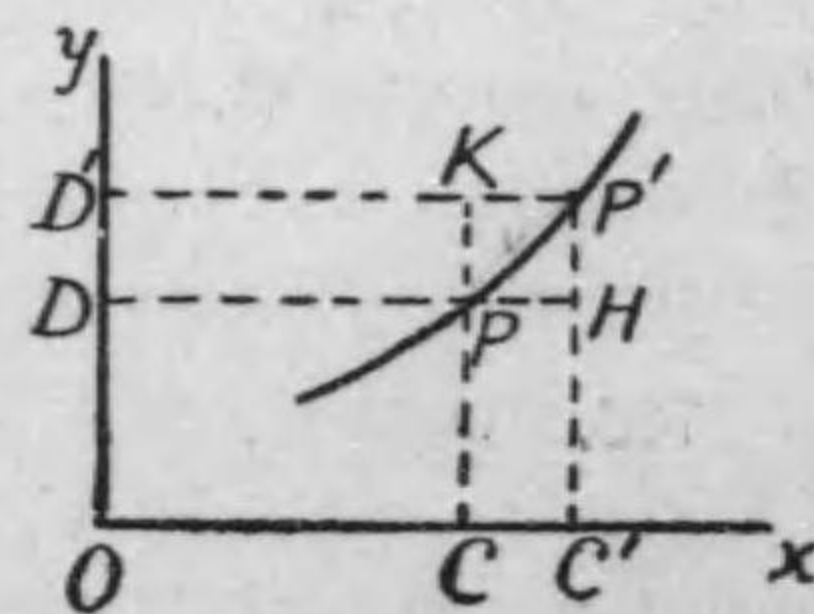
$$\mathbf{V} = \mathbf{V}_1 + \mathbf{V}_2$$

de aru.

110. Sokudo no Bunkai. Sokudo ga Vektor-gôsei no Hôhō de toriatukawareru kara, sore no *Bunkai*, *Bun-sokudo*, *Tyokkaku-seibun* nado wa ippanno Vektor to dôyôni, mata hitotuno Ten ni hataraku Tikara no Baai to dôyôni toriatukawareru.

111. Zahyôdiku no Hôkô ni okeru Bunkai. Sokudo no Bunkai de itiban yôyôna no wa tagaini suitiyokuna Zahyôdiku no Hôkô ni bunkaisuru koto de aru.

Undôten ga xy -Heimen de uguoku mono to site, P (Du 105) ni aru Toki kara kiwamete mizikai Zikan τ -byô no aidani, P' ni kita to suru. PC to $P'C'$ wo Ox ni suitiyokuni, PD to $P'D'$ wo Oy ni suitiyokuni hiku.



Du 105.

Undôten no Sokudo \mathbf{V} wa $\overrightarrow{PP'}$ no $\frac{1}{\tau}$ -bai de arawasareru kara, sore no x -Seibun wa PH , sunawati CC' no $\frac{1}{\tau}$ -bai, y -Seibun wa PK , sunawati DD' no $\frac{1}{\tau}$ -bai de aru. Yueni,

$$\text{Sokudo no } x\text{-Seibun} = \frac{CC'}{\tau}, \quad \text{Sokudo no } y\text{-Seibun} = \frac{DD'}{\tau} \text{ (}^1\text{)}.$$

Undôten P no Zahyô x, y wa iduremo Zikan t to tomoni kawaru Ryô sunawati t no Kansû de aru. CC' wa t no Masidaka τ -byô no aidani okotta x no Masidaka de ari, DD' wa onaziku y no Masidaka de aru kara, τ wo kagirinaku tiisaku sita Baai no $\frac{CC'}{\tau}$ oyobi $\frac{DD'}{\tau}$ wa sorezore $\frac{dx}{dt}$ oyobi $\frac{dy}{dt}$ de aru.

Soreyueni, Sokudo no Ooisa, sore no x -Seibun, y -Seibun wo sorezore V, V_x, V_y de arawaseba, tugino Kwankei ga aru:—

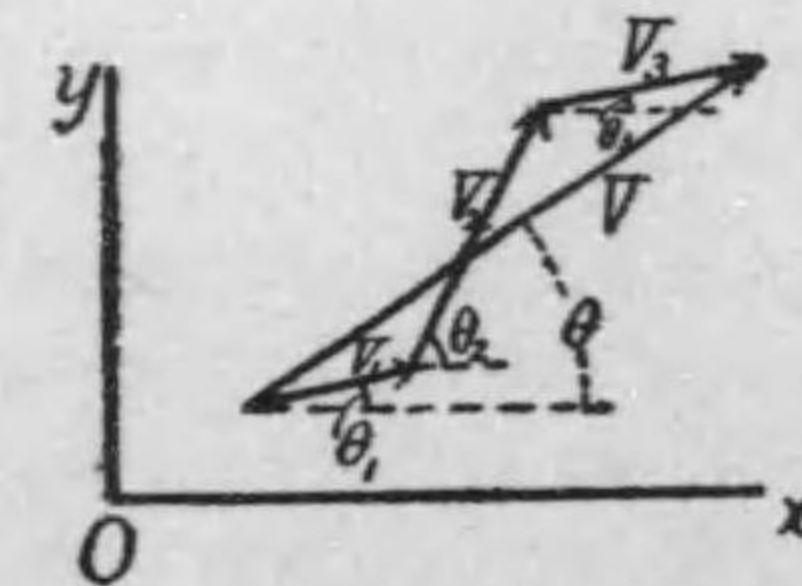
$$V_x = V \cos(x, \mathbf{V}) = \frac{dx}{dt}, \quad V_y = V \sin(x, \mathbf{V}) = \frac{dy}{dt} \text{ (}^2\text{)};$$

tadasi (x, \mathbf{V}) wa x -Diku to \mathbf{V} to no aidano Kaku.

112. Undôten ga hitotuno Heimen ni heikôna ikutu kano Sokudo wo dôzini motte iru Baai ni, sorerano Sokudo no Ooisa wo V_1, V_2, \dots , sorera no Hôkô ga x -Diku to tukururu Kaku wo $\theta_1, \theta_2, \dots$ to si, Gô-sokudo no Ooisa to sore ga x -Diku to tukururu Kaku wo V, θ to sureba, tugino Kwankei ga aru (§ 14 ni aru Tikara no Baai wo mii!)⁽³⁾:—

$$V \cos \theta = V_1 \cos \theta_1 + V_2 \cos \theta_2 + \dots,$$

$$V \sin \theta = V_1 \sin \theta_1 + V_2 \sin \theta_2 + \dots$$



Du 106.

⁽¹⁾ Sokudo no x -Seibun, y -Seibun wa, iduremo (+) (−) no Kigô wo motte iru dake de, Hôkô wo kakiarawasu Hituyô no nai Ryô de aru kara, tokubetuna Hituyô no nai kagiri, Vektor tosite toriatukawanai.

⁽²⁾ $\frac{dx}{dt}$ wo \dot{x} , $\frac{dy}{dt}$ wo \dot{y} tomo kaku.

⁽³⁾ Subeteno Bun-sokudo ga hitotuno Heimen ni heikô de nai Baai no Siki wa Huroku § 293 no Tikara no Baai to dôyôni kakeru.

113. Kyoku-zahyô de arawasu Sokudo-seibun. Hitotuno Heimen ni aru Ten no Iti wo Kyoku-zahyô r, θ de arawasu tokini, sono Ten ga ugokeba r, θ ga Toki to tomoni kawaru.

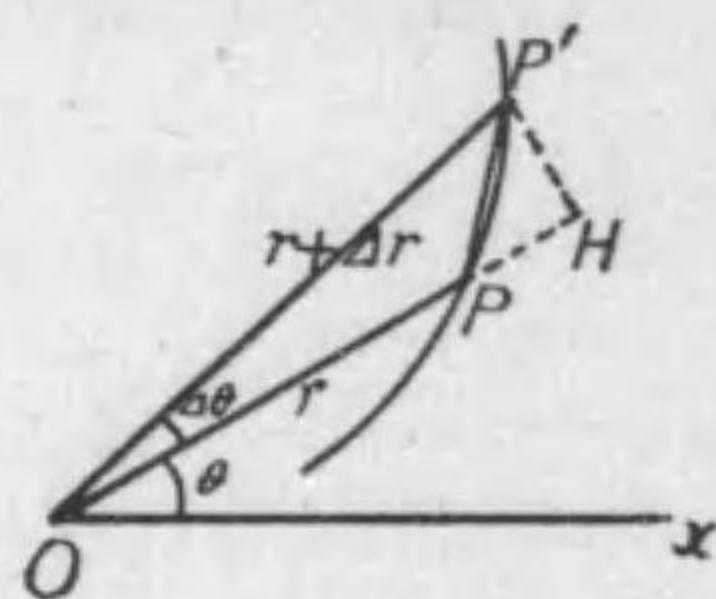
Zikoku t ni Ten ga P ni atte, $OP=r, xOP=\theta$; $t+\Delta t$ ni Ten ga P' ni atte, $OP'=r+\Delta r, xOP'=\theta+\Delta\theta$ de aru to si, Hen'i \vec{PP}' wo OP ni heikôna Hôkô to suitiyokuna Hôkô to ni wakeruto,

OP ni heikôni

$$PH=(r+\Delta r)\cos\Delta\theta-r,$$

OP ni suitiyokuni

$$HP'=(r+\Delta r)\sin\Delta\theta.$$



Du 107.

Kore wo Δt de watta Ryô wo, kagirinaku tiisai Δt ni taisite keisansuruto, Sokudo no, OP ni heikôna Seibun (V_r to kaku) to sore ni suitiyokuna Seibun (V_θ to kaku) to ni naru⁽¹⁾.

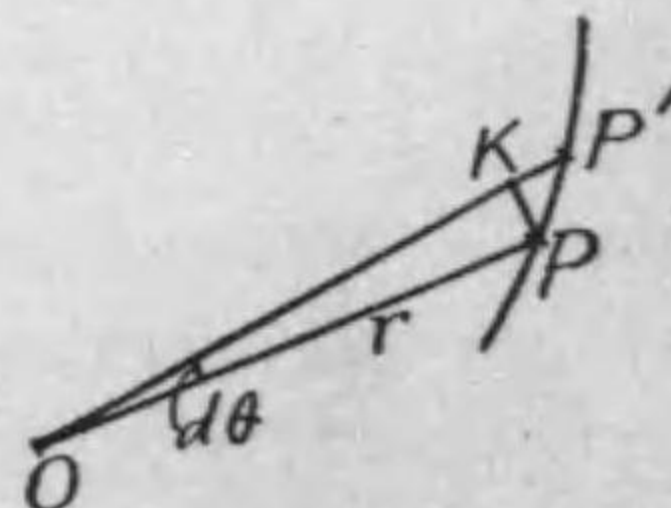
$$V_r = \lim \frac{(r+\Delta r)\cos\Delta\theta - r}{\Delta t} = \frac{dr}{dt};$$

$$V_\theta = \lim \frac{(r+\Delta r)\sin\Delta\theta}{\Delta t} = r \frac{d\theta}{dt}.$$

$\frac{d\theta}{dt}$ wa Dôkei OP no mawaru Hayasa de, kore wo Dôkei no *Kakusokudo* to tonaeru.

114. Kono Tagui no Keisan wo suru kwarini, *kagirinaku tiisai Ryô* wo hutûdaino⁽²⁾ tiisai Ryô no yôni Du ni arawasite siraberu no ga hutû de aru. O (Du 108) wo Tyûsin to site En-no-ko PK wo hikuto,

$$PK=r d\theta, \quad KP'=dr.$$



Du 108.

⁽¹⁾ V_r wa " θ ga kawaranaide" r nomi ga masu Hôkô ni okeru Sokudo no Seibun", V_θ wa " r ga kawaranaide" θ nomi ga masu Hôkô ni okeru Sokudo no Seibun" to iu Imi no Sirusi de aru. V_θ wa $\frac{d\theta}{dt}$ no Imi dewa nai.

⁽²⁾ "Hutûno Ooisa no" no Imi, Eigo no *finite* ni ataru.

$\angle PKP'$ wa kagirinaku tiisai kara, PK mo PP' mo mina Tyokusen to mite yoi; sosite, OP to OP' to wa kekkyoku heikôni nari, PK wa OP to OP' to ni suitiyokuni naru. Sitagatte,

$$V_r = \frac{KP'}{dt} = \frac{dr}{dt}, \quad V_\theta = \frac{PK}{dt} = r \frac{d\theta}{dt}.$$

Tyûi. Korekara notinimo, sizyû kôiu Tokiakasikata—*tadano tiisai Ryô to kagirinaku tiisai Ryô* to wo mazeta yôna Tokiakasikata—wo tukau ga, sore wa ueno Baai no yôni, *madu tadano tiisai Ryô ni tuite kangae, tugini, sore wo kagirinaku tiisaku suru* to iu Tetuduki wo kantanni iarawasita mono de aru.

115. Skalar tosîte tukawareru "Kasokudo". Rikigaku de "Kasokudo" to iu Kotoba wa tugino Setu de noberu yôna Vektor de aru. Sore ni kakawarazu, kimatta Miti ni sôte okoru Undô (tatoeba Tetudô-senro no ueno Kisyâ no Undô) nado dewa, Skalar naru Kasokudo to iu Ryô ga tukawareru. Kore wa "Hayasa ga, Toki ni taisite masu Wariai" wo imisuru Ryô de aru.

Undôten no Hayasa ga, aru Zikoku t ni V , Zikoku $t+\Delta t$ ni $V+\Delta V$ de aru to sureba, konoaidani Hayasa no masu Wariai wa Tan'i-zikan ni taisite $\Delta V/\Delta t$ de aru. Mosi, t kara $t+\Delta t$ madeno aida Hayasa no Masikata ga itiyô de aru naraba, kono Hi $\Delta V/\Delta t$ ga sonomama Kasokudo ni naru. Mosi sono Masikata ga sidaini hagesiku (matawa yuruku) naru tokiniwa, Δt wo (sitagatte ΔV mo) dandan tiisaku totta kyokugenno $\Delta V/\Delta t$ sunawati $\frac{dV}{dt}$ wo toru koto wo yôsuru; yueni,

$$\text{Skalar-kasokudo} = \frac{dV}{dt}.$$

Tatoeba, t byô no Toki ni $V=15$ maibyô-cm., $\Delta t = \frac{1}{100}$

byô to totte, $(t + \frac{1}{100})$ byô no Toki ni $V+\Delta V=25$ maibyô-cm.

de aru to si, $\frac{1}{100}$ byô no aida Hayasa no Kawarikata ga itiyô

da to mireba, $\Delta V = 10$ maibyô-cm.; kore ga $\frac{1}{100}$ byô no aida-ni okotta kara, maibyô niwa 100×10 maibyô-cm.; sunawati, Kasokudo ga "maibyô 1000 maibyô-cm.," matawa Tan'i no Namae wo matomete "1000 maibyô-maibyô-cm." da to iu.

Hokano Rei: Kisyâ ga Teisyaba wo dete kara 3-pun no aida itiyôni Hayasa wo masite. 3-pun no Owari ni 60 maizi-km. ni naru to sureba, Kasokudo wa "20 maihun-maizi-km." de aru⁽¹⁾.

Skalar-kasokudo ga huno Kigô wo motu Baai, sunawati Hayasa ga dandanni heru Baai niwa, sono Skalar-kasokudo no (-)-kigô wo suteta Ryô wo "Gensokudo" to tonacru koto ga aru. Kore wa $-\text{Skalar-kasokudo} = -\frac{dV}{dt}$, sunawati, "V no Toki to tomoni heru Wariai" wo arawasu Ryô de aru.

116. Mosimo Hayasa ga, subeteno Zikoku t ni taisite kimatta Siki

$$V = F(t)$$

de arawasareru naraba, Skalar-kasokudo wa

$$a = \frac{dV}{dt} = F'(t) \dots \dots \dots (1)$$

de ataerareru. Mata, mosimo Mitisudi no aru kimatta Ten kara Mitisudi ni sôte hakatta Mitinori s ga t no Kansû

$$s = f(t)$$

tosite sirete oru Baai niwa,

$$a = \frac{d}{dt} \left(\frac{ds}{dt} \right) = \frac{d^2s}{dt^2} = f''(t) \dots \dots \dots (2).$$

Mata,

$$a = \frac{dV}{dt} = \frac{dV}{ds} \frac{ds}{dt} = V \frac{dV}{ds} = \frac{d}{ds} \left(\frac{1}{2} V^2 \right) \dots \dots \dots (3);$$

⁽¹⁾ § 100 no Sokutyû wo mikurabei! Mata, "maibyô-maibyô-cm." wo cm./byô², "maihun-maizi-km" wo cm./h(zun, zi) nado to kaku.

kore wa V ga Basyo (s) no Kansû tosite sirete iru tokini, Skalar-kasokudo wo s de arawasu Kwankei de aru.

Gyakuni, Kasokudo ga t no Kansû

$$a = \phi(t)$$

tosite ataerareru tokiniwa,

$$V = V_0 + \int_0^t a dt = V_0 + \int_0^t \phi(t) dt \dots \dots \dots (4);$$

tadasi V_0 wa $t=0$ ni okeru Hayasa. Mata,

$$s = s_0 + \int_0^t V dt = s_0 + \int_0^t \left[V_0 + \int_0^t \phi(t) dt \right] dt \dots \dots \dots (5);$$

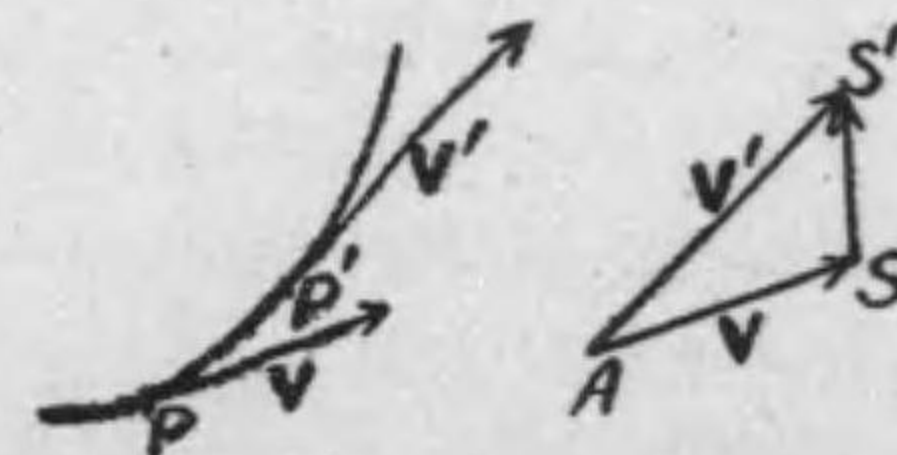
tadasi s_0 wa $t=0$ ni okeru (sunawati Syuppatuten no) s no Atai de aru.

Skalar-kasokudo a ga s no Kansû tosite sirete oru tokiniwa, (3) no kekkwa V ga s de tugino yôni iaraawasareru:—

$$V^2 = V_0^2 + 2 \int_0^s a ds \dots \dots \dots (6).$$

117. Kasokudo. Kasokudo wa "Sokudo no Zikan ni taisite, vektortekino Imi ni oite kawaru Wariai" de aru.

Undôten ga Undô no Hazime kara t byô no Toki ni P (Du 109) ni otte Sokudo \mathbf{V} wo motte ori, nao mizikai Zikan τ byô tatta Toki ni, P' ni kite Sokudo \mathbf{V}' wo motte oru to suru. Kattena Ten A (Du 110) kara \mathbf{V} to \mathbf{V}' to wo hiki, sorera no Yasaki S, S' wo musubeba,



Du 109. Du 110.

$\overrightarrow{SS'}$ wa kono τ byô no aidani okotta Sokudo-masidaka de aru.

Kono Sokudo-masidaka wa, τ wo tiisaku toreba tiisaku toru hodo, \mathbf{V}' ga Hôkô mo Ooisa mo \mathbf{V} ni tikaku naru tameni, tiisaku naru. Kore wo τ de watta Vektor $\frac{\overrightarrow{SS'}}{\tau}$ no kyokugenno Ryô,

sunawati Hôkô wa τ wo kagirinaku tiisaku sita Baai no \vec{SS}' no Hôkô, Ooisa wa onazi Baai no $\frac{SS'}{\tau}$ no Ooisa wo motte oru Vektor ga Undôten no P ni okeru Kasokudo de aru.

118. Ataerareta Undô de, ataerareta Ten ni okeru Kasokudo ga kimatta Hôkô to Ooisa to wo motte iru koto wa, tugino yôna Kangaekata de yoku wakaruru.

Undôten ga Kyokusen no ue wo (Du 111) $P_0, P_1, P_2, P_3 \dots P'$ to ugoite yuku aidano subeteno Iti ni okeru Sokudo wo arawasu Vektor wo, mae to dôyôni, Ten A (Du 112) kara hiita to kangaeruto, \mathbf{V} ga sidai-

sidaini kawatte iru kara, sore no Yasaki ga sidai-sidaini ugoite $S_0, S_1, S_2, S_3 \dots S'$ no yôna Kyokusen wo egaite yuku. Yasaki ga kono Kyokusen no ue wo susumu Sokudo wo sirabe-

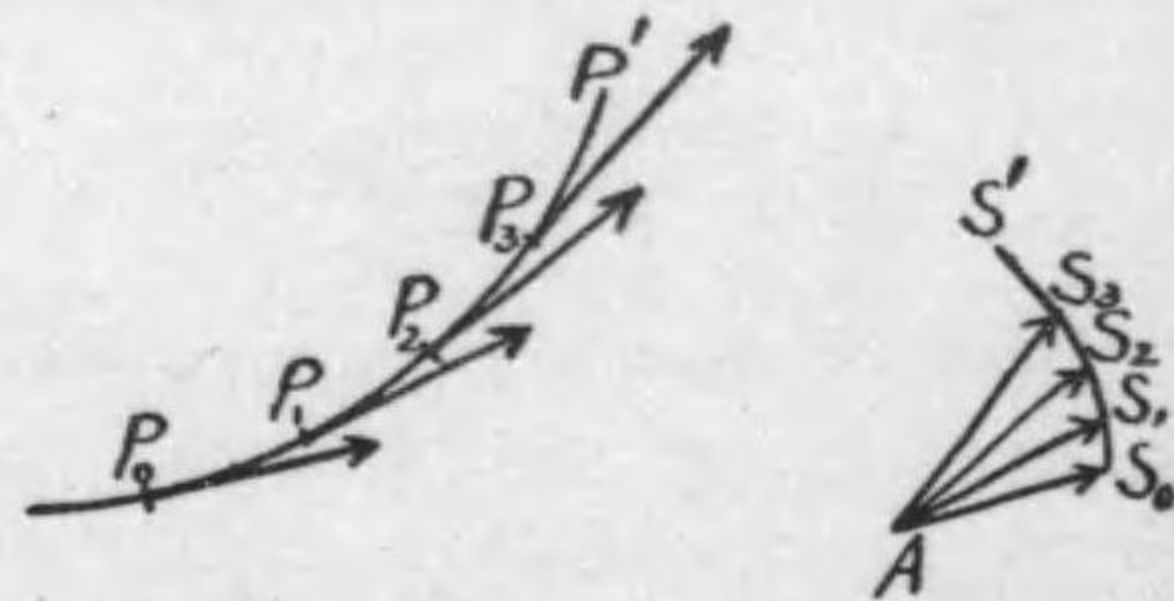
ruto, tatoeba S_2 ni oru tokino Sokudo wa, S_3 wo S_2 ni kiwamete tikaku totta Baai no $\vec{S_2S_3}$ no Hôkô to $\frac{S_2S_3}{\tau}$ no Ooisa to wo motta

Vektor de aru. Tokoroga, kore wa ueno Teigi ni yotte "Undôten no P_2 ni okeru Kasokudo" de aru.

Soreyueni, Undôten no Kasokudo wo siru niwa, Sokudo no Du—sunawati kattena kimatta Ten kara Sokudo no Vektor wo hiita Du—wo tukutte, Sokudo no Vektor no Yasaki no Sokudo wo mireba yoi.

Ueno $AS_0S_1 \dots$ no yôna Du wo Hodograph to tonaeru.

119. Kasokudo no Tyokkaku-seibun. Ugoku Ten P no Kasokudo ga Hodograph ni okeru Sokudo-daihyôten S no Sokudo to onazi de aru to iu Teiri no Kekkwa tosite, sore no Gôsei ya Bunkai wa, Sokudo no Baai to onaziku, ippanno Vektor no tôrini okonawareru. Mata onazi Teiri wo riyôsite, sore wo iroironi

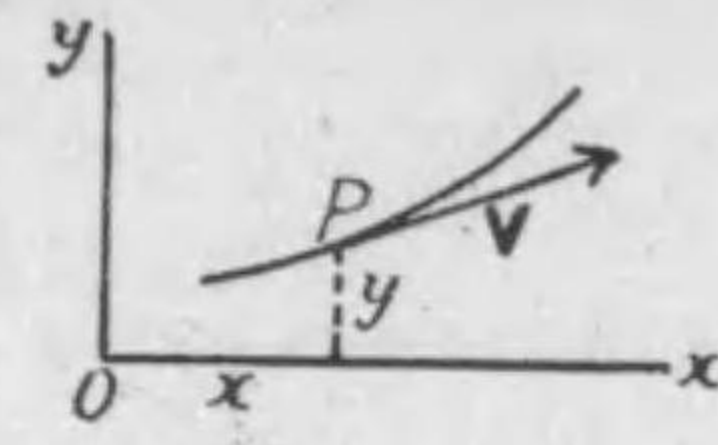


Du 111.

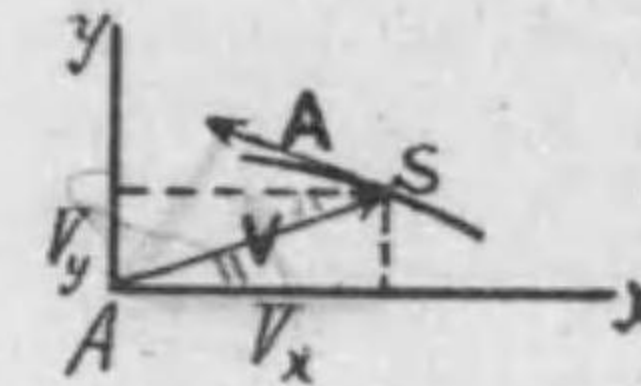
Du 112.

bunkaisita Seibun wo siru koto ga dekuru.

Nakade, Zahyôdiku no Hôkô ni okeru Seibun wa § 111 no Teiri ni yotte erareru.



Du 113.



Du 114.

Sokudo-daihyôten S no Du (Du 114) no Zahyô-genten wo A ni toruto, § 111 no x ni ataru mono wa \mathbf{V} no x -Seibun V_x , y ni ataru mono wa \mathbf{V} no y -Seibun V_y de aru kara,

$$S \text{ no Sokudo no } x\text{-Seibun} = \frac{dV_x}{dt},$$

$$S \text{ no Sokudo no } y\text{-Seibun} = \frac{dV_y}{dt}.$$

S no Sokudo wa Undôten P no Kasokudo de aru kara, P no Kasokudo \mathbf{A} no Ooisa, sore no x -Seibun, y -Seibun wo sorezore A, A_x, A_y to sureba,

$$\left. \begin{aligned} A_x &= A \cos(x, \mathbf{A}) = \frac{dV_x}{dt} = \frac{d^2x}{dt^2}, \\ A_y &= A \sin(x, \mathbf{A}) = \frac{dV_y}{dt} = \frac{d^2y}{dt^2} \end{aligned} \right\} \dots (1);$$

tadasî, (x, \mathbf{A}) wa x -Diku to \mathbf{A} to no aidano Kaku.

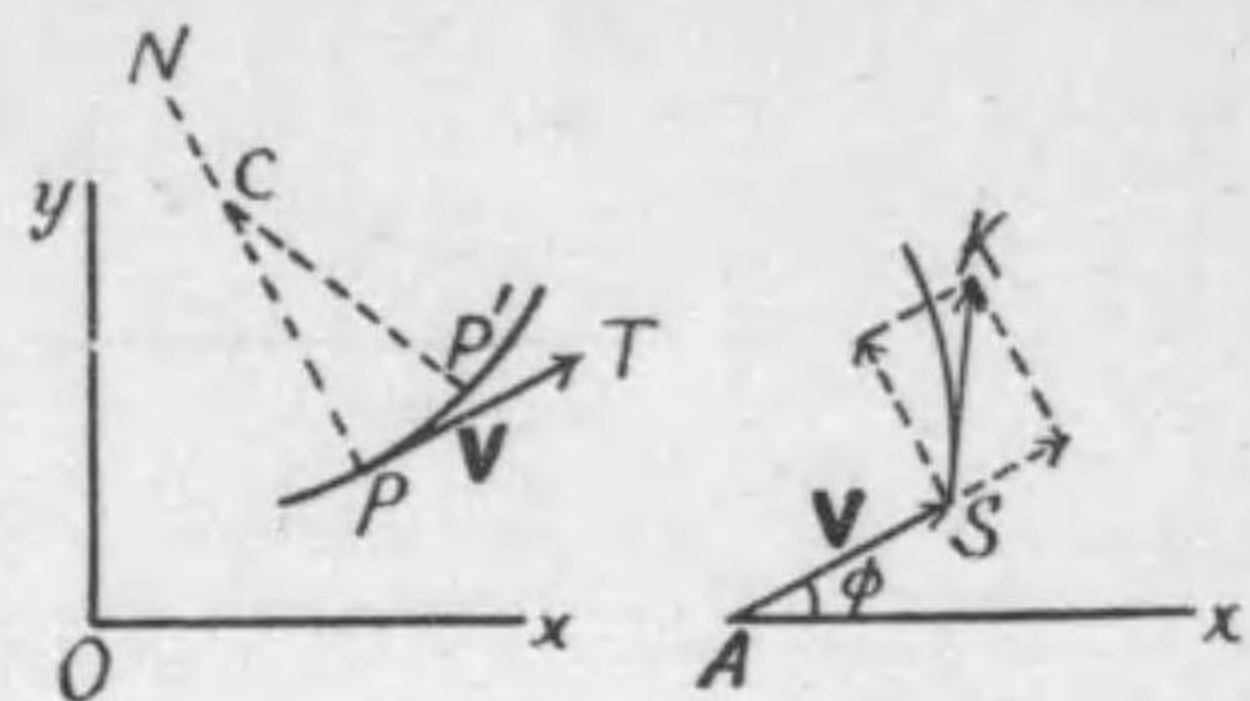
Korerano Siki kara, Kasokudo no Ooisa A oyobi sore no Hôkô ga x -Diku to tukururu Kaku wo arawasu koto ga dekuru:—

$$\left. \begin{aligned} A &= \sqrt{\left(\frac{d^2x}{dt^2}\right)^2 + \left(\frac{d^2y}{dt^2}\right)^2}, \\ \tan(x, \mathbf{A}) &= \frac{d^2y}{dt^2} / \frac{d^2x}{dt^2} \end{aligned} \right\} \dots (2).$$

120. Sessen-kasokudo to Hôsen-kasokudo. § 113 no Teiri wo Sokudo-daihyôten S no Undô ni atchamereba, Undôten P

(1) $\frac{d^2x}{dt^2}, \frac{d^2y}{dt^2}$ wo sorezore \ddot{x}, \ddot{y} tomo kaku.

no Kasokudo wo, \mathbf{V} ni heikôna Hôkô to suitiyokuna Hôkô ni bunkaisita Seibun, sunawati P no Mitisudi ni taisuru Sessen PT to Hôsen PN no Hôkô ni bunkaisita Seibun wo eru. Kaku (x, \mathbf{V}) wo φ to kaite (Du 115, 116),



Du 115.

Du 116.

$$\left. \begin{aligned} P \text{ no Sessen-kasokudo} &= S \text{ no Sokudo no} \\ \mathbf{V} \text{ ni heikôna Seibun} &= \frac{dV}{dt}, \\ P \text{ no Hôsen-kasokudo} &= S \text{ no Sokudo no} \\ \mathbf{V} \text{ ni suitiyokuna Seibun} &= V \frac{d\varphi}{dt} \end{aligned} \right\} \dots (1).$$

$\frac{d\varphi}{dt}$ wa motto benrina Ryô de kakinaosareru. Undôten ga dt no aidani P kara P' ni yuku to si, P' ni okeru Hôsen ga P ni okeru Hôsen to C de deau to sureba,

$$PP' = Vdt, \quad \angle PCP' = d\varphi.$$

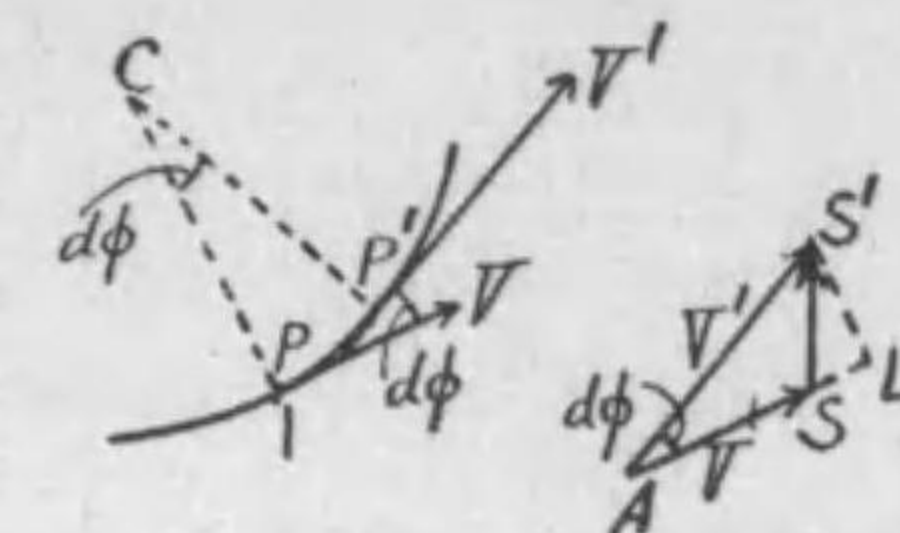
Yueni, $\frac{d\varphi}{dt} = \frac{\angle PCP'}{PP'} \times V = \frac{V}{PC}$, ($\angle PCP' = \frac{PP'}{PC}$ da kara). C wa *Kyokuritu no Tyûsin* de, PC wa P ni okeru Mitisudi no *Kyokuritu-hankei* de aru. Kore wo ρ de arawaseba,

$$\frac{d\varphi}{dt} = \frac{V}{\rho}.$$

Kore wo (1) no Siki ni ireruto, tugino Kekkwa wo eru:—

$$\left. \begin{aligned} P \text{ no Sessen-kasokudo} &= \frac{dV}{dt}, \\ P \text{ no Hôsen-kasokudo} &= \frac{V^2}{\rho} \end{aligned} \right\} \dots (2).$$

121. Ueno Kekkwa wa, § 113 no Teiri wo tukawanaide, tyokuse-tuni kangaetemo yôini erareru. Sunawati, P, P' (Du 117) ni okeru Sokudo no Du wo AS, AS' (Du 118) no yôni kaki, Sokudo no Masidaka $\overrightarrow{SS'}$ wo AS ni heikôna



Du 117.

Du 118.

\overrightarrow{SL} to suitiyokuna $\overrightarrow{LS'}$ to ni wakeru. Sô sureba, Kaku $S'AS, SL, LS'$ nado ga kiwamete tiisai tameni, tugino yôni naru:—

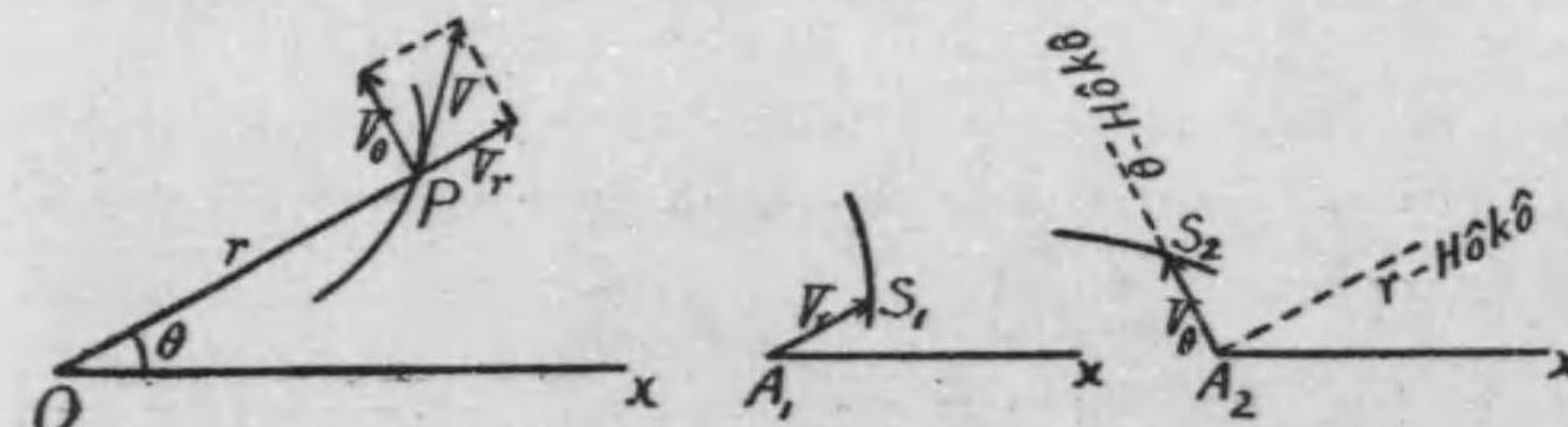
$$\text{Sessen-kasokudo} = \frac{SL}{dt} = \frac{dV}{dt};$$

$$\text{Hôsen-kasokudo} = \frac{LS'}{dt} = \frac{Vd\varphi}{dt} = V \frac{PP'}{\rho dt} = \frac{V^2}{\rho}.$$

122. Ueno Kekkwa ni yotte, § 115 no Skalar-kasokudo to hontôno Kasokudo to no Kwankei ga wakarû.

Skalar-kasokudo = Kasokudo no Sessen-seibun; sosite, *Kasokudo wa Undô no Hôkô (tateno Hôkô) ni okeru Skalar-kasokudo* $\frac{dV}{dt}$ no hokani, sore ni suitiyokuna Hôkô (*yokono Hôkô*) ni okeru $\frac{V^2}{\rho}$ dakeno Seibun wo motte iru.

123. *Kyoku-zahyô de arawasu Kasokudo no Seibun.* Kyoku-zahyô r, θ wo tukatte Kasokudo no Seibun wo arawasu niwa, Sokudo no Baai (§ 113) to onaziku, Seibun wo r -Hôkô (sunawati r nomi ga masu Hôkô) to θ -Hôkô (θ nomi ga masu Hôkô) to ni toru ga yoi.



Du 119.

Du 120.

Du 121.

Kono Mokuteki niwa, Sokudo no hutatuno Seibun V_r to V_θ (Du 119) to ni tuite *betubetuni* Sokudo no Du wo tukuri, Sokudo-daihyôten S_1 (Du 120) to S_2 (Du 121) to no Sokudo wo bunkaisite, onôniono Hôkô ni okeru Seibun wo yose-atunereba yoi. V_r no mawaru Hayasa mo V_θ no mawaru Hayasa mo onaziku $\frac{d\theta}{dt}$ de aru kara,

$$S_1 \text{ no Sokudo no } V_r \text{ ni heikôna Seibun} = \frac{dV_r}{dt},$$

$$S_1 \text{ no Sokudo no } V_r \text{ ni suityokuna Seibun} = V_r \frac{d\theta}{dt},$$

$$S_2 \text{ no Sokudo no } V_\theta \text{ ni heikôna Seibun} = \frac{dV_\theta}{dt},$$

$$S_2 \text{ no Sokudo no } V_\theta \text{ ni suityokuna Seibun} = V_\theta \frac{d\theta}{dt}.$$

V_r no Hôkô wa r -Hôkô de, sore ni suityokuna Hôkô wa θ -Hôkô de aru; mata, V_θ no Hôkô wa θ -Hôkô de, sore ni suityokuna Hôkô wa *gyakuni totta* r -Hôkô de aru. Soreyueni,

$$P \text{ no Kasokudo no } r\text{-Seibun} = \frac{dV_r}{dt} - V_\theta \frac{d\theta}{dt},$$

$$P \text{ no Kasokudo no } \theta\text{-Seibun} = V_r \frac{d\theta}{dt} + \frac{dV_\theta}{dt}.$$

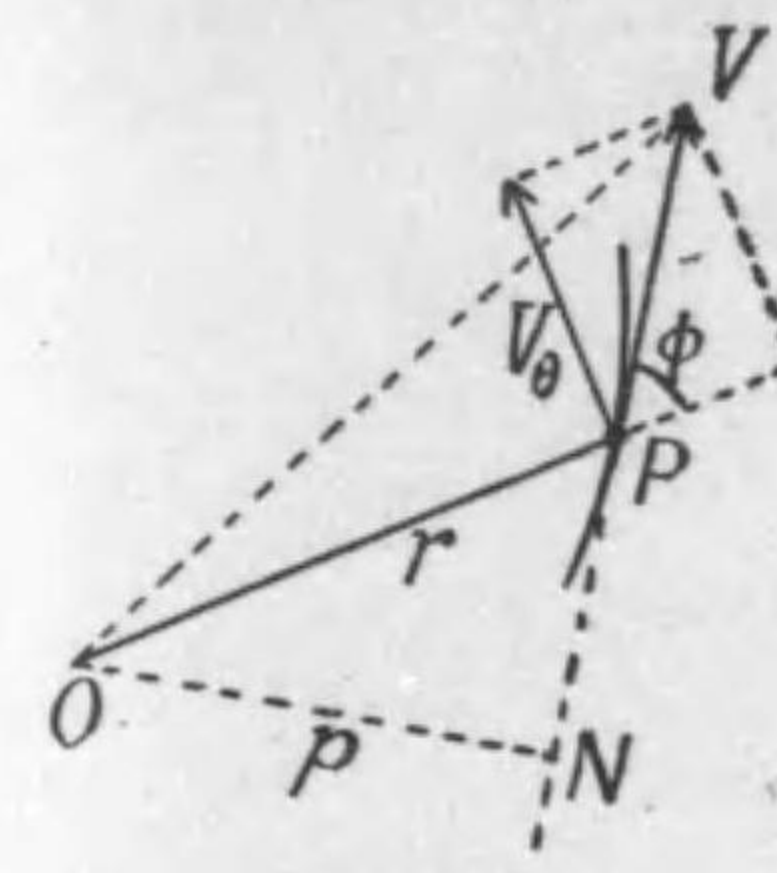
Korerano Siki ni § 113 no Atai $V_r = \frac{dr}{dt}$, $V_\theta = r \frac{d\theta}{dt}$ wo ireruto, tugino Kwankei wo eru:—

$$\left. \begin{aligned} P \text{ no Kasokudo no } r\text{-Seibun} &= \frac{d^2r}{dt^2} - r \left(\frac{d\theta}{dt} \right)^2, \\ P \text{ no Kasokudo no } \theta\text{-Seibun} &= 2 \frac{dr}{dt} \cdot \frac{d\theta}{dt} + r \frac{d^2\theta}{dt^2} \end{aligned} \right\} \dots (1).$$

Tyûi 1. Kasokudo no r -Seibun ga $\frac{d^2r}{dt^2}$ dewa nai koto wo tyûisei!

Tyûi 2. Kasokudo no θ -Seibun wa $\frac{1}{r} \cdot \frac{d}{dt} \left(r^2 \frac{d\theta}{dt} \right)$ no Katati ni kakareru.

124. Sokudo no Moment to Menseki-sokudo. Ten P (Du 122) ni okeru Sokudo V to kimatta Ten O kara V madeno Kyori p to no Zyôseki pV wo, Ten O no mawarino "Sokudo no Moment"



Du 122.

to tonaeru. Sosite, Sokudo no Moment ni, O Ten kara mite, Undôten ga Tokai no Hari to hantaino Hôkô ni ugoku Baai ni (+), sô de nai Baai ni (-) no Kigô wo ataeru.

$$\begin{aligned} \text{Sokudo no Moment} &= pV \\ &= r \sin \angle OPN \cdot V = r \cdot V \sin \phi \\ &= rV_\theta \\ &= r^2 \frac{d\theta}{dt}. \end{aligned}$$

Kono Siki wa Moment ga seino Baai demo huno Baai demo, konomama de tadasii Kigô wo motu.

Mata, P kara Sokudo wo arawasu Vektor PV wo hiite, Sankakukei OPV wo tukuruto, tugino Kwankei ga aru:—

$$\text{Sokudo no Moment} = 2(\Delta OPV).$$

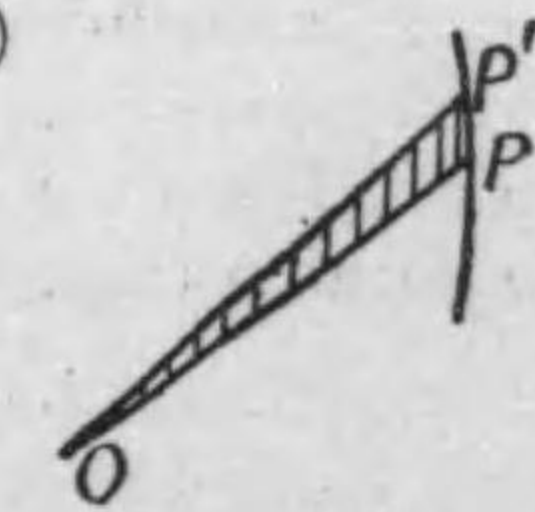
125. Kimatta Ten O kara Undôten P ni hiita Dôkei OP ga ugoku aidani sore ni ôwareru Menseki wo Tan'i-zikan ni taisite i-arawasita mono wo "O no mawarino Menseki-sokudo" to iu.

Zikan dt no aidani Undôten ga P (Du 123) kara P' ni yuku to sureba, $\Delta POP' = \frac{1}{2} r^2 d\theta$;

sitagatte, Menseki-sokudo = $\frac{\Delta POP'}{dt} = \frac{1}{2} r^2 \frac{d\theta}{dt}$.

Sitagatte, tugino Kwankei ga aru:—

$$\text{Menseki-sokudo} = \frac{1}{2} (\text{Sokudo no Moment}).$$



Du 123.

126. § 123 no Owari ni aru Tyûi (2) to kuraberuto, tugino Teiri ga aru koto ga sireru:—

Kasokudo no θ -Seibun ga rei de areba, Sokudo no Moment oyobi Menseki-sokudo ga kawaranai; mata *gyakuni*, Sokudo no Moment oyobi Menseki-sokudo ga kawaranakereba Kasokudo no θ -Seibun ga rei de aru.

127. Zahyô-genten no mawarini totta Sokudo no Moment oyobi Menseki-sokudo wo kaisekitekini arawasu koto wa Tikara no Moment no Arawasikata to dôyôni dekiru. §.38 no Siki (1) ni okeru Tikara no Seibun X, Y no kawarini sorezore $\frac{dx}{dt}, \frac{dy}{dt}$ wo irete,

$$\text{Sokudo no Moment} = x \frac{dy}{dt} - y \frac{dx}{dt},$$

$$\text{Menseki-sokudo} = \frac{1}{2} \left(x \frac{dy}{dt} - y \frac{dx}{dt} \right).$$

Rensyû-mondai III.

1. Sankaku ABC no Tyûsen AD, BE, CF de arawasareru mittuno Vektor no Gô-vektor ga o de aru koto wo syômeisei!

2. Ooisa no hitosii Vektor hutatu wo gôseisite, onazi Ooisa no Vektor wo eru to sureba, sorerano Vektor no Hôkô wa dô ka?

3. Kisyâ ga tomatte iru tokini entyokuni hutte iru Ame ga, sore ga 15 maibyô-m. de susumu tokini, Mado no entyokuna Huti ni taisite 60° no Kaku wo nasite mieru naraba, Ametubu no otiru Hayasa wa ikura ka?

4. 2 maibyô-mêtoru de nagareru Nagare wo yokogitte, sore ni suityokuni susumu niwa, Hune wo dô mukereba yoi ka? Tadasî, Hune wa Midu ni taisite 4 maibyô-mêtoru no Hayasa wo dasu to suru.

5. Haba 100 m. no Kawa no Mannaka ni Bôto ga iru. Soko kara 150 m. simo de, Kawa ga Taki ni naru. Kawa no Nagare ga 5 m./s. de aru to sureba, Bôto ga Taki ni otinaide Kisi ni tassuru tameni hituyôna saisyôno Hayasa wa ikura ka?

6. 10 m./s. no Hayasa de susunde iru Kisyâ no Mado kara Buttai wo otosu tokini, sore ga Kisyâ kara mite entyokuni, t byô no aidani Kyori $s=4.9t^2$ m. dake otiru to sureba, Dimen ni taisite Buttai no ugoku Sokudo wa, otite kara .1, .2, .3, .4, .5-byô tatta tokini sorezore donna Hôkô to Ooisa wo motu ka?

7. 1 maizi-mairu oyobi 1 notto (Eigo no *knot* = 1 maizi-kairi) wa onôno iku-maibyô-mêtoru ni hitosii ka?

8. Hutû okoru Bôhû wa 50 m./s. gurai de aru. Sore ni sakaratte susumi uru Hikôki wa iku-maizi-kiromêtoru izyô no Hayasa wo motu koto wo yôsuru ka?

9. Kisyâ ga ugoki-dasite kara ippun no aidani 50 maizi-km. ni naru. Konoaida Kasokudo ga itiyô da to mireba, sono Kasokudo wa iku-maibyô-maibyô-mêtoru ni hitosii ka? Mata, kono ippun no aidani Kisyâ no susumu Mitinori wa ikura ka?

10. Kisyâ ga Teisyaba wo dete kara 1 km. wo susumu aidani ippaino Hayasa 50 maizi-km. ni nari, mata tugino Teisyaba kara 0.5 km. temae no Tokoro kara Hayasa wo herasite yuku to sureba, Kasokudo oyobi Gensokudo no heikinno Atai wa sorezore ikura ka?

11. Mondai 9 ni aru Kisyâ no Miti ga Teisyaba kara 300 m. no Tokoro de Hankei 100 m. no Magari wo nasite iru tokini, Kasokudo no Hôkô oyobi Ooisa wo dase!

12. Kuruma (Hankei a) ga suiheina Tyokusen no ue wo suberu koto nasini Hayasa v de korogatte iru. Kuruma no Tyûsin O kara Kyori r ni aru Ten P ga, OP ga entyokuni ueni muita Toki kara Zikan t dake sugita Zikoku ni motte iru Sokudo oyobi Kasokudo wo dase!

13. Tugino Hôteisiki de ataerareru Undô no, Zahyô-genten no mawarino Menseki-sokudo ga kawaranai koto wo syômeisei!

$$x = a \cos \omega t, \quad y = b \sin \omega t.$$

14. Kyoku-zahyô no Hôteisiki

$$r = l / (1 + e \cos \theta)$$

de ataerareru Daen no ue wo

$$\dot{r}^2 + r^2 \dot{\theta}^2 = 2k(1/r - C)$$

no Kwankei ni sitagatte ugoku Undô ga, C no Atai ga tekitô de aru tokini, Kyo'ku no mawarini huhenna Menseki-sokudo wo motu koto wo syômeisei!

SYOO IV.
Undô no Hôsoku.

131. Undô no Hôsoku to Sitten. Buttai no Undô wo kimeru Hôsoku wa "NEWTON no mittuno Undô-no-Hôsoku" to tonaeru mono de arawasareru.

Tugini noberu korerano Hôsoku dewa, "Buttai" to iu Kotoba ga tukatte aru keredomo, *Buttai sentai tositeno* Undô dake wo Mondai ni site iru node, sore ga zibun no Muki wo kaeru yôna Undô sunawati Kwaiten-undô wa Mondai ni site inai.

Kwaiten-undô wo Mondai ni site inai to iu koto wa, hitotuno Buttai no nakano iroirona Bubun ga tigau Undô wo site iru koto wo Mondai ni site inai to iu Imi de aru kara, tumari *Ooisa to iu Seisitu wo torisuteta Buttai* wo Mondai ni site iru to itte yoi. Konoyôni,

Situryô wa ari nagara, Ooisa no nai Buttai—sunawati sono *Situryô ga hitotuno Ten ni atumatte iru to kangaeru Buttai*—wo Sitten to nadukeru.

Soreyueni, kono Syô dewa, "Buttai" to iu Kotoba wa "Sitten" to onazi Imi ni ryôkaisite yoi.

132. Undô no Daitino Hôsoku. Hoka kara Tikara wo ukenai aida, seisisite iru Buttai wa Seisi no Arisama wo tuduke, undôsitate iru Buttai wa Tyokusen ni sôte kawaranai Hayasa de susumu. Kono Hôsoku wa, "Buttai wa, zibun de zibun no Undô no Arisama wo kaeru koto ga dekinai" koto wo nobete oru. Konoyôna Seisitu wo "Buttai no *Kwansei*" to tonaeru⁽¹⁾; sosite, ueno Hôsoku wo "*Kwansei no Hôsoku*" to tonaeru⁽²⁾.

Mata, kono Hôsoku wa, *Tikara* wo teigisuru mono de aru

⁽¹⁾ "Kwansei" to iu kowarini "Dasei" to iu Hito mo aru.

⁽²⁾ Ueni iu tôri, Buttai no Kwaiten-undô sonohokano naibuno Undô wa kono Hôsok ni mukwankei de aru.

to iu koto ga dekiru; sunawati, "Buttai ni hataraite, sore no Seisi matawa Tôsokudo-undô no Arisama wo kaeru mono wo Tikara to tonaeru" to itte yoi. Kore wa § 1 de nobeta Koto to onazimono de aru.

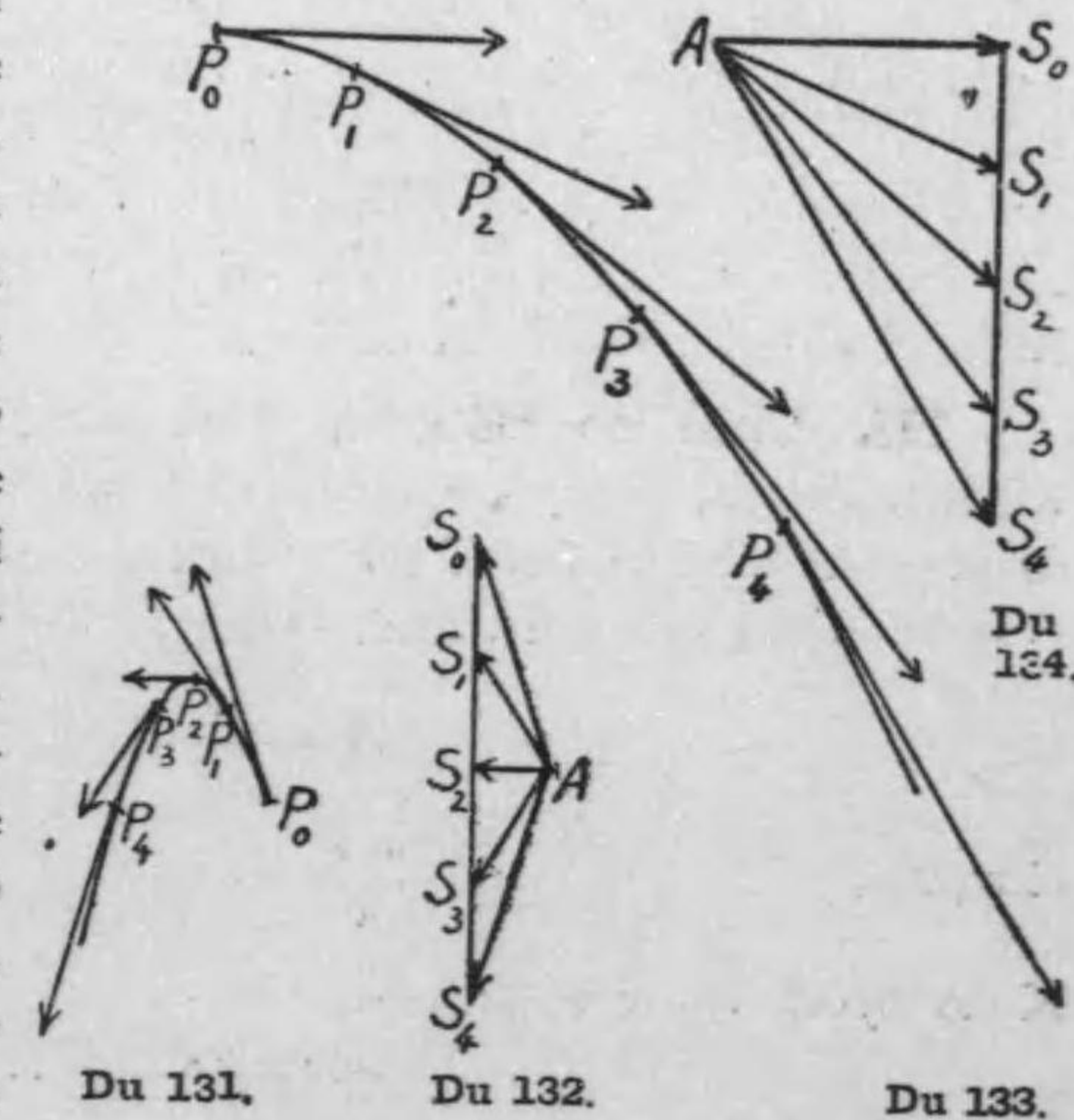
133. Undô no Dainino Hôsoku. Kono Hôsoku wa, Buttai ni Tikara ga hataraku tokini, donoyôni sore no Undô ga Eikyô wo ukeru ka wo simesu mono de, tanni "Undô no Hôsoku" tomo iwareru. Kasokudo wo tukatte iarawaseba, sore ga tugino yôni iarawasareru:—

Buttai no Kasokudo wa, sore ni hataraki tutu aru Tikara no Hôkô ni okori, sore no Ooisa wa Tikara ni hireisi, Buttai no Situryô ni gyakuhireisuru.

134. Madu *onazi* Buttai ga iroirona Tikara wo uke tutu iroirona Undô wo site iru Arisama wo miruto, sore no Kasokudo wa, itu demo, sono Zikoku ni Buttai ni hataraite iru Tikara to Hôkô ga onazi de, katu Ooisa ga hireisuru; sosite sore niwa *genzaino Sokudo wa nanno Kwankei mo Eikyô mo motanai.*

Tatoeba, onazi Buttai ga Du 131, 133 no yôni tigau hutatuno

Undô wo suru Baai — itibyô gotoni sore ga tôru Ten ga P_0, P_1, P_2, \dots de simesite aru — niwa, Hodograph (Du 132, 134) de S_0, S_1, S_2, S_3, S_4 no Ugokikata wo mite wakaruru tôri, onazi Tikara wo ukete ugoite iru no de aru. Onazi Tikara wo ukete iru noni, naze konnani tigau Undô wo suru ka to ieba, sore wa *hazimeno Ugokidasikata* ga ti-



Du 131.

Du 132.

Du 133.

gau kara de aru; sosite, kono hazimeno Ugokidasikata wa sorekara notini hataraku Tikara towa Kwankei ga nai koto wa motiron de aru. (Iroiro tigau Ugokidasikata wo saseru tameni donna Tikarâ wo Buttai ni ataeta ka wa ima Mondai ni site inai; wareware no Mondai wa, *dô demo ugokidasite kara notini* hataraku Tikara no tameni Undô ga dô kawaru ka de aru.

135. Tugini, *tigau* Buttai no Baai wo kangaeru. "Situryô" to iu Kotoba wa "Buttai no Bunryô" to iu Imi no Kotoba de aru. Tetu nara Tetu to iu yôna kimatta Bussitu de dekite iru Buttai naraba, "Bussitu no Bunryô" no Hikaku wa akirakana Imi wo motte oru keredomo, Tetu to Kin to iu yôni tigau Bussitu no Bunryô wo kuraberu koto niwa, Hazime kara kimatte iru Hyôzyun to iu mono ga nai. Soreyueni, "ueno Dainino Hôsoku wa tigau Syurui no Bussitu no Bunryô wo kuraberu Hyôzyun wo ataeru mono de aru" to iu koto ga dekiru. Sunawati, Tetu demo Kin demo, onazi Tikara wo kuwaete onazi Kasokudo wo syôzuru naraba, Situryô ga hitosii to suru no de aru.

136. Wareware ga zissaini Situryô wo hikakusi matawa sokuteisuru niwa, Tenbin ya Saobakari wo tukau. Kore wa Tikyûzyô de (onazi Basyo de) Buttai to Hundô to ga ukeru Dyûryoku wo hikakusuru no de aru ga, konoyôni *Dyûryoku ni motoduite okonau Situryô no Hikaku to ueno § de nobeta Dainino Hôsoku ni motoduku Hikaku to ga itu demo seimituni onazi Kekkwa wo ataeru no de aru.* Kore wa Buturigaku de mottomo itizirusii Hôsoku no hitotu de aru.

137. **Undô no Hôteisiki.** Ima tekigina Tan'i wo kimete tukatte, Tikara, Situryô, Kasokudo wo arawasu to sureba, Situryô *m* no Sitten ni Ooisa *K* no Tikara ga hataraitte, Ooisa *A* no Kasokudo wo syôzuru tokini, Dainino Hôsoku ni yotte,

$$A \propto \frac{K}{m},$$

sitagatte, $\frac{mA}{K} = \text{const.}$

Kono Zyôsû wo *k* to kabeba,

$$mA = kK \dots \dots \dots (1).$$

Kono Hôteisiki wa *A* to *K* to no Ooisa no Kwankei nomi wo arawasu mono de aru ga, nao sonoueni Kasokudo to Tikara to ga onazi Hôkô wo motte iru koto wo arawasô to sureba, *A* to *K* to no kawarini Kasokudo to Tikara no Vektor-hugô wo tukaeba yoi. Sunawati,

$$m\mathbf{A} = k\mathbf{K} \dots \dots \dots (2).$$

Kono Vektor-hôteisiki wa, ataerareta Tikara ni yotte Undô ga donoyôni kawatte yuku ka wo kimeru Hôteisiki de, kore wo "Undô no Hôteisiki" to tonaeru.

Tyûi. $\mathbf{K} = 0$ no Baai niwa $\mathbf{A} = 0$ ni naru. Kore wa Seisi matawa Tôsoku-undô no Baai de, Undô no Daiitino Hôsoku de iu Koto to onazi de aru. Soreyueni, Daiitino Hôsoku wa Dainino Hôsoku no nakani hukumarete iru to ittemo yoi.

138. Zyôsû *k* wa Tan'i no Erabikata ni yotte kimaru mono de, tatoeba, *m* ga Kiroguramu de, *A* ga Maibyô-maibyô-mêtoru de, *K* ga Kiroguramu no Omosa de arawasite aru to sureba, *k*=9.8 gurai de aru (1).

139. **Tikara no Zettai-tan'i.** Mosi, Tikara no Tan'i wo katteni kimeru kawarini, "Tan'i-situryô no Buttai ni hataraitte Tan'i-kasokudo wo syôzuru Tikara" wo Tikara no Tan'i ni erabu to kimereba, *k*=1 ni naru. Kôiu Tikara no Tan'i wo "Tikara no Zettai-tan'i" to tonaeru. Tikara no Zettai-tan'i no Ooisa wa, Situryô to Kasokudo to no Tan'i no Erabikata ni yotte tigau.

Situryô no Tan'i ni Guramu, Kasokudo no Tan'i ni Maibyô-maibyô-sentimêtoru wo totta Baai ni okeru Tikara no Zettai-tan'i, sunawati 1 guramu no Buttai ni 1 maibyô-maibyô-sentimêtoru (cm./sec².) no Kasokudo wo syôzuru dakeno Tikara wo *Dyne* (dain) to yobu. Kore wa, notini (§ 159) siru tôri, 1 guramu no Omosa no 1/980 hodono tiisai Tikara de aru.

1 huransuton (1000 kg.) no Buttai ni 1 mêtoru/(byô)² no Kasokudo wo syôzuru Tikara sunawati itioku (10⁸) dyne ni hitosii Tikara wo *Sthène* (sutein) to yobu.

(1) Kiroguramu no Omosa to iu Tikara wa Tikyûzyô demo Basyo ni yotte sukosi dutu tigau tameni, *k* no Atai mo sukosi dutu tigau.

1 pondo no Buttai ni 1 foot/(byô)² no Kasokudo wo syôzuru Tikara wo *Poundal* to yobu.

140. Zettai-tan'i wo tukau Undô no Hôteisiki. Tikara wo Zettai-tan'i de arawasu to kimereba, Situryô ya Kasokudo no Tan'i ni kakawarazu, Undô no Hôteisiki wa tugino yôni naru :—

$$m\mathbf{A}=\mathbf{K} \dots \dots \dots (1).$$

Sitten ga hitotuno Heimen no ue wo ugoku Baai niwa, Kasokudo \mathbf{A} mo, sitagatte Tikara \mathbf{K} mo, mina onazi Heimen ni sôte aru. Kono Heimen ni xy -Zahyôdiku wo totte, Sitten no Undô wo siraberuto, \mathbf{A} to \mathbf{K} to ga heikô de aru kara, ue to dôyôna Kwankei ga onônono Seibun ni tuite iwareru :—

$$mA_x=K_x, \quad mA_y=K_y.$$

Maeni eta Kwankei

$$A_x=\frac{d^2x}{dt^2}, \quad A_y=\frac{d^2y}{dt^2}$$

wo ire, mata K_x wo X , K_y wo Y to kaite,

$$m\frac{d^2x}{dt^2}=X, \quad m\frac{d^2y}{dt^2}=Y \dots \dots \dots (2).$$

Kore ga Undô no Hôteisiki no kaisekitekinô Katati de aru.

Sokudo-seibun V_x, V_y wo tukatte (2) wo kakikaereba,

$$m\frac{dV_x}{dt}=X, \quad m\frac{dV_y}{dt}=Y \dots \dots \dots (3)$$

ni naru. Kore wa Sokudo no Kawarikata wo kimeru Siki de aru.

(2), (3) dotira karamo, tugino Teiri ga sireru :—

x-Hôkô no Undô to *y*-Hôkô no Undô to wa tagaini kwankeisuru koto naku dokurituni okoru.

141. Vektor-hôteisiki (1) wo bunkaisuru koto wa Zahyôdiku no Hôkô ni kagiranai.

Sitten no ugoku Mitisudi ni taisuru Sessen to Hôsen to no Hôkô ni bunkaisureba, § 120 ni yotte, tugino Siki wo eru :—

$$m\frac{dV}{dt}=K_r, \quad m\frac{V^2}{\rho}=K_n \dots \dots \dots (4).$$

Tadasi V, ρ nado wa maeno tôri (§ 120) de, K_r wa Tikara no Sessen-seibun, K_n wa sore no Hôsen-seibun de aru.

142. Mata, Kyoku-zahyô no r -Hôkô to θ -Hôkô to ni bunkaisureba, Tikara no Seibun wo K_r, K_θ to kaite, § 123 ni yotte,

$$m\left(\frac{d^2r}{dt^2}-r\left(\frac{d\theta}{dt}\right)^2\right)=K_r, \quad \frac{m}{r}\frac{d}{dt}\left(r^2\frac{d\theta}{dt}\right)=K_\theta \dots (5).$$

Tikara no Sayôsen ga itumo kimatta Ten ("Tyûsin") wo hukumu Baai niwa, kono Ten wo Kyoku ni toreba,

$$K_\theta=0, \text{ sitagatte, Kasokudo no } \theta\text{-Seibun}=0.$$

Yueni, ueno (5) matawa § 126 ni yotte, tugino Teiri wo siru :—

"Tyûsin-no-arû Tikara" wo ukete ugoku Sitten no, Tikara no Tyûsin no mawarino Sokudo no Moment oyobi Menseki-sokudo wa kawaranai.

143. Undôryô to Tikara no Ryokuseki. Dainino Hôsoku wa, "Undôryô" to iu Ryô wo tukattemo iarawasareru.

Situryô m no Buttai ga Sokudo \mathbf{V} de ugoite iru tokini, sore ga $m\mathbf{V}$ no Undôryô wo motte iru to iu. Kono Teigi de sireru tôri, Undôryô wa Sokudo to onazi Hôkô wo motta hitotuno Vektor de aru.

Tikara \mathbf{K} ga Zikan t no aida hataraku aidani sore no "Ryokuseki ga $\mathbf{K}t$ dake aru" to iu.

Tikara \mathbf{K} ga Zikan t no aida hataraita tameni, Sokudo ga Du 135 no $\mathbf{V}(=\vec{AS})$ kara $\mathbf{V}'(=\vec{AS}')$ ni kawatta to sureba, \vec{SS}' wa Sokudo no Masidaka de, $(\text{Kasokudo}) \times t$ ni hitosii. Nao, Undô no Hôteisiki ni yotte,

$$\vec{SS}'=\mathbf{A}t=\frac{\mathbf{K}}{m}t.$$

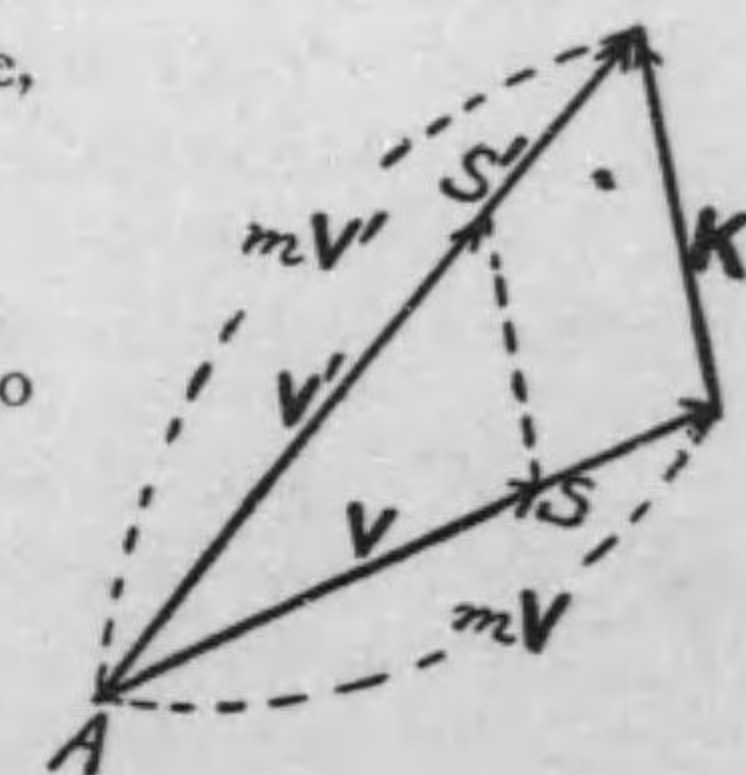
Sokode, Du no yôni, $\mathbf{V}, \mathbf{V}', \vec{SS}'$ no Du wo m -baini ôkiku sita Vektor-du wo tukuruto,

$$m\mathbf{V}'=m\mathbf{V}+m\frac{\mathbf{K}}{m}t,$$

sunawati,

$$m\mathbf{V}'-m\mathbf{V}=\mathbf{K}t \dots \dots \dots (1)$$

no Siki wo eru.



Du 135.

Soreyueni, ueno Kwankei wa tugino yôni iarawasareru:—

Aru Zikan no aidani syôzuru Buttai no Undôryô no (vektortekini totta) Masidaka wa, sonoaida sore ni hataraita Tikara no Ryokuseki ni (vektortekini) hitosii.

Mata,
$$\frac{m\mathbf{V}' - m\mathbf{V}}{t} = \mathbf{K}$$

no Katati de miruto, tugino yôni iu koto mo dekiru:—

Undôryô no Tan'i-zikan no Kawaridaka wa Tikara ni (vektortekini) hitosii.

144. Gekiryoku. Seisisite iru Buttai (A) wo hokano Buttai de utu toki, matawa ugoite iru Buttai (A) ga hokano Buttai ni syôtotusuru tokini, kono Buttai (A) no Sokudo ga kyûni kawaru; sunawati, Undôryô ga kawaru. Kono Undôryô no (vektortekino) Kawaridaka wa $\mathbf{K}t$ ni hitosii hazu de aru ga, sore ga hutûno Oisa wo motte iru noni, kono Sayô no tuduite iru Zikan t ga kiwamete mizikai kara, \mathbf{K} ga kiwamete ôkii. Konoyôni, *kiwamete misikai aida hataraku kiwamete ôkii Tikara wo "Gekiryoku" to iu.*

Utiau Buttai ga katai Baai niwa, kotonî, t ga tiisakute \mathbf{K} ga ôkii. Buttai ga ikura demo Dansei wo motte oreba, t ga ikuraka ôkikute, onazi Undôryô no Henkwa ni taisite \mathbf{K} ga tiisaku naru.

145. Sigoto. Oisa K no Tikara ga Buttai ni hataraita oru aidani, Buttai ga P (Du 136) kara P' ni susumu tokini, $\overrightarrow{PP'}$ wo Tikara no Hôkô ni bunkaisita Tyokkakuseibun sunawati "Tikara no Hôkô ni ugoita Kyori" PQ wo totte, "Tikara ga

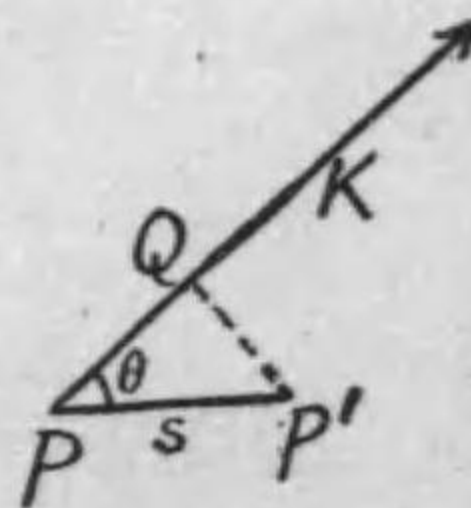
$$K \times PQ$$

dakeno Sigoto wo nasita" to iu (§75).

PP' wo s , Tikara to PP' no aidano Kaku wo θ , Sigoto wo W to sureba, tugino Kwankei ga aru:—

$$W = Ks \cos \theta.$$

PP' ga Tikara to hantaino Hôkô ni Seibun wo motu tokiniwa ($\theta > 90^\circ$ no Baai), Sigoto wa hu de aru.



Du 136.

Du 136 no Baai ni, *Buttai ga okonau Tikara wa, Hansayô no Hôsoku ni yotte, hantaina Hôkô ni okeru K de aru kara, Buttai ga nasita Sigoto wa*

$$-Ks \cos \theta$$

de aru.

Kotonî, Buttai no susumu Hôkô to tyôdo hantaino Hôkô ni Teikôryoku no aru Baai ($\theta = 180^\circ$) niwa "Buttai ga Teikôryoku ni taisite

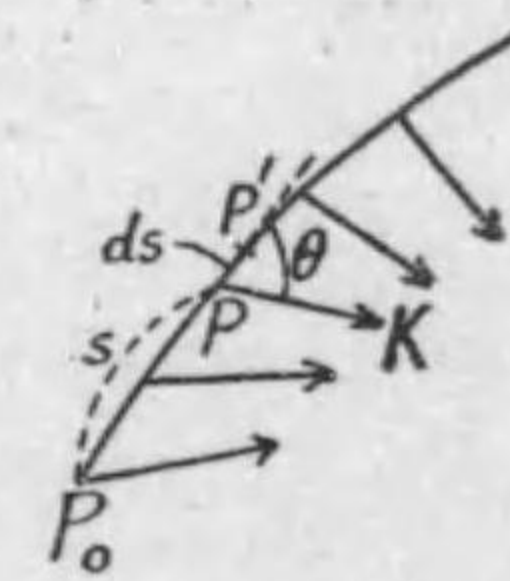
$$W' = \text{Teikôryoku} \times \text{susunda Kyori}$$

dakeno Sigoto wo sita" to iu.

Sitten ga ugoku aida Tikara ga Hôkô mo Oisa mo iroiro kawaru Baai ni, Sitten ga Hazime kara kattena Ten made susunda Mitinori wo s de arawasuto, ds dake susumu aidani Tikara K ga nasu Sigoto wa $K \cos \theta ds$ de aru; tadasi θ wa Susumi no Hôkô to Tikara to no aidano Kaku.

P_0 kara P ni kuru madeni Tikara ga nasita Sigoto wa

$$W = \int_0^s K \cos \theta ds;$$



Du 137.

tadasi s wa P_0 kara Mitisudi ni sôte hakatta

Mitinori, θ wa sozoreno Iti ni oite Susumi no Hôkô to Tikara to no aidano Kaku.

146. Sitten ni ikutu kano Tikara ga dôzini hataraku Baai no Sigoto no Keisan ni tuitewa, §76 de mita tôri, tugino Teiri ga okonawareru:—

Sitten ga dôzini ikutu kano Tikara ni hatarakarete ugoku tokini, sorerano Tikara ga nasu Sigoto no zentaino Bunryô wa, sorerano Tikara hitotu-hitotu ni tuite keisansite kuwaetemo, Gôryoku ni tuite keisansitemo onazi de aru.

147. I kiroguramu no Omosa dakeno Tikara ga hataraita, Buttai ga sono Hôkô ni I mêturu ugoku Baai ni nasareru Sigoto wo *Kiroguramêturu* (kgm.) to iu.

I pondo no Omosa dakeno Tikara ga hataraita, Buttai ga

sono Hôkô ni 1-foot ugoku Baai ni nasareru Sigoto wo *Footpound* to iu.

1 dyne no Tikara ga hataraite, Buttai ga sono Hôkô ni 1 cm. ugoku Baai ni nasareru Sigoto wo *Erg* to iu.

148. Undô-seiryoku to Sigoto. "Seiryoku" (matawa Enerugii) to iu Kotoba wa, Teikôryoku ni taisite Sigoto wo nasi uru Seisitu wo motte iru Buttai ni tuite, sore ga nasi uru Sigoto no Bunryô wo arawasu mono de aru (§ 82); sosite, "Undô-seiryoku" matawa "Undô-no-Seiryoku" wa "undôsite iru ga tameni motte iru Seiryoku" to iu Imi no mono de aru.

Undô-seiryoku no Ooisa, oyobi sore to Sigoto to no Kwankei wa tugino Teiri kara sirareru.

149. Teiri. *Situryô m no Sitten no Sokudo ga V₀ kara V ni kawaru aidani, sotonô Tikara ga sore ni nasita Sigoto no Bunryô ga W de areba, tugino Kwankei ga naritatu:—*

$$\frac{1}{2} mV^2 - \frac{1}{2} mV_0^2 = W \dots \dots \dots (1).$$

Syômei. (a) Madu, Tikara ga ima kangaete iru aida Hôkô mo Ooisa mo *kawaranai* to minasi, katu Sitten no *saisyono Sokudo ga Tikara to onazi Hôkô ni muite iru* Baai wo kangaeru.

Kono Baai niwa, Sitten wa itu mademo onazi Tyokusen no ue wo ugoku koto wa akiraka de aru. Kono Tyokusen wo *x*-Diku to si, Tikara wo *X* de arawasu. Kasokudo wa Sessen-seibun $\frac{dV}{dt}$ nomi de aru kara, Hayasa *V* to Tikara *X* to wa tugino Kwankei wo nasu:—

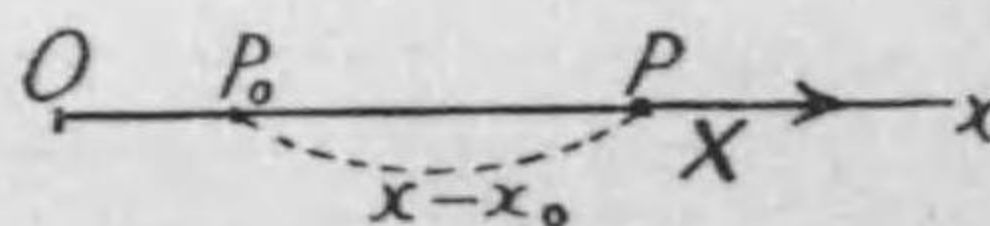
$$m \frac{dV}{dt} = X.$$

Sikaruni,

$$\frac{dV}{dt} = \frac{dV}{dx} \cdot \frac{dx}{dt} = V \cdot \frac{dV}{dx}$$

de aru kara, $mV \frac{dV}{dx} = X,$

sunawati, $d\left(\frac{1}{2} mV^2\right) = Xdx.$



Du 138.

X ga kawaranai kara, kore wo hazimeno Iti $P_0(x=x_0)$ kara $P(x=x)$ made sekibunsite,

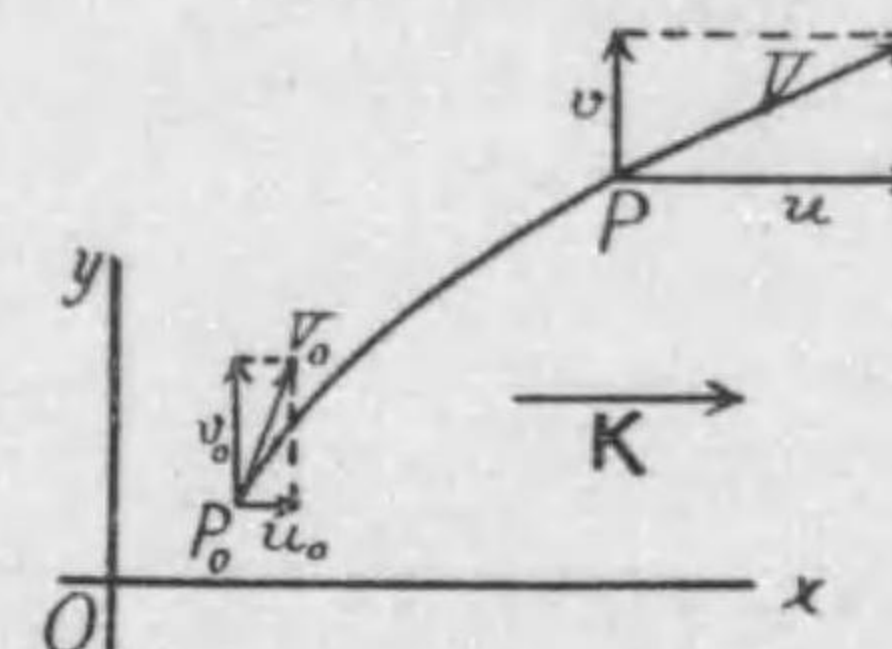
$$\frac{1}{2} mV^2 - \frac{1}{2} mV_0^2 = K(x-x_0)$$

wo eru; tadasi, V_0 wa P_0 ni okeru (sunawati $x=x_0$ ni taisuru) *V* no Atai de aru. Sikaruni, $X(x-x_0)=W$ de aru kara,

$$\frac{1}{2} mV^2 - \frac{1}{2} mV_0^2 = W.$$

(b) Tugini, Tikara wa yahari *kawaranai* to site, Buttai no *saisyono Sokudo V₀ ga Tikara to Hôkô ga tigatte ita* to suru.

Tikara *K* no Hôkô ni *x*-Diku wo tori (Du 139), Buttai no Sokudo wo Tikara ni heikôna *u* to, sore ni suityokuna *v* to ni wakete kangaeru ni, *v* wa Tikara no Eikyô wo ukenai kara, sore no hazimeno Atai v_0 ni hitosii:—



Du 139.

$$v = v_0.$$

Mata Tikara no Hôkô no Undô wa — Kyori mo Sokudo-seibun mo,— *v* no aru-nai ni kakawarazu, Tikara ni taisite kimatta Arisama ni okoru (§ 140) kara, (a) de mita *V* ni tuite to onazi Kwankei ga *u* ni tuite okonawareru; sunawati,

$$\frac{1}{2} mu^2 - \frac{1}{2} mu_0^2 = X(x-x_0).$$

Kono Siki ni

$$\frac{1}{2} mv^2 - \frac{1}{2} mv_0^2 = 0$$

wo kuwaete,

$$u^2 + v^2 = V^2, \quad u_0^2 + v_0^2 = V_0^2$$

no Kwankei wo ireruto, tugino Siki wo eru:—

$$\frac{1}{2} mV^2 - \frac{1}{2} mV_0^2 = X(x-x_0).$$

Koko de, $x-x_0$ wa Tikara no Hôkô ni okeru Hen'i de aru kara, $X(x-x_0)$ wa sotonô Tikara ga nasita Sigoto *W* de aru. Soreyueni,

$$\frac{1}{2} mV^2 - \frac{1}{2} mV_0^2 = W.$$

(c) Tikara no Hôkô mo Ooisâ no kimatte inai Baai niwa, sore no Kawari wo ronzinakutemo yoi hodono kiwamete mizikai Susumi ni taisite ueno Siki wo atchamete, sonoaida no tiisai Sigoto wo dW to kakeba,

$$d(\frac{1}{2}mV^2)=dW.$$

Kore wo sekibunuruto,

$$\frac{1}{2}mV^2 - \frac{1}{2}mV_0^2 = W.$$

Kore de ueno Teiri ga syômeisareta.

150. Ueno Teiri wa, saisyono Sokudo ga V , owarino Sokudo ga 0 de aru Baai niwa (maeno V wo 0 to oki, V_0 wo V to oite)

$$-W = \frac{1}{2}mV^2$$

wo ataeru. $-W$ wa Sitten ga konoaidani nasita Sigoto de, sore ga kono Siki de ataerareru. Soreyueni,

Sokudo V de ugoite iru, Situryô m no Sitten ga Sokudo wo usinawu madeni nasu Sigoto no Bunryô wa

$$\frac{1}{2}mV^2$$

de atte, kore ga sunawati sore no Undô-sciryoku de aru.

Yôsuruni, Undô-sciryoku wo T de arawaseba, tugino Kwankeisiki ga naritatu:—

$$T = \frac{1}{2}mV^2 \dots\dots\dots(2),$$

$$T - T_0 = W \dots\dots\dots(3);$$

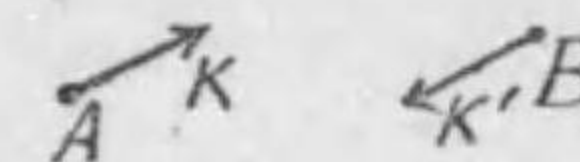
tadasi, W wa, T no Atai ga T_0 de atta toki kara ima madeni sotonô Tikara ga nasita Sigoto. Kono (3) no Hôteisiki (sunawati § 149 no (1)) wo “Seiryoku no Hôteisiki” to iu.

151. Undô no Daisanno Hôsoku (Hansayô no Hôsoku). Hutatuno Buttai A, B ga tagaimi Tikara wo oyobosu Baai ni tuite tugino Hôsoku ga okonawareru:—

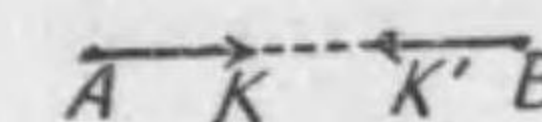
A ga B ni oyobosu Tikara to B ga A ni oyobosu Tikara to wa, Ooisâ ga hitosiku, Hôkô ga hantai de, Sayôsen ga kyôtû de aru.

Kore ga NEWTON no Undô no Daisanno Hôsoku matawa “Hansayô no Hôsoku” to yobareru mono de aru.

Sayôsen ga kyôtû de aru to iu Imi wa, tatoeba Du 140 de A ga B kara ukeru Tikara K to, B ga A kara ukeru Tikara K' to ga, I no yôni, kuitigatta Heikôsen ni sôte hataraku koto ga nakute, kanarazu II no yôni onazi Tyokusen ni sôte sayôsuru to iu Imi de aru.



II



Du 140.

Ueno Hôsoku wa, hutatuno Buttai ga syôtotusuru tokini ukeru Gekiryoku nimo okonawareru; sitagatte, sorerano Gekiryoku no Ryokuseki nimo dôyôna Kwankei ga aru.

Reidai. 100 g. no Sitten A to 10 g. no Sitten B to ga kiwamete karui hikinobasita gomuno Ito de tunaide atte, hazime



Du 141.

ryôhō tomo Seisi no Arisama ni osaete aru. Ryôhō wo dôzini hanasu tokini, A to B to no ugoku Kyori s, s' no Hi wa dô ka?

Hikiai no Tikara wo K to sureba, Undô no Hôteisiki wa

$$100 \frac{d^2s}{dt^2} = K, \quad 10 \frac{d^2s'}{dt^2} = K, \quad \left(s \text{ to } s' \text{ to wa hantaino} \right)$$

(Hôkô ni muite iru.)

yueni, $100 \frac{d^2s}{dt^2} - 10 \frac{d^2s'}{dt^2} = 0;$

sunawati, $\frac{d}{dt} \left(10 \frac{ds}{dt} - \frac{ds'}{dt} \right) = 0;$

sitagatte, $10 \frac{ds}{dt} - \frac{ds'}{dt} = \text{const.} = C.$

Sikaruni, saisyo A, B tomoni Sokudo ga 0 de atta kara, sore wo ireruto, $0 = C.$

Yueni, $10 \frac{ds}{dt} - \frac{ds'}{dt} = 0;$

sunawati, $\frac{d}{dt} (10s - s') = 0;$

sitagatte, $10s - s' = \text{const.} = C'.$

Sikaruni, saisyo $s=0, s'=0$ de atta kara, $0 = C';$

yueni, $10s - s' = 0,$

sunawati, $s' = 10s.$

Rensyû-mondai IV.

1. Taihō no Tutu no Nagasa (Tama no ugoku Kyori) ga 4 m., Tama no Sasiwatasi ga 20 cm., sore no Situryō ga 80 kg. de, sore ga Tutu wo hanareru tokino Hayasa ga 700 m./s. de areba, Tutu no nakano heikinno Aturyoku wa ikura ka?

2. Tukue no ueni aru Kami no ueni Ginkwa ga oite aru. Kami ga zyūbunni ōkii to site, sore wo doko mademo kimatta Hayasa V de hiku tokini, Ginkwa ga donna Undō wo suru ka? Tadasi, Ginkwa to Kami to no aidano Masatu-keisū wo μ to suru.

3. Kōri no ue wo 5 m./s. no Hayasa de suberidasita Isi ga 100 m. susunde tomaru naraba, Masatu-keisū wa ikura ka?

4. Dimen kara 3 m. no Takasa kara tobioriru, Mekata 50 kg. no Hito ga, Asi ga Dimen ni tuita Toki kara Hiza wo orimagete hunbaru koto ni yotte Gekidō wo sakeyō to suru. Hiza wo orimageru koto ni yotte Karada no oriru Bunryō wo 60 cm. to sureba, hunbaru Tikara ga ikura no Omosa ni hitosii ka? Tadasi, Karada zentai no Mekata no $1/5$ dake wa Asi ga Dimen ni tuku to dōzini tomatte simatta mono to suru.

5. 100 maibyō-m. de susumu Teppōdama (Mekata 100 g.) ga Tetuita ni buttukatte, 5 maibyō-m. de hanekaeru to sureba, kono-aidano Undōryō no Kawari wa ikura ka? Koredakeno Henkwa ga $1/500$ byō no aidani okotta to sureba, Teppōdama to Tetuita to no aidani okotta Tikara no heikinno Ooisa wa ikura ka?

6. 10 m./s. no Hayasa de ugoite iru 1 kg. no Buttai ga, Undō no Hōkō ni taisite 45° wo nasu Hōkō ni hikareru tameni, sore no Undō no Hōkō ga 1 byō no aidani 5° no Wariai de kawatta. Hayasa no masu Wariai (Skalar-kasokudo) to Tikara no Ooisa to wo keisansei!

7. Karui nobinai Ito (Nagasa l) de koteisita Ten ni tunaide aru Sitten ga, Ito to Entyokusen to no aidano Kaku ga sizyū α de aru yōni mawatte iru. Iti-byō no aidani Sitten ga mawaru Tabikazu N ga $\frac{1}{2\pi} \sqrt{\frac{g}{l \cos \alpha}}$ de aru koto wo syōmeisei!

8. Situryō 100 g. to 300 g. to no hutatuno Buttai ga Nagasa 1 m. no karui Ito de tunaide atte, zentai ga mattaku namerakana Kōri no ue de, Ito no hitotuno Ten wo Tyūsin to site, mawatte iru. Mawaru Hayasa ga iti-byō ni hutamawari da to sureba, Ito no Tyōryoku wa ikura ka? Mata, Kwaiten no Tyūsin wa Ito wo donna Wariai ni wakatu Ten de aru ka?

9. Arai suiheina Ita (Masatu-keisū = μ) ni notte iru 1 kg. no Buttai ga suiheina Hōkō ni karui Ito ni hikarete iru. Kono Ito wa namerakana suiheina Bō ni kakatte, sore no Hazi niwa 500 g. no Omori ga sagatte iru. Kono Kumiai ga hazime tomatte iru to site, sore no Undō no Sikata oyobi Ito no Tyōryoku wo sirabei!

10. Mondai 1 no Taihō no Hōsin oyobi Huzokubutu no Situryō ga 50-ton aru to si, sore ga usiro e ugoki uru yōni sōtisite aru to sureba, sore ga usiro e donna Sokudo wo cru ka? Mata sore wo 4 m. no aida de tomeyō to sureba, heikin ikurano Tikara wo sore ni kuwaeru koto wo yōsuru ka?

11. Situryō 1 kg. no namarino Tama ga 100 maibyō-mētoru no Hayasa de tonde kite, hantaino Hōkō ni 10 maibyō-mētoru de ugoite iru 5 kg. no namarino Tama ni tukiattatte, hutatu ga hitokatamarini nareba, sono Katamari wa ikurano Sokudo wo motte susumu ka? Mata, konotoki Undō-seiryoku no Henkwa wa dō ka?

12. Ueno Mondai de hutatuno Tama no hazimeno Undō no Hōkō ga tagaini suityoku de atta naraba, notino Undō oyobi Undō-seiryoku no Henkwa wa dō ka?

13. Nagasa 80 cm. Situryō 500 g. no itiyōna Kusari ga Yuka ni katamatte iru no wo hitotuno Hazi wo motte, $1/2$ byō no aidani zentai wo hikiageru yōna Hayasa de hikiageru tokini, hikiageru Tikara ga dō naru ka? $1/10$ byō de hikiagereba dō naru ka?

14. Hakari no Sara ni Oke wo nosete, sore no Maue kara Suidō no Midu wo ireta tokoroga, 20 byō tatta tokini Hakari ga (Oke no Mekata wo nozoite) 15 kg. wo simesita. Sokode Midu wo tometara, Hakari ga 14 kg. wo simesita. Midu no Hayasa wa ikura ka?

Dyûryoku de okoru Undô.

155. Rakutai no Kasokudo. Kûki no nai Tokoro (Sinkû) de, iroirona Buttai wo otosite miruto, Isi demo Hane demo subete mattaku onazi Undô wo suru koto ga zikkenzyô tasikamerareta Zizitu de aru. Sunawati, subeteno Buttai ga onazi Kasokudo wo motte otiru no de, kono Kasokudo sunawati "Rakutai no Kasokudo" wo hutû g de arawasu.

156. Rakutai no Kasokudo g no Oisa wa, tyokusetuni seimituni hakaru koto wa konnan de aru keredomo, kansetuno Hôhō (§ 187,212) ni yoreba zyûbun seimituni sokuteisareru. Sore no Oisa wa Sekidô-tihô ni okeru $978 \frac{\text{cm.}}{\text{s.}^2}$ gurai kara Kyoku-tihô ni okeru $983 \frac{\text{cm.}}{\text{s.}^2}$ made no aidani atte, taiteino Baai ni $980 \frac{\text{cm.}}{\text{s.}^2}$ to totte, ôkina Matigai ga nai.

Basyo no takai Tokoro dewa, g ga heru wake de aru keredomo, Takasa 3000 m. demo senbunno iti gurai no Tigai sika nai kara, kore mo taiteino Baai ni Mondai ni sinakute yoi.

157. Dyûryoku. Tikyûzyô ni aru Buttai ga subete *Omosa* wo motte oru no wa, sore ga sitano hô ni mukau Tikara wo ukete oru tame de aru. Sore ga, sasaeru Mono ga nai Baai ni, otiru no mo onazi Tikara no Sayô ni yoru no de aru. Konoyôni, Tikyûzyô ni aru Buttai ga ukete iru sitani mukau Tikara wo *Dyûryoku* to tonaeru.

Ima Situryô m no Buttai ga Dyûryoku G wo ukete otiru Baai ni tuite, Undô no Hôteisiki wo tukutte miruto, otita Kyori wo s to kaite,

$$m \frac{d^2s}{dt^2} = G;$$

sitagatte,

$$\frac{G}{m} = \frac{d^2s}{dt^2}.$$

Kasokudo $\frac{d^2s}{dt^2}$ ga donna Buttai demo onazi Atai g wo motte iru kara, G/m wa Buttai no Seisitu nimo ôkii-tisai nimo yoranai kimatta Ryô de aru. Sunawati,



Du 151.

Buttai ni hataraku Dyûryoku wa sore no Situryô ni hircisuru.

Kôiu Kwankei kara, Rakutai no Kasokudo $g = \frac{G}{m}$ wo mata "Dyûryoku no Tuyosa" tomo iu.

158. Ueno Siki

$$m \frac{d^2s}{dt^2} = G$$

wa G wo Zettai-tan'i de arawasu Baai ni okonawareru koto wa maeni (§ 140) nobeta. Soreyueni,

$$G = m \frac{d^2s}{dt^2} = mg$$

wa Situryô m no Buttai ga ukeru Dyûryoku wo Zettai-tan'i de arawasita Kazu wo ataeru.

159. Ueno Siki kara sireru tôri, ippanni Tikara no *Dyûryoku-tan'i* tosite tukawareru *Tan'i-situryô no Omosa* wa Zettai-tan'i de g dake aru. Tatoeba, 1 g. no Buttai ni hataraku Dyûryoku sunawati 1 g. no Omosa wa 980 dyne hodo de aru.

160. Rakutai no Undô. Dyûryoku no Hataraki de, Entyokusen ni sôte nasareru Undô wo Rakka-undô to tonaeru. *Entyokuni ue e y-Diku* wo tori, Sokudo v mo ueni mukau no wo *sei* to sureba, $Y = -G = -mg$ de aru kara,

$$m \frac{d^2y}{dt^2} = -mg;$$

sunawati, $\frac{d^2y}{dt^2} = -g$, matawa $\frac{dv}{dt} = -g \dots \dots (1)$.

§ 155 de mita tôri, Rakka-undô ga Situryô ni mukwankei de aru koto ga mieru.

Tyûi. Ueno Siki wa Buttai no Sokudo ga ueni multe itemo sitani multe itemo onaziku okonawareru kara, sore kara hikidasu Kwankeisiki mo, nageageta Undô, nageotosita Undô, nageageta Buttai ga otite kuru madeno Undô nado subete ni okonawareru. Tada, Sokudo $v = \frac{dy}{dt}$ (ueni mukau no ga sei) oyobi y no Kigô ni tyûisuru koto ga hituyô de aru.

161. (a) *Sokudo oyobi Iti to t to no Kwankei.* Hazime ($t=0$) no Iti no y wo y_0 , Sokudo wo v_0 to suru.

(1) no Hôteisiki ni dt wo kakete, $t=0$ kara $t=t$ made sekibunuruto,

$$\int_0^t \frac{dv}{dt} dt = - \int_0^t g dt,$$

sunawati, $v - v_0 = -gt$;

sunawati, $v = v_0 - gt \dots \dots \dots (2)$.

v wo $\frac{dy}{dt}$ to kaite, dt wo kakete mô itido sekibunuruto,

$$y - y_0 = v_0 t - \frac{1}{2} g t^2;$$

sunawati, $y = y_0 + v_0 t - \frac{1}{2} g t^2 \dots \dots \dots (3)$.

(b) *Sokudo no Iti ni taisuru Kwankei.* (2) kara t wo dasite (3) ni ireruto,

$$y = y_0 + v_0 \frac{v_0 - v}{g} - \frac{1}{2} \frac{(v_0 - v)^2}{g}$$

$$= y_0 + \frac{1}{2} \frac{v_0^2 - v^2}{g},$$

sunawati, $v^2 = v_0^2 - 2g(y - y_0) \dots \dots \dots (4)$.

Korerano Kwankeisiki (2), (3), (4) ga Rakka-undô ni okeru dodaino Kwankeisiki de aru. Mosimo y wo Ugokihazime no Ten kara (ue e) hakaru to sureba, $y_0=0$ to okeba yoi.

162. (a) *Hanati-otosita* (sunawati Sokudo wo ataenaide otosita) *Buttai* ga t no aidani otiru Kyori wa ($y_0=0$ to site),

$$y = -\frac{1}{2} g t^2;$$

soko de motte iru Sokudo wa

$$v = -gt;$$

h dake orita Tokoro de motte iru Sokudo wa, $y - y_0 = -h$ to oite,

$$v = \sqrt{2gh}.$$

(b) *Nageageta Buttai no noborikuru Iti to Toki.* $v_0 > 0$ to site, Siki (2) wo miruto, t ga tiisai aidawa $v > 0$ de aru ga, t ga ôkiku nareba, $v < 0$ to naru, sunawati orite kuru. Sonoaidani $v=0$ no Iti ga aru; kore wa Nobori kara Kudari ni uturu Iti sunawati noborikitta Iti de aru. Konotoki no t wo t_1 to kakeba,

$$v = v_0 - g t_1 = 0$$

kara

$$t_1 = \frac{v_0}{g}.$$

Sosite, konotokini Buttai no aru Ten sunawati itiban takai Ten (Tyôten) no Takasa y_1 wa, (4) no Siki de $v=0$ to oite (matawa (3) no t ni t_1 no Atai wo irete) erareru:—

$$y_1 = y_0 + \frac{v_0^2}{2g}.$$

(c) *Nageageta Buttai ga orite kite Ugokihazime no Ten wo tôru Toki to sonotoki no Hayasa.* (3) no Siki de $y=y_0$ to oite,

$$v_0 t - \frac{1}{2} g t^2 = 0,$$

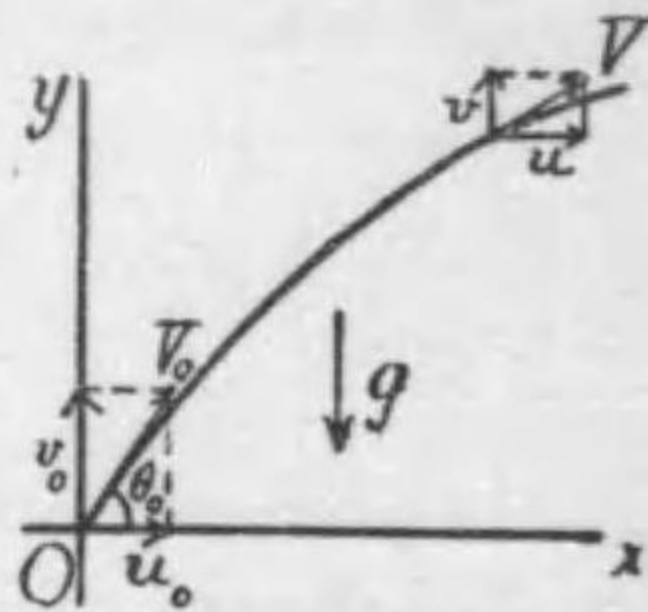
sunawati, $t=0$ matawa $t = \frac{2v_0}{g}$. Hazimeno Kon $t=0$ wa, $y=y_0$ de

dedasu Toki wo simesi, notino Kon $t=t_2 = \frac{2v_0}{g}$ ga motomeru Toki wo ataeru. Kore wa ueno t_1 no nibai de aru kara, Tyôten

ni tassite kara motono Iti ni kudarû Zikan ga noboru no ni yôsite Zikan ni hitosii.

Mata konotokino Hayasa wa, (4) ni $y=y_0$ to oite $v=\pm v_0$. Otiru Baai da kara huno Kigô wo torubeki wa akiraka de aru ga, (2) Siki no t ni t_2 no Atai wo irereba, \pm nado nasini, $v=-v_0$ wo eru.

163. Hôbutu-undô. Sitten ga entyoku de nai Hôkô ni nagerareta Baai no Undô wo Hôbutu-undô to iu; sosite, sonoyôni nagerareta Buttai wo Hôtai (matawa Hôbutu) to iu.



Du 152.

Hazime Sitten wo OV_0 (Du 152) no Hôkô ni nageta to sureba, Sokudo wa itu mademo OV_0 wo hukumu Entyokumen ni ari, Sitten zisin mo itu mademo onazi Entyokumen ni aru koto wa akiraka de aru.

Kono Heimen de, Syuppatuten O kara suiheina Hôkô ni x -Diku, entyokuna Hôkô ni y -Diku wo totte, Undô no Hôteisiki (§ 140 no (2) matawa (3)) wo kakuto, tugino yôni naru:—

$$m \frac{d^2x}{dt^2} = 0, \quad m \frac{d^2y}{dt^2} = -mg,$$

sunawati, $\frac{d^2x}{dt^2} = 0, \quad \frac{d^2y}{dt^2} = -g \dots \dots \dots (1).$

Kore de kono Undô wa Situryô ni mukwankei de aru koto ga wakarû.

Hazimeno Sokudo V_0 to Kaku $(V_0, x)=\theta_0$ to ga ataete aru to suru. Mata kattena Zikoku ni okeru Sokudo no x -Seibun wo u , y -Seibun wo v to si, Ugokihazime ni okeru sorera no Atai wo u_0, v_0 to sureba,

$$u_0 = V_0 \cos \theta_0, \quad v_0 = V_0 \sin \theta_0.$$

164. (a) t ni okeru Sokudo oyobi Iti. (1) wo sekibunsite,

$$\left. \begin{aligned} \frac{dx}{dt} &= u = \text{const.} = u_0, \\ \frac{dy}{dt} &= v = v_0 - gt \end{aligned} \right\} \dots \dots \dots (2).$$

Mô itido sekibunsite, — $t=0$ ni taisite $x=0, y=0$ ni totte aru kara, —

$$\left. \begin{aligned} x &= u_0 t, \\ y &= v_0 t - \frac{1}{2} g t^2 \end{aligned} \right\} \dots \dots \dots (3).$$

(2) to (3) to ga kattena Zikoku t ni okeru u, v, x, y wo ataeru.

(b) Sitten no susumu Mitisudi. (3) no hutatuno Hôteisiki kara t wo oidaseba,

$$y = \frac{v_0}{u_0} x - \frac{g}{2u_0^2} x^2,$$

sunawati,

$$y = \tan \theta_0 x - \frac{g}{2V_0^2 \cos^2 \theta_0} x^2 \dots \dots \dots (4).$$

Kore ga Sitten no susumu Mitisudi no Hôteisiki de, sore wa Kikagaku de Hôbutusen to tonaeru Kyokusen de aru.

Kono Siki wo, hutû Kikagaku de miru yôna Katati, sunawati Tyôten wo Zahyô-genten ni, Diku wo hitotuno Zahyô-diku ni sita Katati ni kakinaosu niwa, sore wo

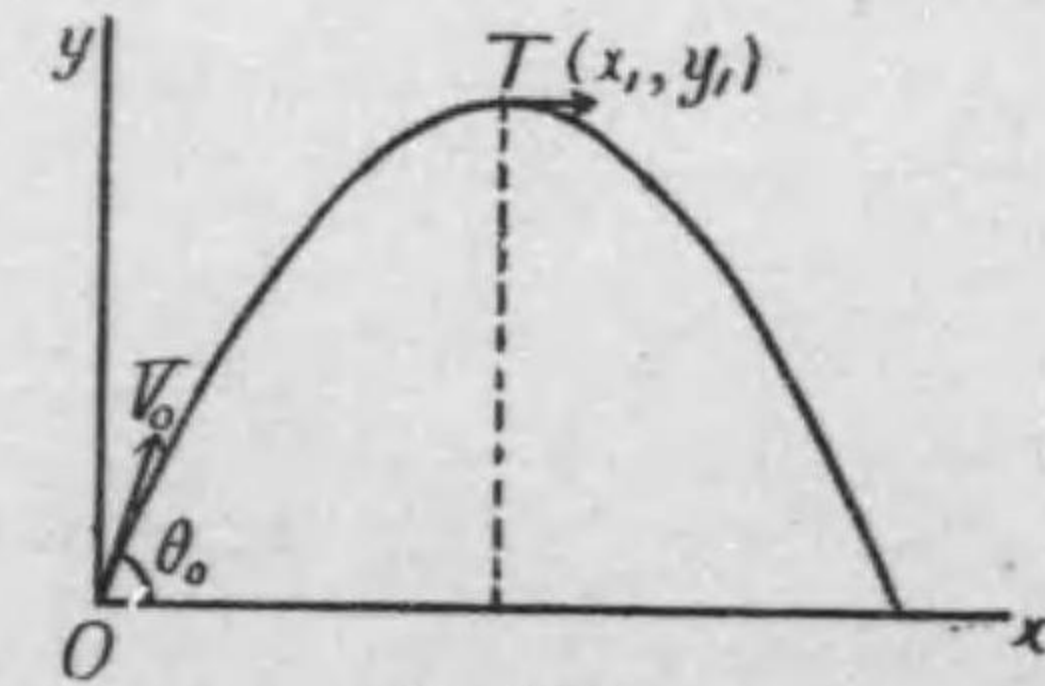
$$\left(x - \frac{V_0^2 \sin 2\theta_0}{2g} \right)^2 = - \frac{2V_0^2 \cos^2 \theta_0}{g} \left(y - \frac{V_0^2 \sin^2 \theta_0}{2g} \right)$$

kô kakinaosite, Genten wo

$$x_1 = \frac{V_0^2 \sin 2\theta_0}{2g}, \quad y_1 = \frac{V_0^2 \sin^2 \theta_0}{2g}$$

e utuseba yoi. Sô sureba, atarasii Zahyô wo x', y' to kaite,

$$x'^2 = - \frac{2V_0^2 \cos^2 \theta_0}{g} y' \dots \dots (4a)$$



Du 153.

to naru. Sitagatte, kono Kyokusen wa (Du 153)

$$x_1 = \frac{V_0^2 \sin 2\theta_0}{2g}, \quad y_1 = \frac{V_0^2 \sin^2 \theta_0}{2g}$$

ni Tyôten (T) wo motte, sitano Hôkô ($-y$ no Hôkô) ni Diku wo motte iru Hôbutusen de aru.

Kono Hôbutusen no Tyôten no Iti wo kokoni dasita yôni kikagakuteki de naku, motto undôgakutekini dasu niwa :— soko dewa $v=0$ de aru kara, (2) kara $t_1 = \frac{v_0}{g}$ wo e, sore wo (3) no t ni irereba yoi.

(c) *Iroirona Hôkô ni okeru Tôtatû-kyori.* Ugokihazime no Ten O (Du 154) kara ataereta Hôkô (x -Diku to Kaku i wo tukuru Hôkô) ni hiita Tyokusen wo Hôtai ga kiru Ten Q wa O kara ikura no Kyori ni aru ka?

Motomereta Kyori wo R to si, Mitisudi no Hôteisiki (4) ni $x=R \cos i$, $y=R \sin i$ to irete R wo dasitemo yoi (mattaku kikagakutekino Hôhō).

Mata dokurituni tugino yôni keisansitemo yoi. OQ (Du 155) no Hôkô wo x' -Diku ni, sore to suityokuna Hôkô wo y' -Diku to site, Tikara, Kasokudo, Sokudo wo mina korerano Hôkô ni bun-kaisuru. Sô suruto, x' no Hôkô ni :

Tikara = $-mg \sin i$,
 hazimeno Sokudo
 = $V_0 \cos(\theta_0 - i)$,

„ Iti, $x'_0 = 0$;

y' no Hôkô ni :

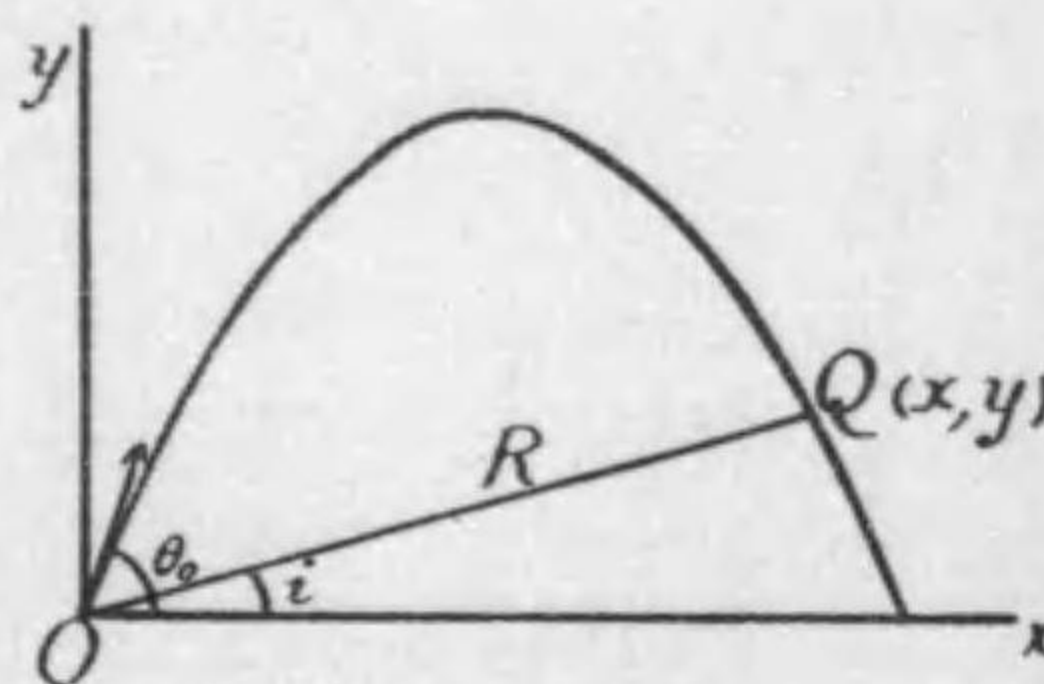
Tikara = $-mg \cos i$,
 hazimeno Sokudo
 = $V_0 \sin(\theta_0 - i)$,

„ Iti, $y'_0 = 0$.

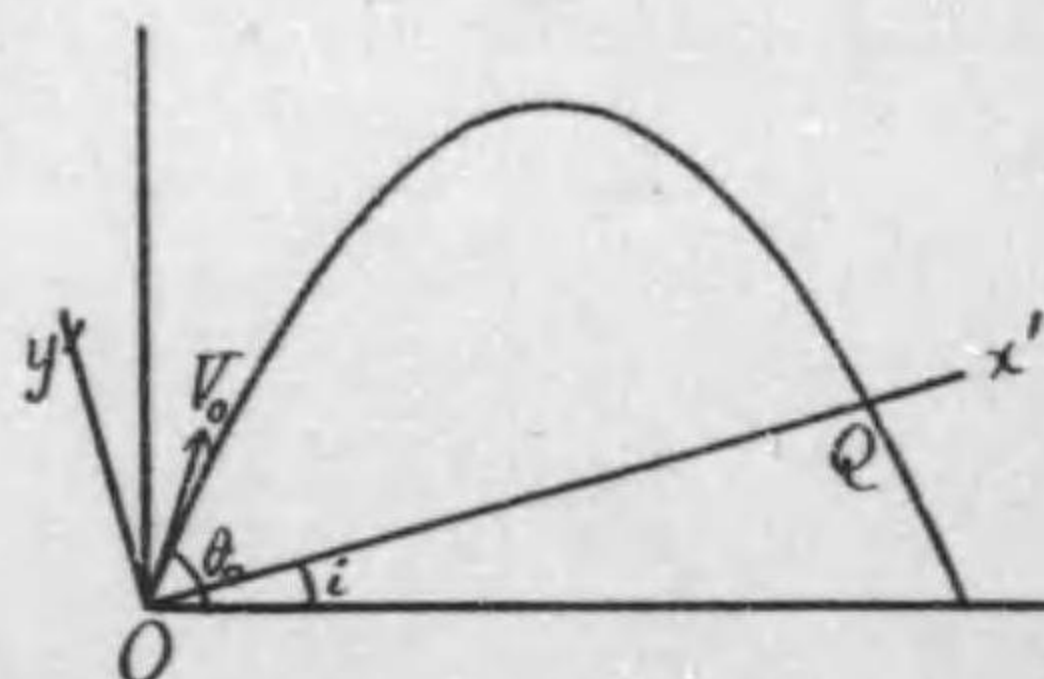
de aru. Mata, Undô no Hôteisiki wa

$$m \frac{d^2 x'}{dt^2} = -mg \sin i, \quad m \frac{d^2 y'}{dt^2} = -mg \cos i.$$

Korera no Kai wa



Du 154.



Du 155.

$$x' = V_0 \cos(\theta_0 - i) \cdot t - \frac{1}{2} g \sin i \cdot t^2, \quad y' = V_0 \sin(\theta_0 - i) \cdot t - \frac{1}{2} g \cos i \cdot t^2.$$

Q dewa $y'=0$. Sore kara ($t=0$ wo sutete),

$$t = \frac{2V_0 \sin(\theta_0 - i)}{g \cos i}.$$

Kore wo x' no Siki ni irete,

$$\begin{aligned} R = x' &= \frac{2V_0^2 \sin(\theta_0 - i)}{g \cos i} (\cos(\theta_0 - i) - \tan i \sin(\theta_0 - i)) \\ &= \frac{2V_0^2 \sin(\theta_0 - i) \cos \theta_0}{g \cos^2 i} \\ &= \frac{V_0^2}{g \cos^2 i} \{ \sin(2\theta_0 - i) - \sin i \} \dots \dots \dots (5). \end{aligned}$$

Mondai. Ataereta V_0 to θ_0 de tasserareru suiheino Tôtatû-kyori wo dase! [(5) karamo sugu kakeru ga, dokurituni toku hô ga yoi.]

(d) *Ataereta Hôkô ni okeru saidaino Tôtatû-kyori.* V_0 to i to ga ataereta Baai ni, Tôtatû-kyori R wo itiban ôkiku suru no niwa,

$$\sin(2\theta_0 - i) = 1, \quad \text{sunawati} \quad 2\theta_0 - i = \frac{\pi}{2},$$

sunawati, $\theta_0 = \frac{1}{2} \left(\frac{\pi}{2} + i \right)$

to toreba yoi. Sunawati, i no Hôkô to y -Diku to no aida wo tôbunsuru Hôkô ni nagereba yoi. Sosite, saidaino Tôtatû-kyori wa

$$R_m = \frac{V_0^2}{g \cos^2 i} (1 - \sin i) = \frac{V_0^2}{g(1 + \sin i)} \dots \dots \dots (6).$$

Kotoni, suiheina Hôkô no saidaino Tôtatû-kyori wa, $i=0$ to site,

$$R_m = \frac{V_0^2}{g}.$$

Kore wa, onazi Sokudo V_0 de entyokuni ueni nageta tokini noboru Kyori no tyôdo nibai de aru.

Mondai. Hitotuno Ten kara, ataereta V_0 de (hitotuno

Entyokumen ni aru) subeteno Hôkô ni nagedasita Buttai no tassi uru Basyo no Kuiki ga, sono Ten wo Syôten to suru Hôbutusen no naka de aru koto wo syômeisci! [(6) no Siki kara ieru.]

(e) *Atarareta V₀ de nagedasitê, Buttai ga atarareta Ten ni ataru tamenô Nagedasikata.* Kore wa (5) no Siki de R to i to V₀ ga ataete atte, θ₀ wo motomereba yoi; sunawati,

$$\sin(2\theta_0 - i) = \frac{gR \cos^2 i}{V_0^2} + \sin i.$$

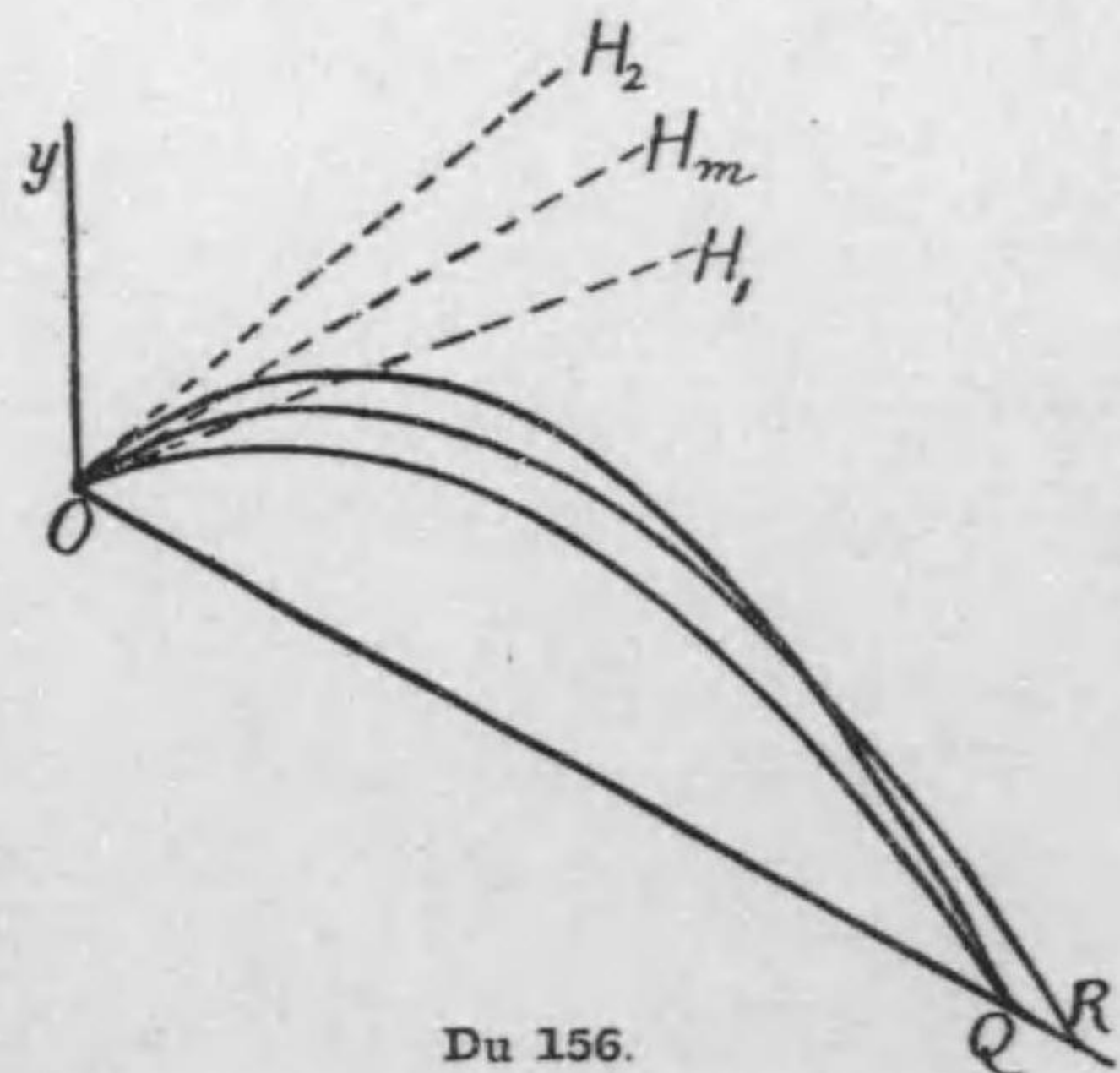
Kono Siki no Migigawa wo =1 ni suru yôna R wa ueno R_m de aru kara, atarareta R ga R_m yorimo tiisai naraba, Migigawa ga kanarazu 1 yorimo tiisakute, sikamo sin i yorimo ôkii. Soreyueni, Migigawa wo sin ni suru Kaku ga i to $\frac{\pi}{2}$ to no aidani

hitotu aru. Sore wo α ($\frac{\pi}{2} > \alpha > i$) to sureba,

$$2\theta_0 - i = \alpha \text{ matawa } \pi - \alpha;$$

sitagatte, $\theta_0 = \frac{\alpha + i}{2}$ matawa $\frac{\pi}{2} - \frac{\alpha - i}{2}$.

Dotira mo, donna i ($\frac{\pi}{2} > i > -\frac{\pi}{2}$) ni taisitemo, $\frac{\pi}{2}$ to $-\frac{\pi}{2}$ to no aidani aru Kaku de, zissai tukau koto no dekiru Kaku de aru.



Du 156.

- OR: i no Hôkô;
- OH_m: saidaino Tôtatukyori wo ataeru Hôkô;
- OH₁: θ₁ no Hôkô;
- OH₂: θ₂ no Hôkô;
- ∠yOH_m = ∠H_mOR,
- ∠yOH₂ = ∠H₁OR.

Korerano hutatuno Atai wo θ₁, θ₂ to sureba, tugino Kwankei ga aru:—

$$\frac{\pi}{2} - \theta_2 = \theta_1 - i.$$

Soreyue, korerano Kaku no Kwankei wa oyoso Du 156 no yôni naru (i < 0 no Baai wo kaita).

165. Reidai. *Syamen no ueno Undô.* Suiheimen ni taisite Kaku i wo nasu Syamen no ue de, “saidaino Katamuki no Sen” (sunawati Syamen to Suiheimen to no Kiriaisen ni suitiyokuna Tyokusen) ni sôte ugoku Sitten no Undô wo siraberu.

(a) Syamen ga namerakana Baai. Syamen no Suiheimen ni taisuru Katamuki wo i to si, x-Diku (Du 157) wo saidaino Katamuki no Sen ni sôte ueni toreba,

$$X = -mg \sin i.$$

[Syamen wa nameraka de, x ni heikôna Tikara wo Sitten ni oyobosanai.] Soreyueni, Undô wa tugino Hôteisiki de kimaru:—

$$\frac{d^2x}{dt^2} = -g \sin i \dots\dots\dots(1).$$

Yueni, Sokudo = $\frac{dx}{dt} = V_0 - g \sin i \cdot t \dots\dots\dots(2);$

Iti wo simesu x wa,

$$x = x_0 + V_0 t - \frac{1}{2} g \sin i \cdot t^2 \dots\dots\dots(3).$$

Kono Siki wa Nobori to Kudari to ni tûzite atehamaru; tadasi, V₀ wa uemuki wo sei (+) to kimeru.

Kono Baai ni Syamen ga Sitten ni oyobosu Tikara wo N to sureba, N wa Syamen ni suitiyokuna y-Hôkô ni atte, y ga tuneni

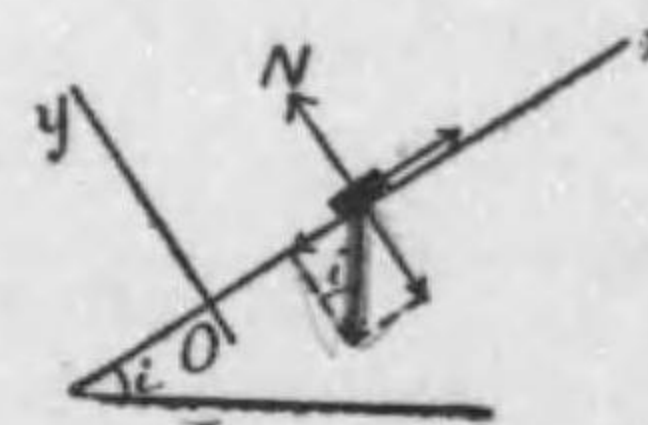
= 0 de aru kara, $\frac{d^2y}{dt^2} = 0 = N - mg \cos i$; yueni,

$$N = mg \cos i \dots\dots(4).$$

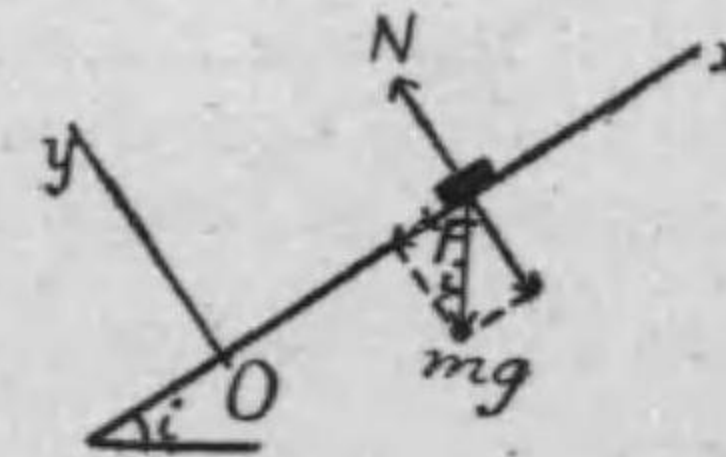
(b) Syamen ga arai Baai. Undômasatu no Keisû wo μ, Masaturyoku wo F, Suitiyoku-hankôryoku wo N to sureba,

$$F = \mu N.$$

Tadasi kore no Hôkô wa, Sitten ga (Men ni sôte) noboru tokiniwa sita e, Sitten



Du 157.



Du 158.

ga kudaruru tokiniwa ue e multe iru.

y -Hôkô (Du 158) no Kwankei wa (a) no Baai to onazi de aru kara, $N=mg \cos i$; yueni $F=\mu mg \cos i$. Soreyueni, x -Hôkô no Undô no Hôteisiki wa

noboru toki ($\frac{dx}{dt} > 0$):

$$m \frac{d^2x}{dt^2} = -mg \sin i - \mu mg \cos i \dots \dots (5);$$

kudaruru toki ($\frac{dx}{dt} < 0$):

$$m \frac{d^2x}{dt^2} = -mg \sin i + \mu mg \cos i \dots \dots (6).$$

Sitagatte,

noboru aida, $\left\{ \begin{array}{l} V = + \frac{dx}{dt} = V_0 - g(\sin i + \mu \cos i)t, \\ x = x_0 + V_0 t - \frac{1}{2}g(\sin i + \mu \cos i)t^2 \end{array} \right\} \dots (7);$
 [V to V_0 wa noboru Hayasa]

kudaruru aida, $\left\{ \begin{array}{l} V = - \frac{dx}{dt} = V_0 + g(\sin i - \mu \cos i)t, \\ x = x_0 - V_0 t - \frac{1}{2}g(\sin i - \mu \cos i)t^2 \end{array} \right\} \dots (8).$
 [V to V_0 wa kudaru Hayasa]

Noboru Baai niwa, $t = \frac{V_0}{g(\sin i + \mu \cos i)}$ no Zikoku ni $V=0$ ni naru. (i) Mosi, Seisimasatu no Keisû wo μ' to suru tokini,

$$\mu' N = \mu' mg \cos i \geq mg \sin i, \text{ sunawati, } \mu' \geq \tan i \dots (9)$$

de areba, Sitten wa sonomama tomatte otite konai. (ii) Mosi $\mu' < \tan i$ de areba, naosara $\mu < \tan i$; sitagatte, Sitten wa (8) no Siki ni sitagatte kudaru Undô wo suru.

Kudaruru Baai niwa, (i) $\sin i - \mu \cos i \geq 0$, sunawati $\mu \leq \tan i$ de areba V ga heranai kara (8) no Siki ga itu mademo okonawareru. (ii) $\mu > \tan i$ no Baai niwa, $t = \frac{V_0}{g(\mu \cos i - \sin i)}$ no Zikoku ni $V=0$ ni natte, Seisi-masatu no Keisû μ' wa naosara $\mu' > \tan i$ de aru kara, Sitten wa sonomama tomatte iru.

166. Seiryoku no Kwankeisiki. § 150 no Seiryoku no Teiri wo, Dyûryoku wo ukete ugoku Buttai ni ôyôsuru.

y -Diku (Du 159) wo entyokuni ueni toreba, Buttai ga P_0 kara P ni kuru madeni Dyûryoku no Hôkô ni okeru Hen'i wa Du no P_0Q sunawati $y_0 - y$ de aru kara, Dyûryoku ga nasita Sigoto wa

$$W = mg(y_0 - y)$$

de aru. Kono Siki wa $y_0 - y$ ga hu de aru Baai demo, mata Buttai ga Rakutai ya Hôtai no Undô to tigau kattena Undô wo suru Baai demo tadasii.

Soreyueni, *Dyûryoku no hokani Sigoto wo suru Tikara ga nai Baai niwa*, Seiryoku no Teiri ni yotte

$$\frac{1}{2}mV^2 - \frac{1}{2}mV_0^2 = mg(y_0 - y) \dots \dots (1).$$

[Sitten ni kattena Katati no Miti wo susumasete, sikamo Dyûryoku no hokani Sigoto wo suru Tikara ga nai yôni suru Hôhô wa nozomino Katati ni *namerakana Kuda* wo ugokanai yôni toritukete, Buttai wo sore no naka wo ugokasereba yoi. Kuda no Hankôryoku wa Sitten no susumu Hôkô to suityoku de aru tameni, sore no nasu Sigoto wa itumo o de aru.]

Kono Siki de miruto, Dyûryoku nomi ni Sigoto wo serarete ugoku Buttai no Undô-seiryoku no Masidaka wa hazimeno Iti to owarino Iti to no entyokuni hakatta Takasa no Tigai ni nomi yoru.

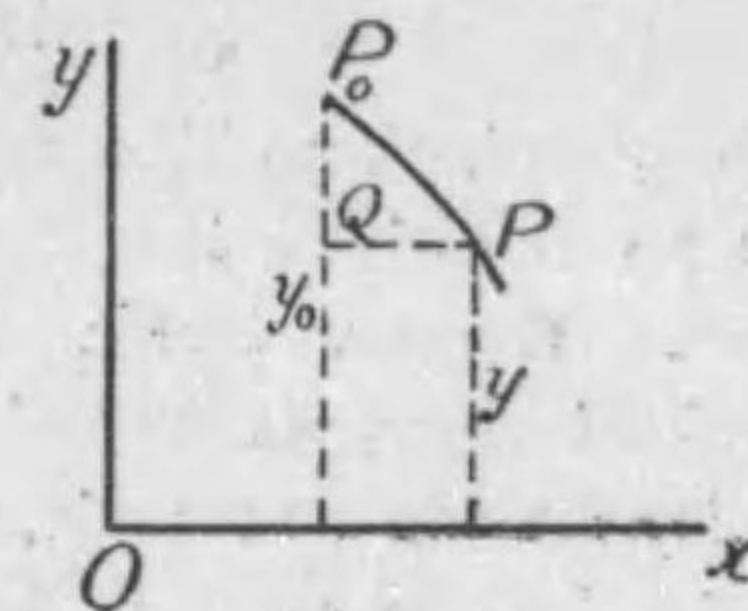
167. Dyûryoku ni yoru Iti-seiryoku. Buttai ga Dyûryoku no Sayô wo ukeru hokani, Teikôryoku ni *taisite* Sigoto wo nasi tutu ugoite iru to suru. Kono Teikôryoku ni taisuru Sigoto ga hazime kara ima madeni W' de aru to sureba, maeno § no (1) no Siki no kawarini,

$$\frac{1}{2}mV^2 - \frac{1}{2}mV_0^2 = mg(y_0 - y) - W',$$

kono Kwankei ga naritatu. Kore wo kakikaete

$$W' = (\frac{1}{2}mV_0^2 + mgy_0) - (\frac{1}{2}mV^2 + mgy)$$

to kaite, kono Buttai ga $y=0$ to iu kimatta Takasa e kite $V=0$



Du 159.

ni naru madehi, hazime kara ikura no Sigoto W' wo nasubeki ka wo miruto,

$$W' = \frac{1}{2}mV_0^2 + mgy_0.$$

Soreyueni, y_0 no Takasa ni atte V_0 no Sokudo wo motu Situryô m no Buttai wa $\frac{1}{2}mV_0^2 + mgy_0$ dakeno Seiryoku wo motte iru to ieru. Konouti $\frac{1}{2}mV_0^2$ wa mae kara sitte iru Undô-seiryoku de, Nokori mgy_0 wa Buttai ga takai Basyo ni aru tameni motte iru Seiryoku de aru node, kore wo *Iti-seiryoku* (matawa Iti-no-Seiryoku) to tonaeru. Ippanni.

Aru hyôzyunno Suiheimen kara hakatte, Takasa y no Basyo ni aru Situryô m no Buttai wa, hyôzyunno Suiheimen ni aru ni kurabete mgy dake no Iti-seiryoku wo motte iru.

168. *Teikôryoku ga nai Baai niwa, $W' = 0$ de,*

$$\frac{1}{2}mV^2 + mgy = \frac{1}{2}mV_0^2 + mgy_0;$$

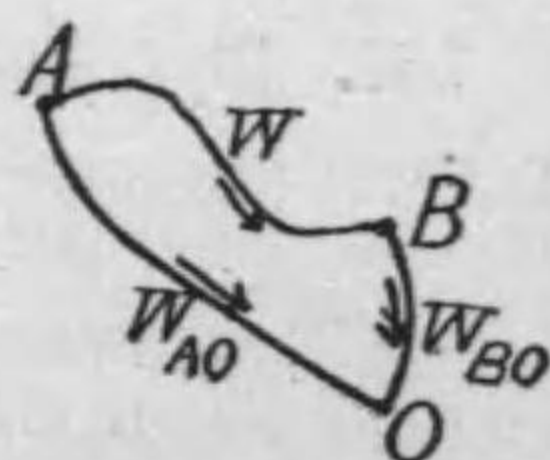
sunawati, Undô-seiryoku to Iti-seiryoku to no Wa wa kawaranai.

169. *Iti-seiryoku no ippanno Baai.* Dyûryoku no Baai ni kagirazu, katteni eranda Ten $A(x_1, y_1)$ kara tano katteni eranda Ten $B(x_2, y_2)$ made Sitten ga ugoku aidani, sore ni hataraku Tikara ga nasu Sigoto no Bunryô ga, *totyû donna Miti wo tôte yuku ni kakawarazu,* kimatta Ooisa wo motu yôna Baai niwa, kono Sigoto wa kanarazu

$$W = \Phi(x_1, y_1) - \Phi(x_2, y_2) \dots \dots \dots (1)$$

no Katati ni naru.

Syômei. Madu, ueno Katei ni yotte, W ga x_1, y_1, x_2, y_2 yottuno Ryô de iiarawa-sareru koto ga sireru. Sono Kwankeisiki no Katati wo kangaeru tameni, aru kimatta Iti O (Du 160) wo totte, A kara O ni yuku tokino Sigoto W_{AO} , B kara O ni yuku tokino Sigoto W_{BO} wo kangaeru. Ueno Katei ni yotte,



Du 160.

$$W_{AO} = W + W_{BO};$$

yueni,

$$W = W_{AO} - W_{BO}.$$

Sikaruni, W_{AO} wa B ni mukwankei de aru kara, x_2, y_2 wo hukuma-

nai, mata W_{BO} wa A ni mukwankei da kara, x_1, y_1 wo hukumanai. Sunawati, W_{AO} wa x_1, y_1 nomi wo hukumu Ryô, W_{BO} wa x_2, y_2 nomi wo hukumu Ryô de, tyôdo (1) no Katati ni natte iru.

Ima A, B ni okeru Sokudo wo sorezore V_1, V_2 to kakeba,

$$\frac{1}{2}mV_2^2 - \frac{1}{2}mV_1^2 = W = \Phi(x_1, y_1) - \Phi(x_2, y_2),$$

sitagatte $\frac{1}{2}mV_2^2 + \Phi(x_2, y_2) = \frac{1}{2}mV_1^2 + \Phi(x_1, y_1).$

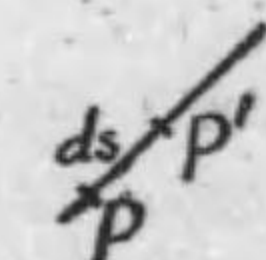
Yueni, mae to dôyôna Kangaekata ni yotte, $\Phi(x, y)$ ga *Iti-seiryoku* ni naru.

Tyûi. Tikara ga nasu Sigoto wa Iti-seiryoku Φ no *Heridaka* de ataerareru.

170. **Potential.** Dyûryoku no Baai ni okeru mgy , motto ippanni maeno § no Φ , sunawati Iti-seiryoku wo arawasu Ryô wo mata *Potential* to yobu.

Potential Φ niwa tugino Seisitu ga aru :—

P (Du 161) ni okeru *Potential* wo Φ, P ni *kiwamete tikai kattena Ten P' ni okeru Potential wo $\Phi + d\Phi$ to si, PP' no Kyori wo ds to sureba,*



$$\text{Tikara no } PP'\text{-Hôkô no Seibun} = -\frac{d\Phi}{ds} \dots (1). \quad \text{Du 161.}$$

Syômei. Sitten ga P kara P' ni yuku tokini Tikara ga nasu Sigoto wo dW to sureba,

$$dW = \Phi(P) - \Phi(P') = \Phi - (\Phi + d\Phi) = -d\Phi \dots (2);$$

sikaruni,

$$dW = \text{Tikara no } PP'\text{-Hôkô no Seibun} \times ds \dots (3).$$

(2) to (3) to kara suguni (1) ga deru.

PP' wo x -Hôkô, y -Hôkô ni toreba, Tikara no x -Seibun, y -Seibun wo Φ wo tukatte arawasu Siki wo eru :—

$$X = -\frac{\partial \Phi}{\partial x}, \quad Y = -\frac{\partial \Phi}{\partial y} \dots \dots \dots (4).$$

Ueno (1), (4) no yôna Keisan wo “Tikara wo Potential kara *mitibikidasu*” to tonaeru.

Dyûryoku no Baai niwa, $\Phi = mgy$ de aru kara

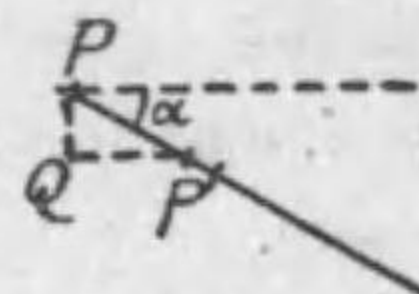
$$X = -\frac{\partial}{\partial x}(mgy) = 0,$$

$$Y = -\frac{\partial}{\partial y}(mgy) = -mg;$$

Mata, Suiheisen-kara sita e α dake katamuita Hôkô ni okeru Tikara K wo dasuto, (Du 162)

$$PP' = ds, \quad PQ = -dy,$$

$$\frac{dy}{ds} = -\frac{PQ}{PP'} = -\sin \alpha$$



Du. 162

no Kwankei wo tukatte,

$$K = -\frac{d}{ds}(mgy) = -\frac{d}{dy}(mgy) \frac{dy}{ds} = -mg \cdot \frac{dy}{ds} \\ = +mg \sin \alpha$$

wo eru.

Tyûi. Ueno yôna Potential no naritatu no wa, § 169 de nobeta Dyôken—katteni eranda Ten kara tano katteni eranda Ten made Buttai ga ugoku aidani sore ni hataraku Tikara ga nasu Sigoto no Bunryô ga, *totyû donna Miti wo tôte yuku ni kakawarasu*, kimatta Oôisa wo motu koto—ga okonawareru Baai ni kagitte, matawa sôiu. Seisitu wo motu Tikara dake ni taisite, okonawareru no de aru. Tatoeba, Masaturyoku nado ni taisitewa Potential wa nai.

Rensyû-mondai V.

(Sitano Mondai dewa Kûki no Teikô wa nai to suru.)

1. Entyokuni Hayasa 50 m./s. de nagegeta Buttai ga noboritureru Takasa, oyobi sore ga otite kite, dedasita Ten wo tôru madeno Zikan wo keisansei!

2. Onazi Basyo O kara hitosii Hayasa V de entyokuni nagegeta Buttai to nageotosita Buttai to wa, O kara h m. dake hikui Ten wo tôru madeni sorezore ikura no Zikan wo yôsuru ka, mata soko de donna Hayasa wo motu ka?

3. Kimatta Hayasa de nobori tutu aru Hûsen no ueni iru Hito ga Te ni motta Isi wo hanasu tokini, sore ga (a) Hûsen ni taisite, (b) Dimen ni taisite, donna Undô wo suru ka?

4. Suiheina Nohara no hitotuno Ten kara ataereta Hayasa V de utidasita Teppôdama no tassi uru saidaino Kyori wa ikura ka?

5. Suiheina Nohara no hitotuno Ten kara kimatta Aomuki-kaku wo motte Tama wo utidasu no ni, todoku Kyori wo nibai ni suru niwa, utidasu Hayasa wo nanbai ni sureba yoi ka?

6. Suiheina Nohara kare h m. dake takai Ten kara suiheini V m./s. de utidasita Teppô-no-tama wa suiheini ikura hedatatta Ten ni otiru ka?

7. Ueno Mondai de, nagedasu Hôkô ga ueni α dake katamuite oreba, otiru Ten wa doko ka?

8. Ueno Mondai de, Tama no Hayasa to, Tama wo ateru Ten no Suiheikyori x ga ataete aru tokini, Aomuki-kaku α wo dô toreba yoi ka?

9. Ueno Mondai de, ataereta Hayasa no Tama no todoki uru saidaino Kyori wo dase!

10. Ataereta Hayasa de iroirona Katamuki wo motte nagedasareta Hôtai ga Entyoku-kyori y dake otita Tokoro de Sokudo v wo motu to sureba,

$$v^2 - 2gy = \text{const.}$$

de aru koto wo syômeisei!

11. Onazi Basyo kara onazi Toki ni kattena Hayasa de nagedasareta mittuno Buttai wo musubitukete erareru Sankakukei ga itu mademo sôzino Katati wo motte ite, katu Hen no Ooisa wa Zikan ni hireisite masu koto wo syômeisei!

12. Hitotuno Ten kara kimatta Hayasa de iroirona Hôkô ni nagedasareta Buttai ga tassi uru Basyo no Kuiki wo sirabei!

13. Suiheimen ni taisite 30° no Keisya wo nasu namerakana Heimen no ue de, Suiheisen ni taisite ueno hô ni α dake katamuita Hôkô ni Buttai wo nagedasu tokini, sore ga donna Undô wo suru ka?

14. Hitotuno Ten kara iroirona Katamuki wo motta namerakana massuguna Kuda no naka wo, onazitokini hanatarete ugokidasu Sitten wa, itu demo hitotuno En no ueni aru koto wo syômeisei!

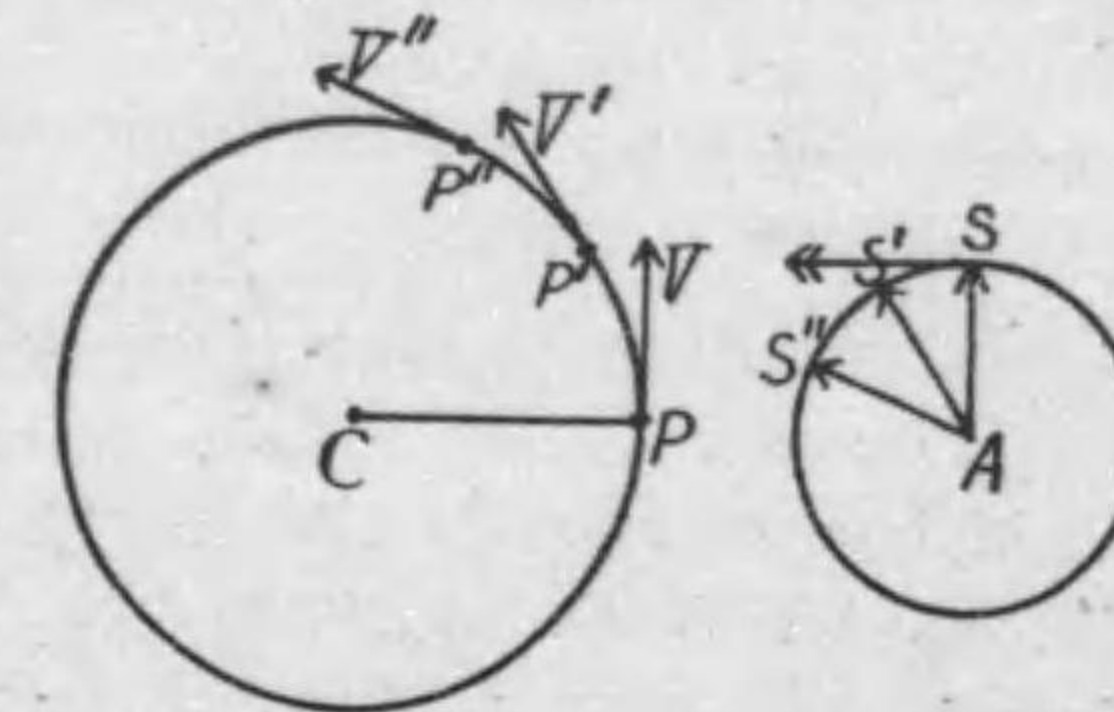
15. Masatu-keisû 0.2, Keisya 30° no Syamen no ue de, saidaino Katamuki no Sen ni sôte ueno hô e 10 m./s. de Buttai wo ugokasidasu tokini, sore wa Kyori ikura susunde tomaru ka? Mata, sore kara notini sore ga donna Undô wo suru ka?

SYOO VI.

Kantanna Sindô to Wakusei
no Undô.

175. Hayasa no kawaranai En-undô. Hankei r no En no ue wo itiyôna Hayasa v de ugoku Sitten ga aru to suru.

Sore ga $P, P', P'' \dots$ to (Du 171) mawaru aidani, Sokudo no Hôkô wa sorezoreno Ten de, Ensyû no Sessen no Hôkô wo motte ite, $V, V', V'' \dots$ to sidaini kawatte yuku, sosite, sore no Ooisa wa itumo onazi v de aru.



Du 171.

Du 172.

Soreyueni, Sokudo-daihyôten no Du wa Hankei v no En (Du 172) de atte, Sitten ga Mitisudi no En C wo hitomeguri meguru Zikan $\frac{2\pi r}{v}$ ni Sokudo-daihyôten S mo En A wo hitomeguri meguru. P no Kasokudo wa sunawati S no Sokudo de atte, sore no Ooisa wa, En A no Ensyû $2\pi v$ wo, hitomeguri no Zikan $T = \frac{2\pi r}{v}$ de watta

$$\frac{2\pi v}{\frac{2\pi r}{v}} = \frac{v^2}{r}$$

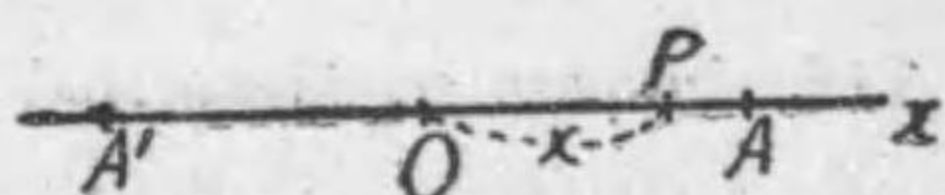
de aru. Mata, S no Sokudo no Hôkô wa, AS sunawati V ni suityoku de, PC ni heikô de aru. Soreyueni,

Kimatta Hayasa v de, Hankei r no En wo egaitte ugoku Sitten no Kasokudo wa, itumo Ensin ni mukatte, $\frac{v^2}{r}$ no Ooisa wo motte oru.

Kono Kekkwa wa § 120 no ippanno Teiri kara wakatte ita Koto de aru keredomo, ima dokurituni sore wo dasita no de aru.

Ue no Kekkwa tosite, *Situryô m no Buttai ga En (Hankei r) no ue wo kimatta Hayasa v de ugoku Baai niwa, En no Tyûsin ni mukatte Zettai-tan'i de mv^2/r dakeno Tikara ga hataraite inakereba naranai.*

176. Kantanna Sindô. "Kantanna Sindô (matawa Tansindô)" wa, hitotuno Tyokusen no ueno Undô de, onazi Tyokusen no ueno hitotuno kimatta Ten O kara Undôten P ni itaru Kyori x ga



Du 173.

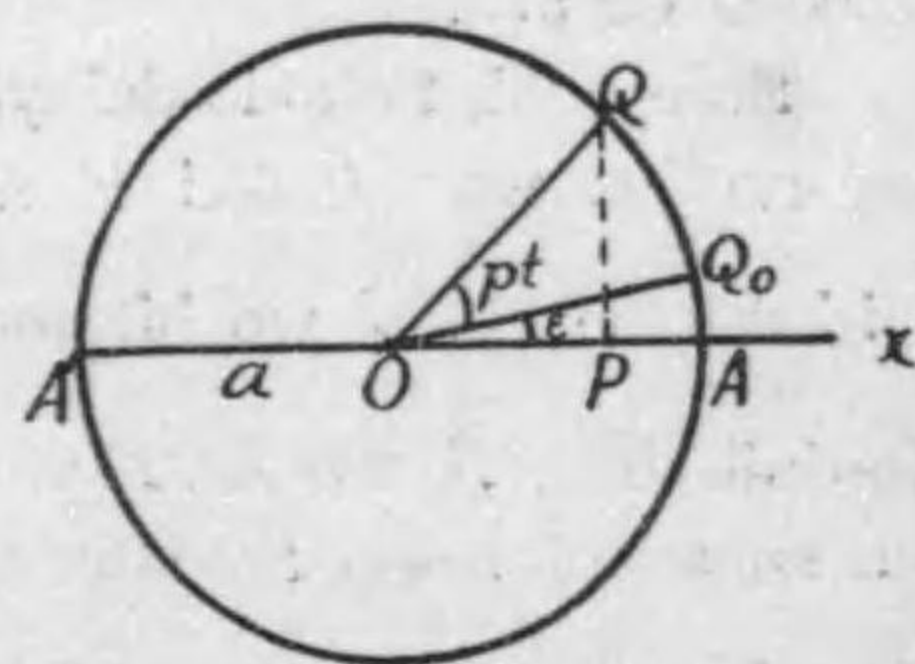
$OP=x=a \cos(pt+\epsilon)$ [a, p, ε wa Zyôsû] ..(1) ni sitagatte kawaru yôna Undô de aru.

Kore wa, O wo Tyûsin to suru Hankei a no Ensyû no ue wo itiyôna Hayasa de mawaru Ten Q wo AA' no ueni syaeisita Ten no Undô to onazi de aru.

Tadasi, OQ wa saisyô (sunawati t=0 ni) AOQ_0=ε naru OQ_0 ni ite, sorekara p to iu kimatta Kakusokudo de mawaru no de,

$$\angle AOQ=pt+\epsilon,$$

sitagatte, $OP=a \cos(pt+\epsilon)$ ni naru no de aru.



Du 174.

Kono Kangaekata de wakaru tôri, Ten P wa O kara Ryôgawa ni a dutu no Kyori no Ten A to A' no aida wo yukikaerisuru.

O wo kono kantanna Sindô no Tyûsin to ii, a wo Sinpuku (Hurihaba) to ii,⁽¹⁾ AOQ=pt+ε wo "Undôten ga P ni aru tokino Isô" to iu. ε wa hazimeno Isô de aru. Mata, itido yukikaerisuru Zikan wo Syûki to iu; kore wa, OQ-Sen no hitomawari no Zikan to onaziku,

$$T = \frac{2\pi}{p} \dots\dots\dots(2)$$

⁽¹⁾ Du no AA' sunawati 2a wo Sinpuku to yobu koto mo aru.

de aru. p wo Syûki T de arawasite, (1) no Siki wo tugino yôni kaitemo yoi :—

$$p = \frac{2\pi}{T}, \quad x = a \cos\left(\frac{2\pi t}{T} + \epsilon\right) \dots\dots(3).$$

Q no En-undô wo "P no kantanna Sindô ni huzokusita En-undô" to iu.

177. Sokudo oyobi Kasokudo. Kantanna Sindô wa, Tyokusen no ueno Undô de aru kara, Sokudo oyobi Kasokudo mo Undô no Tyokusen ni sôte iru. Sorera no Ooisa V oyobi A wa, ippanno Torikime ni sitagatte, tugino Siki de atarereru :—

$$V = \frac{dx}{dt} = -ap \sin(pt+\epsilon) \dots\dots(4),$$

$$A = \frac{d^2x}{dt^2} = -ap^2 \cos(pt+\epsilon) \dots\dots(5).$$

Tyûi. Korerano Atai wa Q no En-undô no Sokudo (Sessen-hôkô no ap) oyobi Kasokudo (Ensin ni mukau $\frac{a^2p^2}{a} = ap^2$, § 175) wo Ox no ueni bunkaisitemo erareru.

178. Tikara no Hôsoku. Situryô m no Sitten ga Tyûsin O no migihidarini kantanna Sindô wo suru Baai ni, sore ni hataraite iru Tikara wa

$$X = mA = -mp^2a \cos(pt+\epsilon)$$

de aru. Kore wo $x = a \cos(pt+\epsilon)$ to kuraberuto,

$$X = -mp^2x = -m \cdot \frac{4\pi^2}{T^2} x$$

no Kwankei ga aru koto ga sireru. $x > 0$ naraba $X < 0$ de ari, $x < 0$ nareba $X > 0$ de aru kara,

Sitten ga ukeru Tikara wa itu demo Tyûsin O ni muite ite, sikamo Ooisa ga O karano Kyori x ni hireisite iru. Katu,

$$\frac{X}{x} \text{ no Hi wa Syûki } T \text{ ni nomi kwankeisite, Hurihaba } a$$

ya ε niwa kwankeisinai.

179. **Ataerareta Tikara ni yotte okoru kantanna Sindô.** Zis-saino Mondai niwa, Tikara no Hatarakikata ga ataete atte, sore ni yotte syôzuru Undô wo motomeru Baai ga ôi. Kore wa, ataerareta Undô kara Kasokudo wo dasi, Tikara wo keisansuru no ni taisite *gyakuno* Mondai de aru. Kantanna Sindô ni kwan-suru konoyôna Mondai wa tugino Teiri ni yotte toriatukawareru.

Teiri I. *Sitten ni hataraku Tikara ga itumo kimatta Ten ni mukatte, sore madeno Kyori ni hireisi, katu saisyono Sokudo ga Sitten to sono kimatta Ten to wo musubu Tyokusen ni sôte iru naraba, kono Sitten no Undô wa kantanna Sindô de aru.*

II. *Kono kantanna Sindô no Sinpuku wa Sitten no saisyono Iti to Sokudo to ni yotte tigau keredomo, sore no Syûki wa korerano Ryô ni kakawarazu kimatte iru.*

Ueno Teiri I wo syômeisuru niwa, madu tugino "ippanno Teiri" wo mitomeru ga yoi.

180. **Ippanno Teiri.** *Subete Buttai no saisyono Iti to saisyono Sokudo to, subeteno Zikoku ni okeru Kasokudo to ga ataete areba, sore no Undô wa mattaku kimaru; iikaereba, korerano mono ga subete ataerareta tôrini naru Undô wa hitotu sika nai.*

Nazekanareba, saisyono Sokudo ga kimatte ite, tugitugino Zikoku ni okeru sore no Kawarikata ga Kasokudo ni yotte kimatte iru kara, subeteno Zikoku ni okeru Sokudo ga kimaru; saisyono Iti ga kimatte ite, tugitugino Zikoku ni okeru sore no Kawarikata ga Sokudo ni yotte kimatte iru kara, subeteno Zikoku ni okeru Iti ga kimaru. Kasokudo ga Zikoku ni taisite ikura to tyokusetuni ataete nakute, Sitten no Iti ni yotte kimaru yôni ataete attemo, Sokudo to Iti to ga tugitugini kimatte kuru koto ni Kawari wa nai.

181. Teiri I no Syômei. Sitten no saisyono Iti P_0 (Du 175) to, sore ni hataraku Tikara ga itumo mukau Ten O to wo musubu Tyokusen wo x -Diku ni tori [(+)-Hôkô wa dotirani erandemo yoi], OP_0 wo x_0 to kaku. Saisyono Sokudo ga OP_0 -Sen ni sôte iru koto ga sirete iru; sore wo V_0 to suru. Mata

Tikara ga O ni mukatte iru kara, kono Sitten ga itu mademo Ox -Sen kara hadureru koto ga nai.

Sitagatte, Tikara mo onazi Tyokusen ni sôte hataraku X nomi de aru. Kono X ga O ni mukatte ite, O karano Kyori ni hireisuru koto ga wakatte iru kara, $X = -kx$ to kaku koto ga dekiru; k wa ataerareta Ryô de aru.

Kasokudo wa $A = \frac{X}{m} = -\frac{k}{m}x$ de aru.

Soreyueni, mosimo *tekitôni eranda* kantanna Sindô ga

$$\left. \begin{aligned} t=0 \text{ de, } & x=x_0; \\ t=0 \text{ de, } & \frac{dx}{dt} = V_0; \\ \text{itu demo, } & \frac{d^2x}{dt^2} = -\frac{k}{m}x; \end{aligned} \right\}$$

korerano mittuno Dyôken wo mitasu nareba, ueno ippanno Teiri ni yotte, ataerareta Sitten no Undô wa kono kantanna Sindô to onazi Undô de aru ni sôinai.

Kantanna Sindô wo

$$x = a \cos(pt + \varepsilon)$$

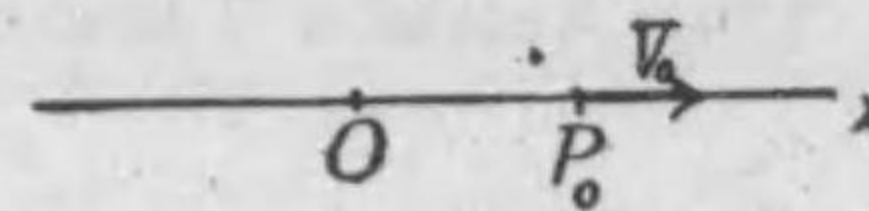
to tori, ueno mittuno Dyôken wo kakuto,

$$\left. \begin{aligned} a \cos \varepsilon &= x_0, \\ -ap \sin \varepsilon &= V_0, \\ p^2 &= \frac{k}{m}. \end{aligned} \right\}$$

Korera wo mitasu koto wa

$$\left. \begin{aligned} p &= \sqrt{\frac{k}{m}}, \\ a &= \sqrt{x_0^2 + V_0^2 \frac{m}{k}}, \\ \tan \varepsilon &= -\frac{V_0}{x_0} \sqrt{\frac{m}{k}} \end{aligned} \right\}$$

no yôna p , a , ε wo erabu koto ni yotte dekiru.



Du 175.

Kore de Teiri I ga syômeisareta.

182. Teiri II wa, ueno a ga x_0 to V_0 ni yotte tigau koto, oyobi

$$T = \frac{2\pi}{p} = 2\pi \sqrt{\frac{m}{k}}$$

ga x_0 to V_0 ni yoranakute, Sitten no Situryô m to Tikara no Kimari (sunawati $X: x = -k$ no Atai) to nomi de kimaru koto wo mireba, akiraka de aru.

Syûki T ga Sinpuku a ni mukwankei de aru koto wo "kantanna Sindô no Tôzisei" to iu.

183. Undô no Hôteisiki no tyokusetuno Tokikata. Ataereta Tikara de okoru Undô wo, hazimeno Iti to Sokudo ni kakawarazu, ippanni kimeru koto wo "Undô no Hôteisiki (§ 140) wo toku" to iu, Situryô m no Sitten no x -Diku ni sôta Tyokusen-undô, de $X = -kx$ to ataete aru tokiniwa, Undô no Hôteisiki wa

$$m \frac{d^2x}{dt^2} = -kx \dots\dots\dots (1)$$

de aru. Kore kara x wo t no Kansû tosite dasu niwa, tugino yôni suru.

Madu (1) no Ryôgawa ni $2 \frac{dx}{dt}$ wo kakeru :-

$$m \cdot 2 \frac{dx}{dt} \cdot \frac{d^2x}{dt^2} + k \cdot 2x \frac{dx}{dt} = 0,$$

sunawati,
$$\frac{d}{dt} \left(m \left(\frac{dx}{dt} \right)^2 + kx^2 \right) = 0;$$

yueni,
$$m \left(\frac{dx}{dt} \right)^2 + kx^2 = \text{const.}$$

Kono const. wo ka^2 to kaite,

$$m \left(\frac{dx}{dt} \right)^2 + kx^2 = ka^2. \dots\dots\dots (2).$$

Kore kara
$$\frac{dx}{dt} = \pm \sqrt{\frac{k}{m}} \sqrt{a^2 - x^2},$$

sunawati,
$$\int \frac{dx}{\pm \sqrt{a^2 - x^2}} = \sqrt{\frac{k}{m}} dt \dots\dots\dots (3).$$

Sekibunsite,
$$\pm \cos^{-1} \left(\frac{x}{a} \right) = \sqrt{\frac{k}{m}} t + \text{const.}$$

Kono const. wo ϵ to kaite,

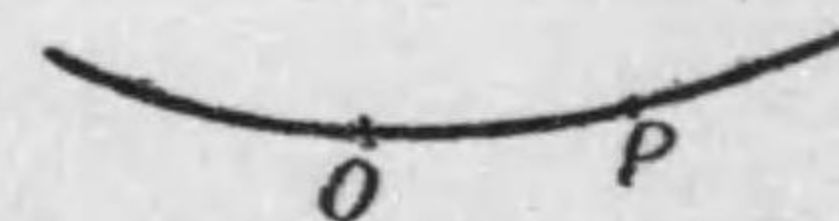
$$x = a \cos \left(\sqrt{\frac{k}{m}} t + \epsilon \right) \dots\dots\dots (4).$$

Kore ga (1) no Kotae de aru; tadasi, a to ϵ to wa kattena Kazu.

Tyûi. (3) no Siki wo sekibunuru tokoro de, $\cos^{-1} \left(\frac{x}{a} \right)$ no kawarini $\pm \sin^{-1} \left(\frac{x}{a} \right)$ to kakuto, $x = \pm a \sin \left(\sqrt{\frac{k}{m}} t + \epsilon \right)$ wo eru ga, a to ϵ to ga kattena Kazu de aru kara, ϵ no kawarini $\epsilon - \frac{\pi}{2}$ to kaki, $\pm a$ no kawarini $-a$ to kaite miruto (4) to onazini naru.

184. Kyokusen no ueno kantanna Sindô. Kantanna Sindô wa honrai Tyokusen no ueno Undô de aru keredomo, ataerareta Kyokusen no ue de sore to dôyôna Undô ga okoru koto ga aru.

Sore wa, sono Kyokusen no ueno hitotuno Ten O (Du 176) kara Kyokusen ni sôte hakatta Sitten P no Kyori $\widehat{OP} = s$ ga t ni taisite § 176 no (1) no Siki to dôyôna Kwankei



Du 176.

$$s = a \cos (pt + \epsilon)$$

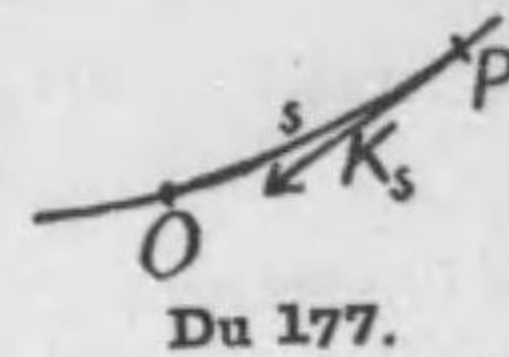
wo nasu Baai de aru. Kono Baai ni

$$\frac{d^2s}{dt^2} = -ap^2 \cos (pt + \epsilon) = -p^2s$$

de aru koto wa Tyokusen-undô no Baai to dôyô de aru. Tadasi, kono $\frac{d^2s}{dt^2}$ wa Kasokudo dewa nakute, Kasokudo no Sessen-seibun de aru (§ 120).

185. Gyakuno Teiri. Namerakana Sokubaku ni yotte kimatta Kyokusen no ue wo susumu yôni kimerarete aru Sitten ga

atte, sore ni hataraku Tikara no Sessen-seibun K_s ga Kyokusen ni sôte hakatta Nagasa OP ni hireisite, katu, itumo O no aru Gawa ni multe iru tokiniwa, kono Sitten wa Kyokusen no ueno kantanna Sindô wo suru.



Du 177.

Nazekanareba, kôiu Sitten no Iti wa, sono Kyokusen no ueno kimatta Ten O kara Kyokusen ni sôte hakatta Kyori s hitotu de kimaru (Du 177). Sitagatte, sore no Undô wa s no t ni taisuru Kwankei dake de kimaru. Sikaruni, kono Baai niwa,

$$K_s = -ks$$

no Kwankei ga aru kara, Kasokudo no Sessen-seibun wa

$$A_s = \frac{K_s}{m} = -\frac{k}{m}s;$$

yueni,

$$\frac{d^2s}{dt^2} = -\frac{k}{m}s.$$

Kore wa Tyokusen no ueno Undô ni tuite § 112 de x ni taisite okonawareta Siki to mattaku onazi de aru. Kono Hôteisiki to, s no saisyono Atai s_0 , Hayasa V no saisyono Atai V_0 de Mondai ga mattaku kimaru koto wa § 180 no Baai to onazikoto de aru kara, Kekkwa mo mae to onaziku,

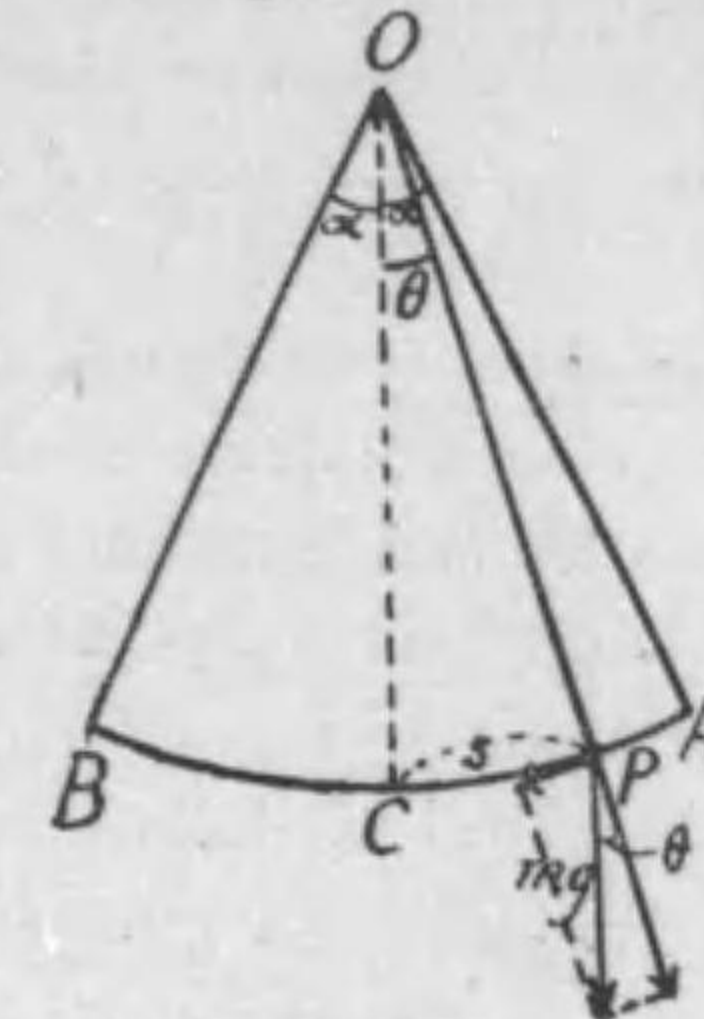
$$s = a \cos\left(\sqrt{\frac{k}{m}}t + \varepsilon\right)$$

ni naru; sosite a to ε ga s_0 to V_0 to kara kimaru koto mo mae to kawaranai.

Kono Baai ni, Mitisudi ni suityokuna Hôkô niwa, Mitisudi no Kyokuritu-hankei wo ρ to sureba, $\frac{V^2}{\rho}$ dakeno Kasokudo, sitagatte $m \frac{V^2}{\rho}$ dakeno Tikara ga Magari no Utigawa ni mukatte hataraite iru. Kore wa hoka kara hataraku Tikara no Hôsen-seibun to, namerakana Sokubaku no Tikara to wo kuwaeta mono de aru.

186. Sitten-huriko. Situryô no nai nobinai Ito de koteisita Ten kara Sitten wo turusi, Entyokumen no ue de sindôsuru yôni sita mono wo "Sitten-huriko" (matawa *Tansinsi*) to tonaeru.

Koteisita Ten wo O (Du 178) to si, Ito no Nagasa wo l to sureba, Sitten wa O wo Tyûsin to sita Hankei l no Ensyû no ue wo ugoku. Turiai no Iti C kara Sitten no kattena Iti P made Ensyû ni sôte hakatta Kyori wo s , Kaku COP wo θ to suru; $\theta = \frac{s}{l}$.



Du 178.

Tikara no Sessen-seibun wa $mg \sin \theta$ de, C no hô e multe iru kara,

$$K_s = -mg \sin \theta = -mg \sin \frac{s}{l}.$$

Soreyueni, Undô wo kimeru Hôteisiki wa

$$m \frac{d^2s}{dt^2} = -mg \sin \frac{s}{l} \dots \dots \dots (1),$$

matawa, s no kawarini θ wo tukatte,

$$\frac{d^2\theta}{dt^2} = -\frac{g}{l} \sin \theta \dots \dots \dots (1a).$$

Ima $\theta = \frac{s}{l}$ ga taihen tiisakute, $\sin \theta$ wo θ ni hitosii to miru koto ga yurusareru to suru. Sô sureba,

$$m \frac{d^2s}{dt^2} = -mg \theta = -mg \frac{s}{l}.$$

Sunawati,

$$\frac{d^2s}{dt^2} = -\frac{g}{l} s \dots \dots \dots (2).$$

Kono Bibun-hôteisiki wo mitasite, nao hazimeno Iti to Sokudo ni awaserareru Kotae wa

$$s = a \cos\left(\sqrt{\frac{g}{l}}t + \varepsilon\right) \dots \dots \dots (3)$$

de, sitagatte Sitten no Undô wa Kyokusen no ueno kantanna Sindô de aru. Sosite, Syûki wa

$$T = \frac{2\pi}{\sqrt{\frac{g}{l}}} = 2\pi \sqrt{\frac{l}{g}} \dots \dots \dots (4).$$

Mata θ no t ni taisuru Kwankei wa,

$$\theta = \alpha \cos \left(\sqrt{\frac{g}{l}} t + \varepsilon \right) \dots \dots \dots (3a);$$

tadasi,

$$\alpha = \frac{a}{l}.$$

Tadasi, korerano Kekkwa wa, θ ga itu demo (sunawati itiban ôkii θ mo) zyûbunni tiisai Baai, sunawati, $\frac{a}{l} = \alpha$ ga zyûbunni tiisai Baai ni dake okonawareru no de aru.

187. *Rakutai no Kasokudo* (matawa *Dyûryoku no Tuyosa*) g wo tyokusetuni Rakutai ni tuite sokuteisuru koto wa konnan de aru ga, Sitten-huriko wo tukaeba, warini kantanni sore no Atai ga erareru. Sunawati, l to T to wo hakatte

$$g = \frac{4\pi^2 l}{T^2}$$

wo keisansureba yoi no de aru (ueno (4) no Siki).

Tadasi, kore mo zyûbun seimituna Sokutei ni tekitôsite iru no dewa nai. Motto yoi Hôhō wa § 212 ni toite aru.

188. *Syûki no Siki no Naosi.* (1a) no Siki no $\sin \theta$ wo θ to oite simawazuni, sorera hutatu no Tigai wo mitomete kandyô-suru niwa :—

(1a) no Siki,

$$\frac{d^2\theta}{dt^2} = -\frac{g}{l} \sin \theta \dots \dots \dots (1a)$$

no Ryôgawa ni $2 \frac{d\theta}{dt}$ wo kakete,

$$2 \frac{d\theta}{dt} \frac{d^2\theta}{dt^2} = -2 \frac{g}{l} \sin \theta \frac{d\theta}{dt},$$

sunawati,

$$\frac{d}{dt} \left\{ \left(\frac{d\theta}{dt} \right)^2 - 2 \frac{g}{l} \cos \theta \right\} = 0;$$

yueni,

$$\left(\frac{d\theta}{dt} \right)^2 - 2 \frac{g}{l} \cos \theta = \text{const.}$$

Kono const. wo $-2 \frac{g}{l} \cos \alpha$ to kakuto, α wa $\frac{d\theta}{dt}$ ga 0 ni natta Baai, sunawati, Sitten ga yukidomatta tokino θ no Atai de aru. Sosite,

$$\begin{aligned} \left(\frac{d\theta}{dt} \right)^2 &= 2 \frac{g}{l} (\cos \theta - \cos \alpha) \\ &= 2 \frac{g}{l} \{ (1 - \cos \alpha) - (1 - \cos \theta) \} \\ &= 4 \frac{g}{l} \left(\sin^2 \frac{\alpha}{2} - \sin^2 \frac{\theta}{2} \right). \end{aligned}$$

Yueni,

$$\frac{d\theta}{dt} = 2 \sqrt{\frac{g}{l}} \sqrt{\sin^2 \frac{\alpha}{2} - \sin^2 \frac{\theta}{2}};$$

sitagatte,

$$dt = \frac{1}{2} \sqrt{\frac{l}{g}} \frac{d\theta}{\sqrt{\sin^2 \frac{\alpha}{2} - \sin^2 \frac{\theta}{2}}}.$$

Syûki T wa, Sitten ga $\theta=0$ no Iti kara ippôno kyokutanno Iti ni tassuru madeno Zikan, sunawati θ ga 0 kara masite α ni naru madeno Zikan no 4-bai de aru kara,

$$T = 2 \sqrt{\frac{l}{g}} \int_0^\alpha \frac{d\theta}{\sqrt{\sin^2 \frac{\alpha}{2} - \sin^2 \frac{\theta}{2}}} \dots \dots (5).$$

Kono Sekibun wo keisansuru tamenî,

$$\sin \frac{\theta}{2} = \sin \frac{\alpha}{2} \sin \varphi$$

to oite, θ no kawarini φ wo tukau. $\theta=0$ dewa $\varphi=0$, θ ga saidaino Atai α ni naru tokini $\varphi = \frac{\pi}{2}$ ni naru. Kono Siki wo bibunsite,

$$\frac{1}{2} \cos \frac{\theta}{2} d\theta = \sin \frac{\alpha}{2} \cos \varphi d\varphi,$$

sunawati,

$$d\theta = \frac{2 \sin \frac{\alpha}{2} \cos \varphi}{\sqrt{1 - \sin^2 \frac{\alpha}{2} \sin^2 \varphi}} d\varphi.$$

Mata,

$$\sqrt{\sin^2 \frac{\alpha}{2} - \sin^2 \frac{\theta}{2}} = \sin \frac{\alpha}{2} \cos \varphi.$$

Yueni, (5) wa

$$T = 4\sqrt{\frac{l}{g}} \int_0^{\frac{\pi}{2}} \frac{d\varphi}{\sqrt{1 - \sin^2 \frac{\alpha}{2} \sin^2 \varphi}} \dots (6)$$

ni naru.

Kono Siki de $\sin^2 \frac{\alpha}{2}$ wa tiisai Ryô de aru. Karini α ga 10^0 aru to sitemo, $\sin \frac{\alpha}{2}$ wa $\frac{1}{10}$ yorimo tiisaku, $\sin^2 \frac{\alpha}{2}$ wa $\frac{1}{100}$ yorimo tiisai. Soreyueni, Nikôsiki de hirogete,

$$\frac{1}{\sqrt{1 - \sin^2 \frac{\alpha}{2} \sin^2 \varphi}} = 1 + \frac{1}{2} \sin^2 \frac{\alpha}{2} \sin^2 \varphi + \frac{3}{8} \sin^4 \frac{\alpha}{2} \sin^4 \varphi + \dots$$

Kore wo (6) ni irete,

$$T = 4\sqrt{\frac{l}{g}} \int_0^{\frac{\pi}{2}} d\varphi \left(1 + \frac{1}{2} \sin^2 \frac{\alpha}{2} \sin^2 \varphi + \frac{3}{8} \sin^4 \frac{\alpha}{2} \sin^4 \varphi + \dots \right).$$

Hutuno Mokuteki niwa $\sin^2 \frac{\alpha}{2}$ no Kô dake wo tomete motto tiisai

Kô wo sutete yoi. Sô suruto, $\int_0^{\frac{\pi}{2}} \sin^2 \varphi d\varphi = \frac{\pi}{4}$ wo tukatte,

$$T = 2\pi \sqrt{\frac{l}{g}} \left(1 + \frac{1}{4} \sin^2 \frac{\alpha}{2} \right).$$

$\sin^4 \frac{\alpha}{2}$ wo suteta to onazi Riyû de, $\sin \frac{\alpha}{2}$ wo $\frac{\alpha}{2}$ to kaite yoi.

Sô sureba,

$$T = 2\pi \sqrt{\frac{l}{g}} \left(1 + \frac{\alpha^2}{16} \right) \dots (7).$$

α^2 no Kô ga "Naosi" de aru. $\alpha = 10^0$ no Baai nimo, $\frac{\alpha^2}{16}$ wa

$\frac{1}{500}$ ika de aru.

189. Undô no Gôsei. Ataerareta hutatuno Undô wo gôsei-suru to iu no wa, onônono Zikoku ni, sorerano Undô no Sokudo hutatu wo gôseisita yôna Sokudo wo motte ugoku Undô wo tukuru koto de aru.

Kono Mokuteki niwa, ataerareta Undô no onôno ni taisuru Zahyô x_1, y_1 oyobi x_2, y_2 no (t de arawasita) Siki wo totte,

$$x = x_1 + x_2, \quad y = y_1 + y_2$$

wo Zahyô to suru Ten no Undô wo mireba yoi; nazekanareba, konoyôna Ten no Sokudo wa,

$$\frac{dx}{dt} = \frac{dx_1}{dt} + \frac{dx_2}{dt}, \quad \frac{dy}{dt} = \frac{dy_1}{dt} + \frac{dy_2}{dt};$$

korerano Siki de wakaruru tōri, ataerareta hutatuno Undô ni okeru Sokudo wo gôseisita mono ni hitosii kara.

Hutatu yorimo ôkuno Undô wo gôseisuru koto mo dōyōni toriatukawareru.

190. Syûki no hitosii ikutu kano Tansindô no Gôsei.

(a) *Onazi Tyokusen ni heikôna, Syûki no hitosii kantanna Sindô no Gôsei.* Hutatuno kantanna Sindô wo ataeru Zahyô no Siki ga

$$\left. \begin{aligned} x_1 &= a_1 \cos \left(\frac{2\pi t}{T} + \varepsilon_1 \right), \\ x_2 &= a_2 \cos \left(\frac{2\pi t}{T} + \varepsilon_2 \right) \end{aligned} \right\} \dots (1)$$

de aru to sureba, gôseisita Undô wo ataeru Zahyô no Siki wa

$$\begin{aligned} x &= x_1 + x_2 \\ &= (a_1 \cos \varepsilon_1 + a_2 \cos \varepsilon_2) \cos \frac{2\pi t}{T} \\ &\quad - (a_1 \sin \varepsilon_1 + a_2 \sin \varepsilon_2) \sin \frac{2\pi t}{T} \dots (2). \end{aligned}$$

Kore wo

$$\left. \begin{aligned} a_1 \cos \varepsilon_1 + a_2 \cos \varepsilon_2 &= a \cos \varepsilon, \\ a_1 \sin \varepsilon_1 + a_2 \sin \varepsilon_2 &= a \sin \varepsilon \end{aligned} \right\} \dots (3)$$

ni naru yôna a to ε wo tukatte kakinaoseba.

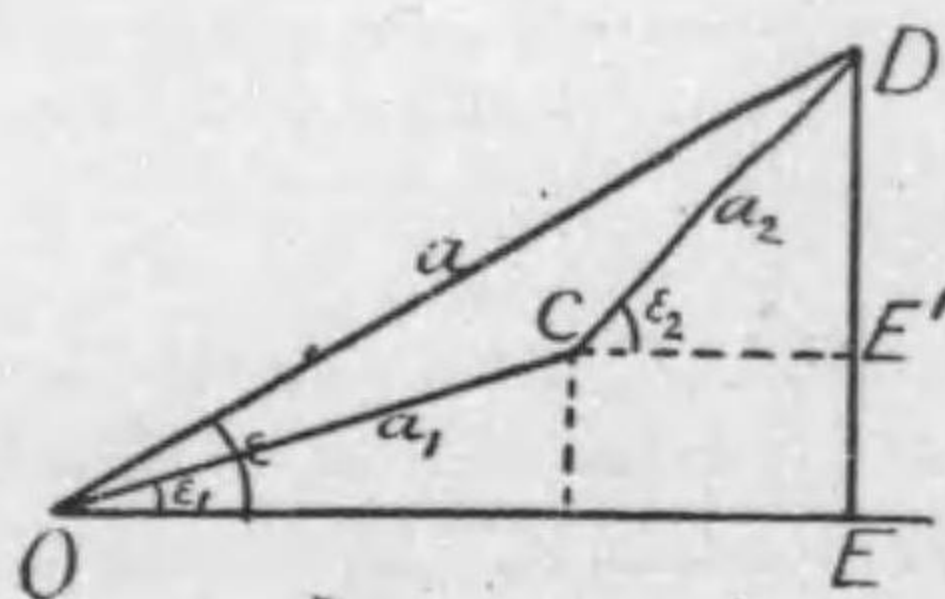
$$x = a \cos \left(\frac{2\pi t}{T} + \varepsilon \right) \dots \dots \dots (4).$$

Sunawati, gôseisita Undô wa onazi Syûki wo motta kantanna Sindô de atte, sore no Siapuku a oyobi hazimeno Isô ε wa, (3) no Hôteisiki kara tugino yôni kimaru:—

$$\left. \begin{aligned} a &= \sqrt{a_1^2 + a_2^2 + 2a_1a_2 \cos(\varepsilon_2 - \varepsilon_1)}, \\ \tan \varepsilon &= \frac{a_1 \sin \varepsilon_1 + a_2 \sin \varepsilon_2}{a_1 \cos \varepsilon_1 + a_2 \cos \varepsilon_2} \end{aligned} \right\} \dots \dots (5).$$

a to ε to wo kimeru ni (5) no Keisan ni yoru kawarini, Du 179 no yôna Sakudu wo tukau koto ga dekiru.

$OC = a_1, \quad EOC = \varepsilon_1;$
 $CD = a_2, \quad E'CD = \varepsilon_2$
 (tadasi $CE' \parallel OE$)



Du 179.

to toreba,

$$\begin{aligned} OE &= a_1 \cos \varepsilon_1 + a_2 \cos \varepsilon_2, \\ ED &= a_1 \sin \varepsilon_1 + a_2 \sin \varepsilon_2 \end{aligned}$$

de aru kara, OD wo musubeba,

(3) ni yotte,

$$OD = a, \quad EOD = \varepsilon$$

de aru.

Ue to dôyôna kantanna Sindô wo mittu izyô gôseisuru Keisan ya Sakudu wa ueno Hôhō kara osite sirareru.

190. (b) *Tigau Hôkô ni aru, onazi Syûki no kantanna Sindô no Gôsci.* x -Diku ni taisite α_1 (Du 180) no Kaku wo nasu A_1B_1 no Hôkô ni

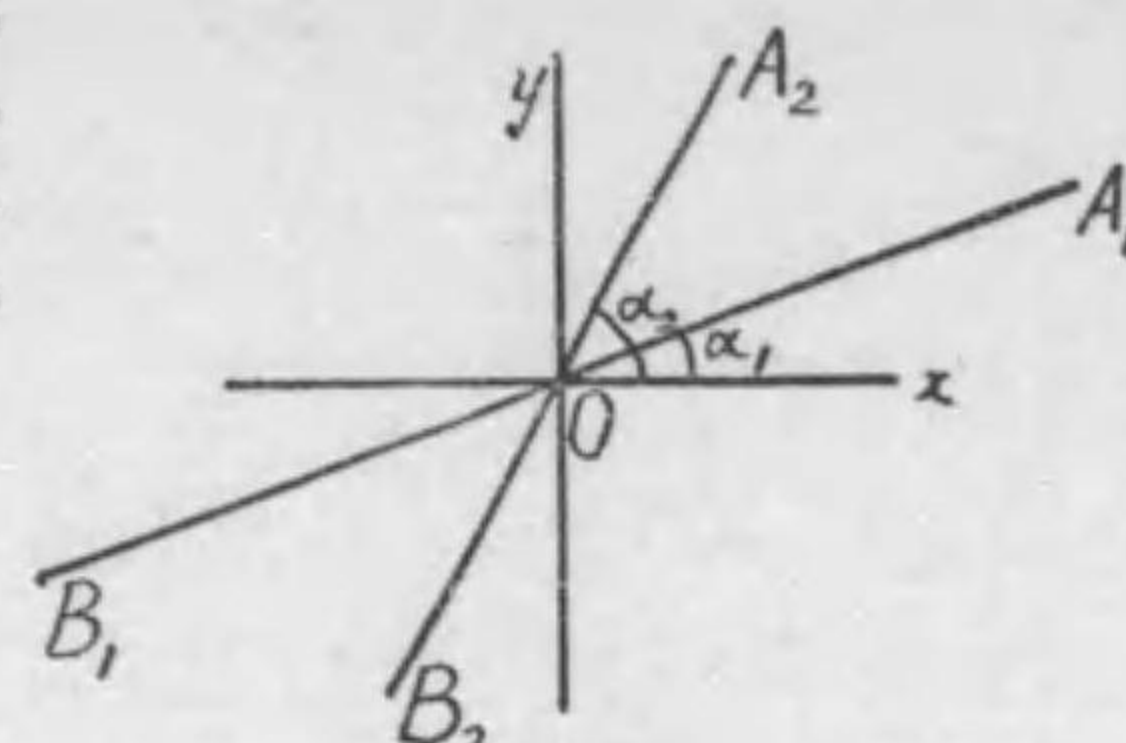
$$s_1 = a_1 \cos \left(\frac{2\pi t}{T} + \varepsilon_1 \right);$$

α_2 no Kaku wo nasu A_2B_2 no Hôkô ni

$$s_2 = a_2 \cos \left(\frac{2\pi t}{T} + \varepsilon_2 \right)$$

de atarereru yôna hutatuno kantanna Sindô ga aru to sureba, korera wo gôseisita Undô wo suru Ten no Zahyô wa

$$\begin{aligned} x &= s_1 \cos \alpha_1 + s_2 \cos \alpha_2, \\ y &= s_1 \sin \alpha_1 + s_2 \sin \alpha_2; \end{aligned}$$



Du 180.

sunawati,

$$\begin{aligned} x &= (a_1 \cos \varepsilon_1 \cos \alpha_1 + a_2 \cos \varepsilon_2 \cos \alpha_2) \cos \frac{2\pi t}{T} \\ &\quad - (a_1 \sin \varepsilon_1 \cos \alpha_1 + a_2 \sin \varepsilon_2 \cos \alpha_2) \sin \frac{2\pi t}{T}, \\ y &= (a_1 \cos \varepsilon_1 \sin \alpha_1 + a_2 \cos \varepsilon_2 \sin \alpha_2) \cos \frac{2\pi t}{T} \\ &\quad - (a_1 \sin \varepsilon_1 \sin \alpha_1 + a_2 \sin \varepsilon_2 \sin \alpha_2) \sin \frac{2\pi t}{T} \end{aligned}$$

de atarereru. x -Hôkô no Undô to y -Hôkô no Undô to wa iduremo onazi Syûki wo motta kantanna Sindô de aru keredomo, sorera wo gôseisita moño wa nanamena Hôkô no kantanna Sindô niwa naranai.

Madu, *Sitten no ugoku Mitisudi* wo siraberu. Ueno Siki ni aru Zyôsû wo kantanna Kigô de arawasite,

$$\left. \begin{aligned} a_1 \cos \varepsilon_1 \cos \alpha_1 + a_2 \cos \varepsilon_2 \cos \alpha_2 &= C, \\ a_1 \sin \varepsilon_1 \cos \alpha_1 + a_2 \sin \varepsilon_2 \cos \alpha_2 &= D, \\ a_1 \cos \varepsilon_1 \sin \alpha_1 + a_2 \cos \varepsilon_2 \sin \alpha_2 &= E, \\ a_1 \sin \varepsilon_1 \sin \alpha_1 + a_2 \sin \varepsilon_2 \sin \alpha_2 &= F \end{aligned} \right\} \dots \dots (6)$$

to kakeba,

$$\left. \begin{aligned} x &= C \cos \frac{2\pi t}{T} - D \sin \frac{2\pi t}{T}, \\ y &= E \cos \frac{2\pi t}{T} - F \sin \frac{2\pi t}{T} \end{aligned} \right\} \dots \dots (7).$$

Korera kara t wo oidasu yôni toriatukatte,

$$Fx - Dy = (CF - DE) \cos \frac{2\pi t}{T},$$

$$Ex - Cy = (CF - DE) \sin \frac{2\pi t}{T};$$

sitagatte,

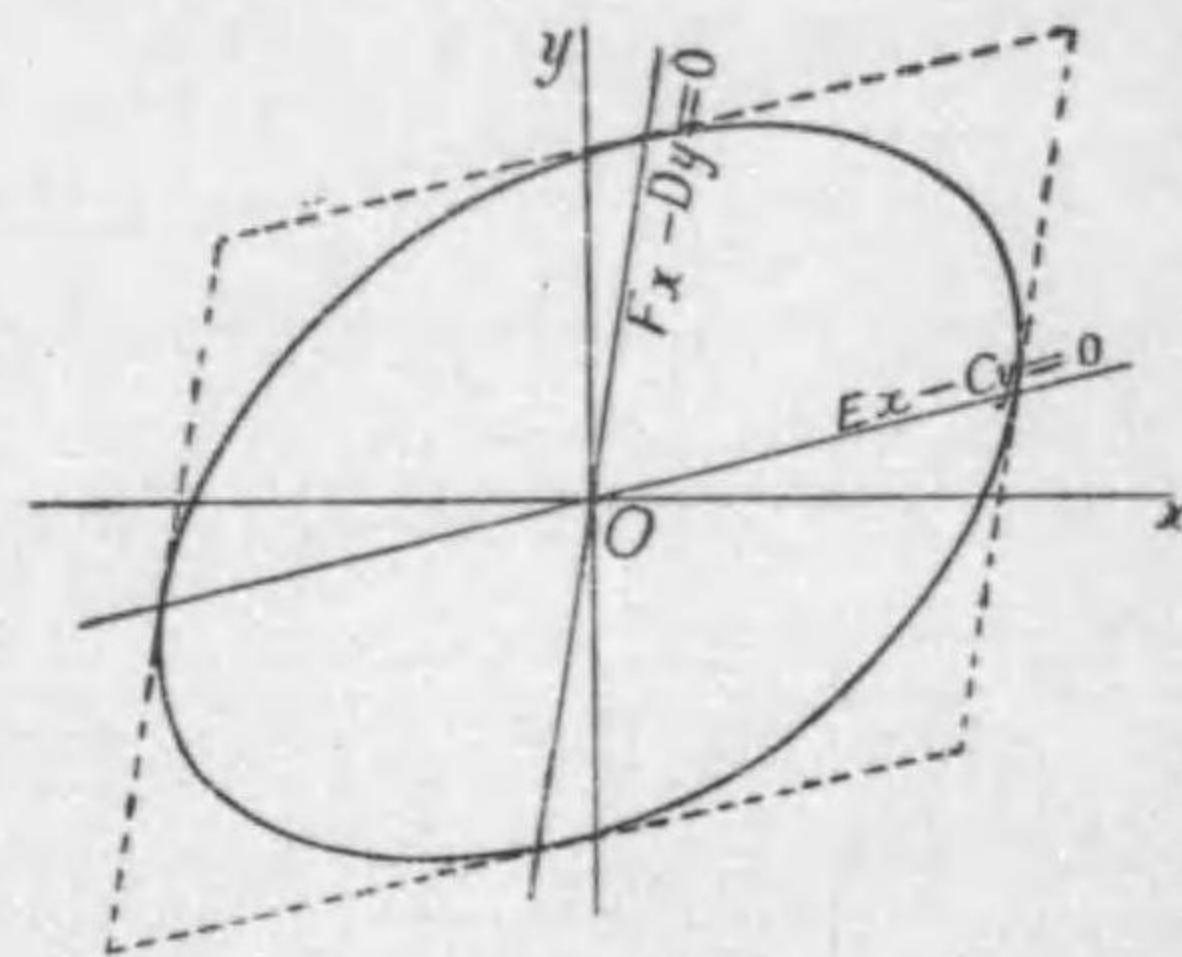
$$(Fx - Dy)^2 + (Ex - Cy)^2 = (CF - DE)^2 \dots (8).$$

Kore ga Mitisudi no Hôtei-siki de aru. Kono Kyokusen wa Du 181 no yôni $Ex - Cy = 0$ to $Fx - Dy = 0$ to iu hutatuno (O wo tôru) Tyokusen wo *Kyôyaku-tyokkei* to suru Daen de atte, Undôten wa kono Daen no ue wo guruguru mawa'te iru no de aru.

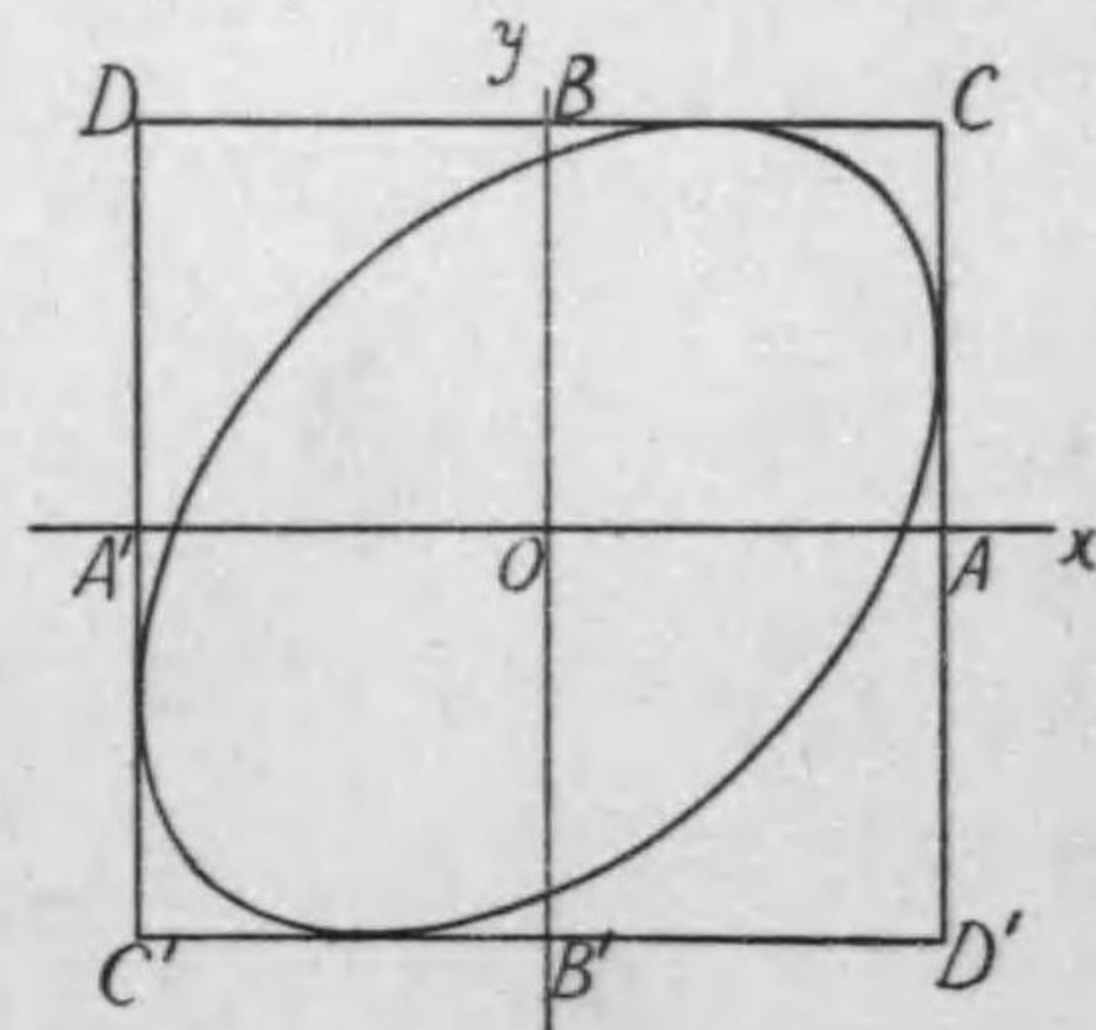
Kono Undô wo *Daen-sindô* to tonaeru.

(7) de simesareru x -Hôkô no kantanna Sindô wa Sinpuku ga $OA = OA' = \sqrt{C^2 + D^2}$, y -Hôkô no Sindô wa $OB = OB' = \sqrt{E^2 + F^2}$ de aru kara, Mitisudi no Daen wa, Du 182 no yôni, A, A', B, B' ni hiita tate-yokono Sen ni hurete iru. Sore ga korerano Sen ni doko de hureru ka, mata sono Daen no ue wo Undôten ga dôiu Muki ni mawaru ka wa, x -Hôkô to y -Hôkô no hazimeno Isô no Tigai ni yoru mono de aru.

Tatoeba, hutatuno Isô ga hitosikereba, Daen ga COC' no Tyokusen ni nari; 180° dake tigaeba, DOD' no Tyokusen ni naru. Mata Isô ga 90° dake tigaeba, Daen ga Du 183 no yôn



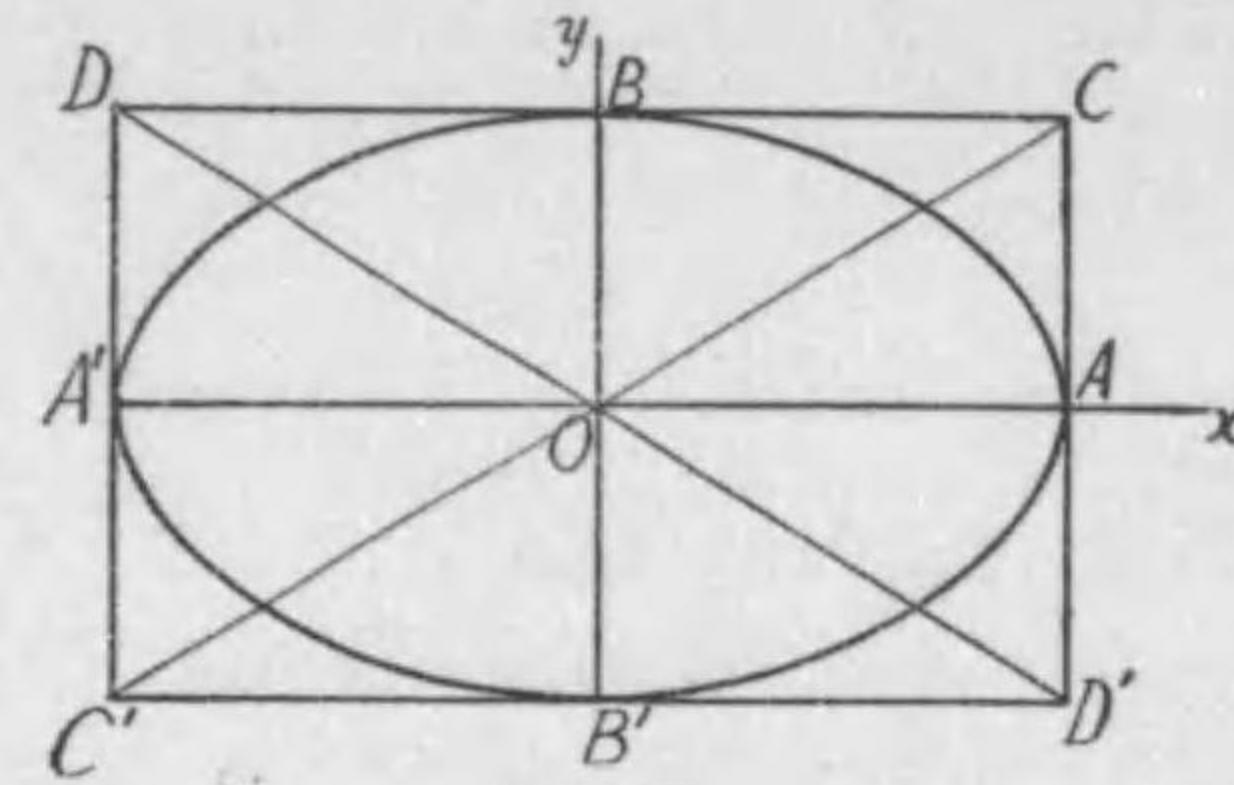
Du 181.



Du 182.

A, B, A', B' no yottuno Ten de hurete, sore no ue wo Undôten ga mawaru Muki wa, x no hô no Isô ga ôkikereba hidari-mawari (sunawati Tokei no Hari to hantai), y no hô no Isô ga ôkikereba migi-mawari (Tokei no Hari to onazi) de aru.

Ataerareta kantanna Sindô ga mittu izyô (onazi Heimen ni) aru Baai niwa, (1) no Siki ni aru C, D, E, F ga onôno mittu izyôno Kô wo motu dake de, Kekkwa wa ue to mattaku onazi de aru.



Du 183.

192. Daen-sindô ni okeru Tikara no Hatarakikata. Situryô m no Sitten ga maeno § de nobeta yôna Daen-sindô, sunawati

$$\left. \begin{aligned} x &= C \cos \frac{2\pi t}{T} - D \sin \frac{2\pi t}{T}, \\ y &= E \cos \frac{2\pi t}{T} - F \sin \frac{2\pi t}{T} \end{aligned} \right\} \dots (1)$$

de ataerareru Undô wo nasu Baai ni, sore ni hataraitte iru Tikara no Seibun wa

$$\begin{aligned} X &= m \frac{d^2 x}{dt^2} = -\frac{\Delta \pi^2 m}{T^2} \left(C \cos \frac{2\pi t}{T} - D \sin \frac{2\pi t}{T} \right), \\ Y &= m \frac{d^2 y}{dt^2} = -\frac{\Delta \pi^2 m}{T^2} \left(E \cos \frac{2\pi t}{T} - F \sin \frac{2\pi t}{T} \right); \end{aligned}$$

sunawati,

$$\begin{aligned} X &= -\frac{\Delta \pi^2 m}{T^2} x, \\ Y &= -\frac{\Delta \pi^2 m}{T^2} y. \end{aligned}$$

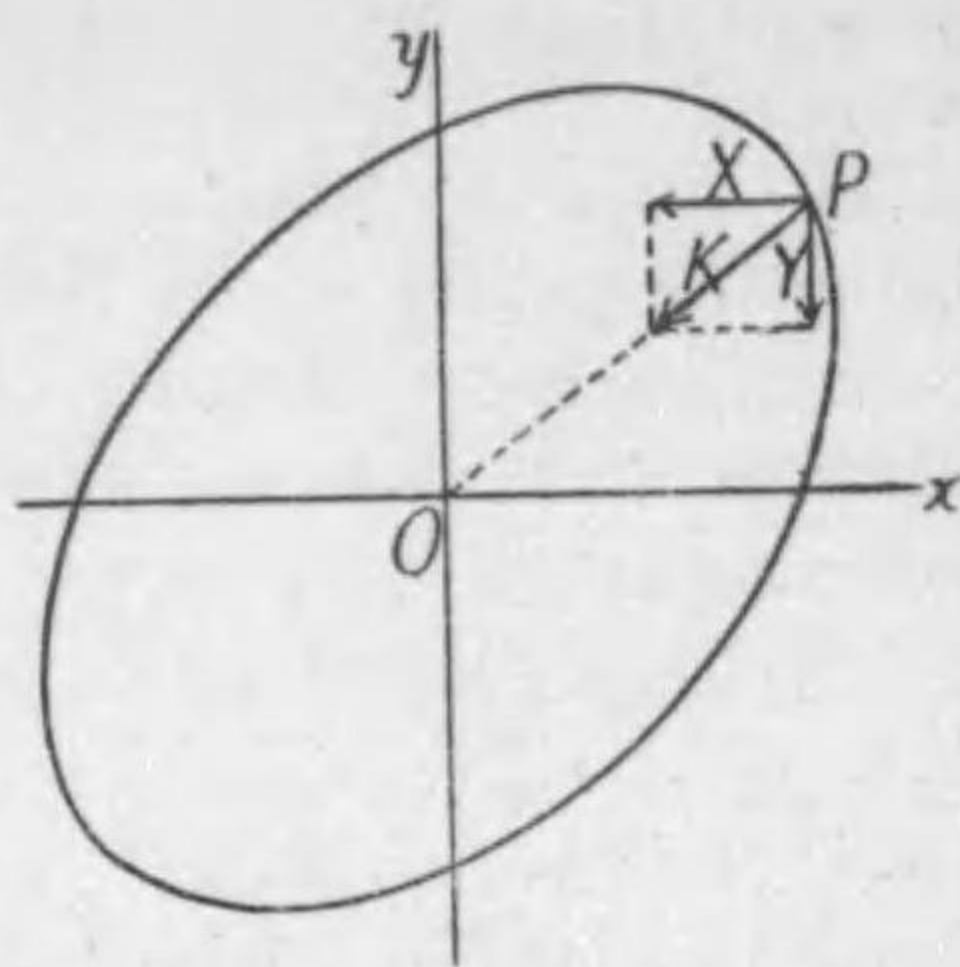
X/x mo Y/y mo hu de atte, katu

$$\frac{Y}{X} = \frac{y}{x}$$

de aru kara, Tikara ga tyôdo PO no Hôkô ni multe iru. Sono-ue, kono Tikara no Ooisa K wa

$$K = \sqrt{X^2 + Y^2} = \frac{4\pi^2 m}{T^2} \sqrt{x^2 + y^2} \\ = \frac{4\pi^2 m}{T^2} \cdot \overline{OP}.$$

Sunawati, Sitten ga ukeru Tikara wa doko demo Daen no Tyûsin O ni mukatte, katu sore karano Kyori ni hireisite iru.



Du 194.

Kono Baai ni Dôkei OP no Menseki-sokudo (§ 124) wo miruto,

$$\begin{aligned} \text{Menseki-sokudo} &= \frac{1}{2} \left(x \frac{dy}{dt} - y \frac{dx}{dt} \right) \\ &= -\frac{1}{2} \left\{ \left(C \cos \frac{2\pi t}{T} - D \sin \frac{2\pi t}{T} \right) \frac{2\pi}{T} \left(E \sin \frac{2\pi t}{T} + F \cos \frac{2\pi t}{T} \right) \right. \\ &\quad \left. - \left(E \cos \frac{2\pi t}{T} - F \sin \frac{2\pi t}{T} \right) \frac{2\pi}{T} \left(C \sin \frac{2\pi t}{T} + D \cos \frac{2\pi t}{T} \right) \right\} \\ &= \frac{\pi}{T} (ED - CF). \end{aligned}$$

Kore wa t wo hukumanai kara, Menseki-sokudo wa ittei de aru. Kono Koto wa, Tikara ga OP no Hôkô ni aru koto, sunawati Tikara sitagatte Kasokudo no θ -Seibun ga o de aru koto karamo matimôkerareta (§ 126) Koto de aru.

193. Ueno Teiri no Gyaku mo naritatu :—

Gyakuno Teiri. Sitten ga ukeru Tikara ga itumo kimatta Ten O ni multe ite, katu sore no Ooisa ga sono Ten karano Kyori ni hireisuru Baai niwa, Sitten no Undô wa sono Ten O wo Tyûsin to sita Daen-sindô de aru.

Nazekanareba, Tikara no Hatarakikata ga konoyô de areba, $OP=r$, $\angle POx=\theta$ to oite, $K=kr$; sitagatte,

$$X = -K \cos \theta = -k \cdot r \cos \theta = -kx, \\ Y = -K \sin \theta = -k \cdot r \sin \theta = -ky;$$

yueni, § 179 no Teiri ni yotte, x -Hôkô no Undô mo y -Hôkô no

Undô mo kantanna Sindô ni natte, § 191 no Baai ni naru kara.

194. Syûki no tîgau kantanna Sindô no Gôsei. Syûki no tîgau kantanna Sindô no Gôsei niwa, sore no hitosii mono no yôna ippantekina kantanna Toriatukai ga dekinai. Daitaino Kekwa wo miru niwa, Dukei wo tukatte miru no ga yoi.

(a) Hôkô ga onazi Baai.

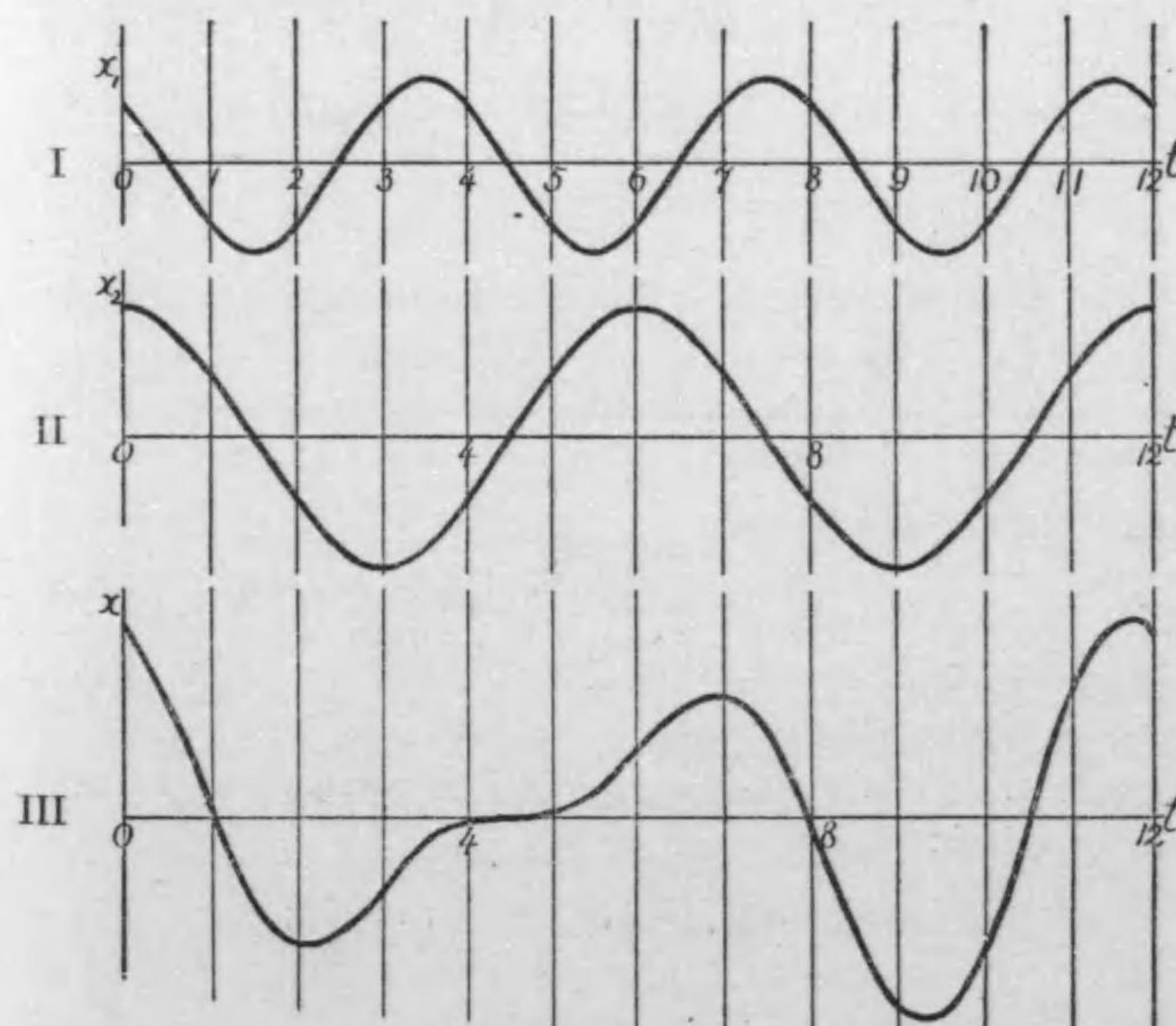
$$x_1 = a_1 \cos \left(\frac{2\pi t}{T_1} + \varepsilon_1 \right), \quad x_2 = a_2 \cos \left(\frac{2\pi t}{T_2} + \varepsilon_2 \right), \dots$$

wo gôseisuru no ni, onônono x wo t ni taisuru Seigen-kyokusen tosite egaki, onônono t ni taisuru subeteno x wo kuwaete,

$$x = x_1 + x_2 + \dots$$

no Kyokusen wo kakeba, x no Kawarikata de Gôsei-undô ga sireru.

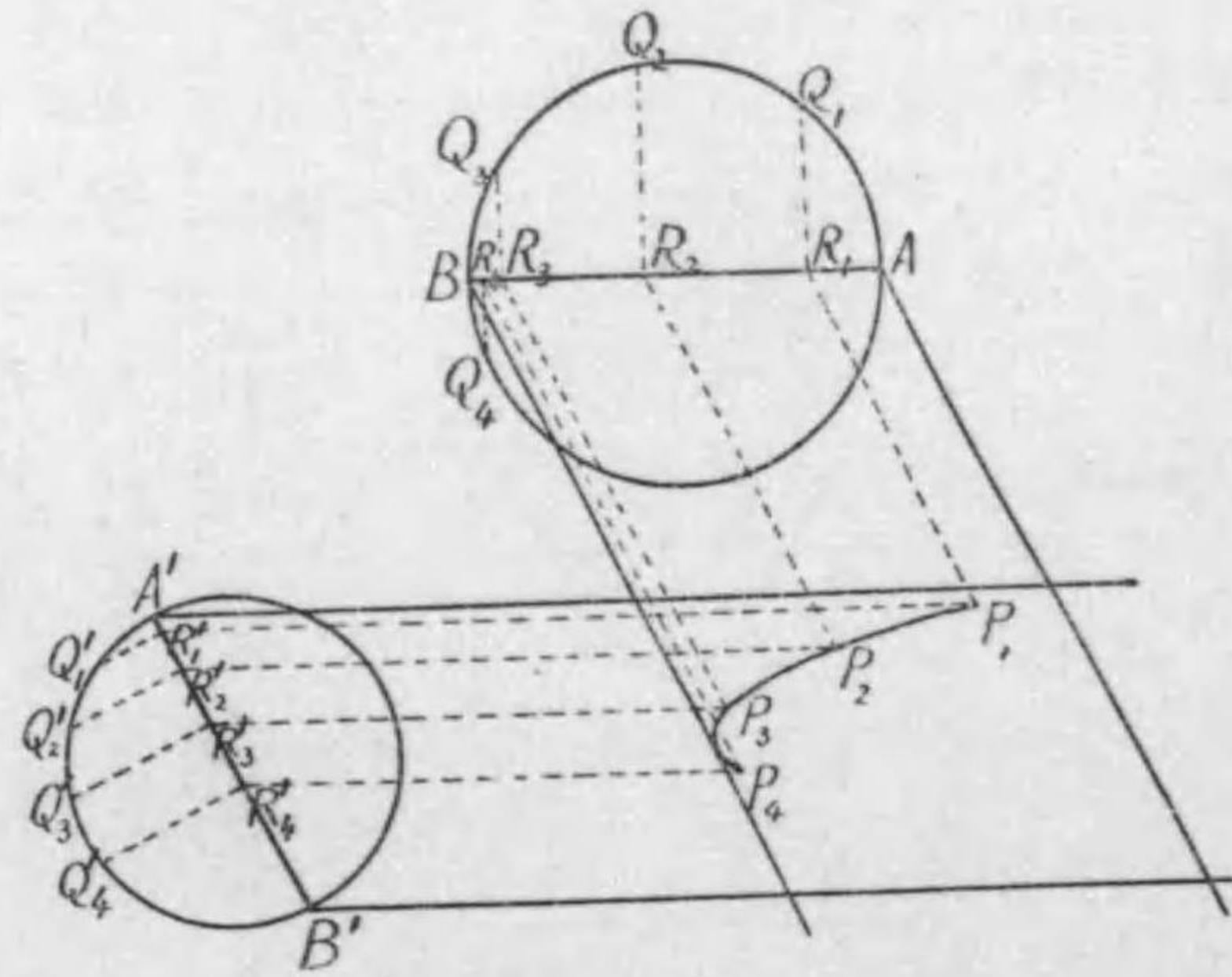
Rei. $a_1=1$ cm., $T_1=4$ s., $\varepsilon_1=\pi/4$; $a_2=1.5$ cm., $T_2=6$ s., $\varepsilon_2=0$. Korera (Du 185 no I, II) no Gôsei-undô wa III no yôni erareru.



Du 185.

(b) *Hôkô ga tigau Baai.* Hôkô mo tigai, Syûki mo tigau hutatuno kantanna Sindô wo dusikini gôscisuru niwa, madu onônono Sindô no Sen $AB, A'B'$ (Du 186) no ueni, kimatta mizikai Zikan dutu hedatatta Zikoku ni Undôten ga simeru Iti $R_1, R_2, \dots, R_1', R_2', \dots$ wo sirusu. (Kono Mokuteki niwa sore ni "huzokusuru En-undô" no Ensyû wo sono Zikan ni ataru hodo dutu ni hitosiku kitte, sorerano Ten $Q_1, Q_2, \dots, Q_1', Q_2', \dots$ kara Suityokusen wo orosite Undôten no Iti wo kimeru ga yoi).

Tugini, hutatuno Sindô ni okeru onazi Zikoku no Undôten no Iti R_1 to R_1', R_2 to R_2', \dots no onôno kara, aitenô Sindô no



Du 186.

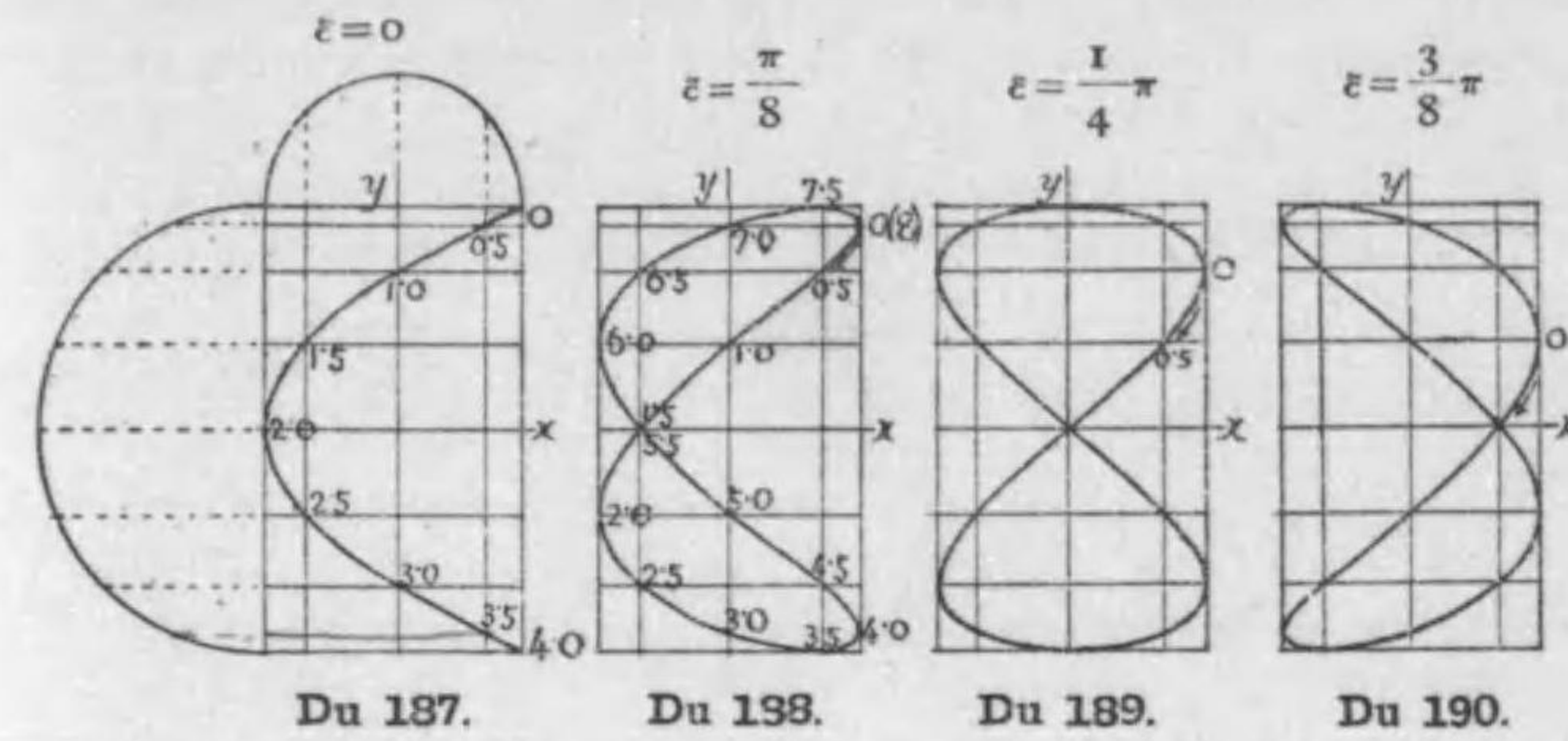
Sen ni heikôna Tyokusen R_1P_1 to $R_1'P_1, R_2P_2$ to $R_2'P_2, \dots$ wo hiite, Kiriai no Ten P_1, P_2, \dots wo kimeru. Kore ga sorerano Zikoku ni taisuru Gôsei-undô no Undôten no Iti ni naru.

Rei 1. Tagaini suityokuna Hôkô ni aru tugino kantanna Sindô no Gôsei:—

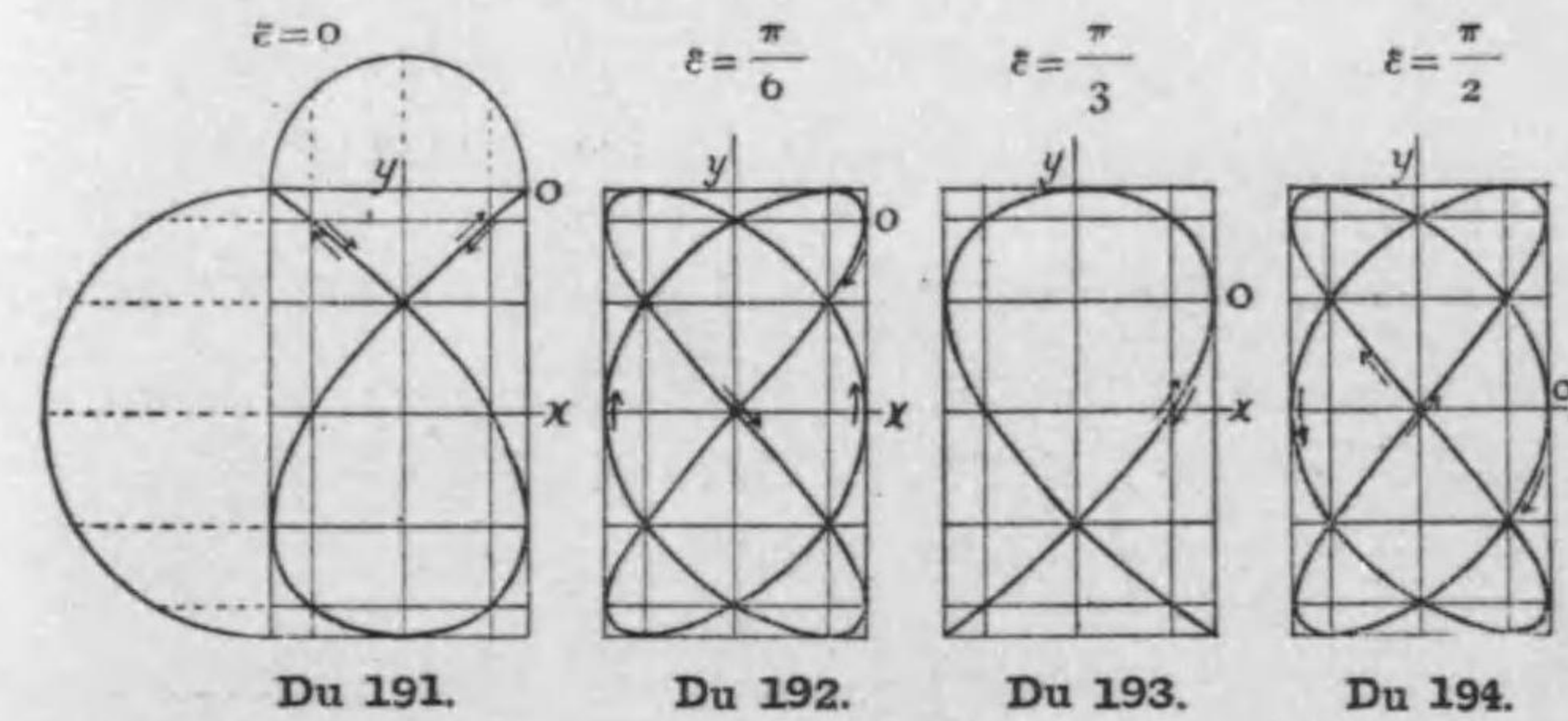
$$x = a \cos\left(\frac{2\pi t}{T_1}\right), \quad [T_1 = 4 \text{ byô}];$$

$$y = b \cos\left(\frac{2\pi t}{T_2} + \varepsilon\right), \quad [T_2 = 8 \text{ byô}].$$

Du niwa 0.5 byô gotono Ten no Iti ga kaite aru.



Rei 2. $x = a \cos\left(\frac{2\pi t}{T_1}\right), \quad [T_1 = 4 \text{ byô}];$
 $y = b \cos\left(\frac{2\pi t}{T_2} + \varepsilon\right), \quad [T_2 = 6 \text{ byô}].$



195. **Wakusei no Undô.** Mokusei, Dosei sonohokano Wakusei no Undô wo kwansokusita kekkwa, KEPLER wa tugino Hôsoku no okonawareru koto wo sitta.

(i) Wakusei wa Taiyô wo Syôten to suru Daen no ue wo ugoku.

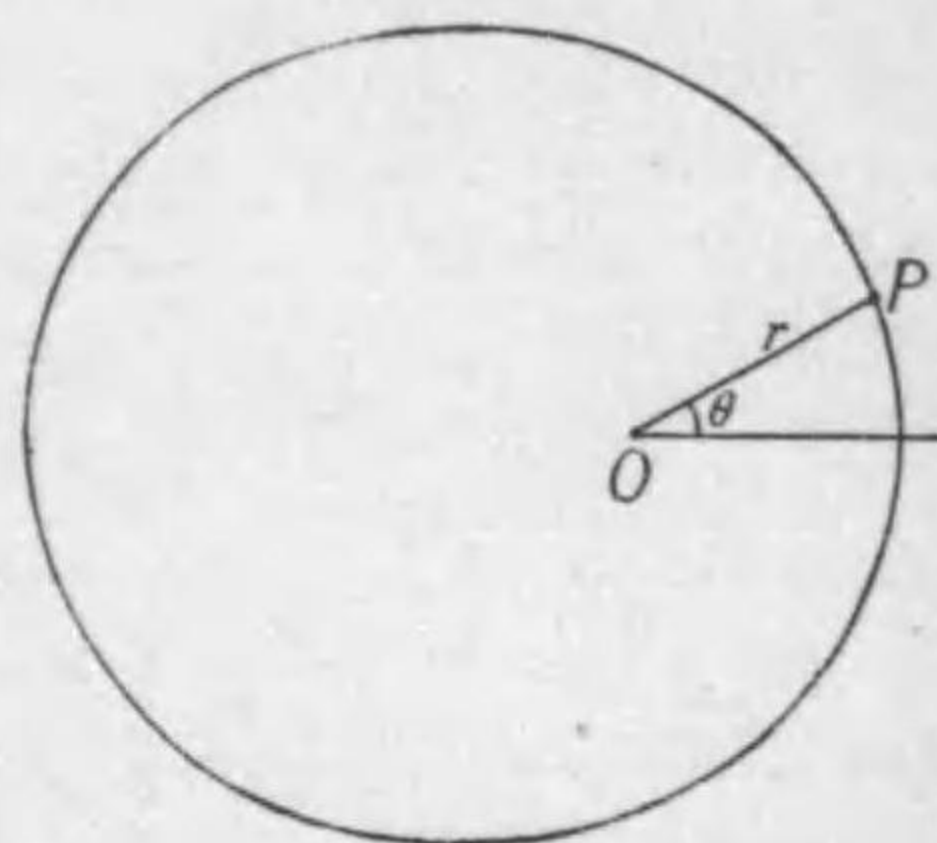
(ii) Taiyô kara Wakusei e hiita Dôkei no Menseki-sokudo wa onônono Wakusei ni tuite ittei de aru.

(iii) Tigau Wakusei ga zibun no Kidô wo hitomawari-suru Zikan no Nizyô ga Kidô no Dai-tyokkei no Sanzyô ni hireisuru.

Konoyôna Undô wo suru Wakusei ga donna Tikara wo ukete iru ka wo miyô.

196. Kidô no Heimen de Taiyô wo Kyoku to suru Kyoku-zahyô r, θ wo motte Wakusei P no Iti wo arawasi, $\theta=0$ wo, r no itiban tiisai Hôkô ni toru. Hôsoku (i) ni yotte, Dai-tyokkei wo $2a$, Risinritu wo e de arawaseba, Daen no Siki

$$r = \frac{a(1-e^2)}{1+e \cos \theta} \dots (1)$$



Du 195.

no Kwankei ga aru.

Tugini Hôsoku (ii) ni yotte, Menseki-sokudo no nibai wo h de arawaseba, (§ 125)

$$r^2 \frac{d\theta}{dt} = h \dots (2)$$

$r^2 \frac{d\theta}{dt} = \text{const.}$ de aru kara, Wakusei no ukeru Tikara wa mattaku r -Hôkô sunawati OP no Hôkô e multe iru (§ 142); kore wo, r no masu Hôkô wo (+) ni site, K to suru. Sôsûreba, Wakusei no Situryô wo m to kaite, § 123 ni yotte,

$$K = m \left(\frac{d^2 r}{dt^2} - r \left(\frac{d\theta}{dt} \right)^2 \right) \dots (3)$$

(1) wo bibunsi, mata (2) wo tukatte,

$$\begin{aligned} \frac{dr}{dt} &= \frac{a(1-e^2)}{(1+e \cos \theta)^2} e \sin \theta \frac{d\theta}{dt} \\ &= a e h (1-e^2) \frac{\sin \theta}{(1+e \cos \theta)^2} \frac{1}{r^2} = \frac{e h \sin \theta}{a(1-e^2)}; \end{aligned}$$

sitagatte,
$$\frac{d^2 r}{dt^2} = \frac{e h \cos \theta}{a(1-e^2)} \frac{d\theta}{dt} = \frac{e h^2 \cos \theta}{a(1-e^2)} \frac{1}{r^2}.$$

Soreyueni,

$$K = m \left\{ \frac{e h^2 \cos \theta}{a(1-e^2)} \frac{1}{r^2} - \frac{h^2}{r^3} \right\};$$

kore ni (1) kara eru Kwankei

$$e \cos \theta = \frac{a(1-e^2)}{r} - 1$$

wo ireruto,

$$\begin{aligned} K &= m \left\{ \frac{h^2}{r^3} - \frac{h^2}{a(1-e^2)} \frac{1}{r^2} - \frac{h^2}{r^3} \right\} \\ &= - \frac{m h^2}{a(1-e^2)} \frac{1}{r^2} \dots (4). \end{aligned}$$

$e < 1$ de aru kara, $K < 0$; sunawati, Tikara ga r no heru Hôkô ni multe ite, r^2 ni gyakuhireisuru. Sunawati, hitotuno Wakusei wa Taiyô kara Kyori no Nizyô ni gyakuhireisuru Tikara de hikarete iru.

Nao, Hôsoku (iii) ga ataeru Kwankei wo siraberu. Wakusei ga Kidô wo hitomawari-suru Zikan sunawati Syûki wo T to sureba, Daen no Menseki S wa Menseki-sokudo no Kwankei kara $\frac{h}{2} T$ ni naru. Mata Daen no Syô-tyokkei wo $2b$ to sureba, Kikagaku kara,

$$S = \pi ab = \pi a^2 \sqrt{1-e^2};$$

yueni,

$$hT = 2\pi a^2 \sqrt{1-e^2},$$

sitagatte,

$$\frac{h^2}{a(1-e^2)} = 4\pi^2 \left(\frac{a^3}{T^2} \right).$$

Kore wo (4) ni irete,

$$K = -m \cdot 4\pi^2 \left(\frac{a^3}{T^2} \right) \frac{1}{r^2}.$$

Sikaruni, $\frac{a^3}{T^2}$ wa, Hôsoku (iii) ni yotte, subeteno Wakusei ni kyôtûna Atai wo motte iru. Yueni, subeteno Wakusei wo issyoni kangaete, tugino Hôsoku ga okonawareru no de aru:—

Subeteno Wakusei wa Taiyô kara, zibun no Situryô ni hireisi, Kyori no Nizyô ni gyakuhireisuru Tikara de hikarete iru.

197. Kore wa NEWTON no Ban'yû-inryoku no Hôsoku—

Donna hutatuno Buttai demo, ryôhō no Situryō m, m' ni hireisi, Kyori, r no Nizyō ni gyakuhireisuru (sunawati $\frac{mm'}{r^2}$ ni hireisuru) Tikara de hikiatte iru,

to iu Hôsoku no hitotuno Baai de aru. Wakusei no Baai niwa hikiau Buttai no katahō ga itumo Taiyō de aru tameni, sore no Situryō ni hireisuru koto ga ueno K no Siki ni arawarenai no wa atarimae de aru.

198. Tyûsin-no-arû Tikara no Potential. Sitten ni hataraku Tikara K ga Tyûsin (§ 142) wo motte ite, katu Tyûsin karano Kyori r ni taisite kimatta Kwankei

$$K=f(r)$$

[K niwa, haneru Tikara (r wo masu yōni hataraku Tikara) naraba (+)-Kigō, hiku Tikara (r wo herasu yōni hataraku Tikara) naraba (-)-Kigō wo tukete oku koto ni kimeru.] wo nasu tokiniwa, § 169 no Dyōken ga okonaware, sitagatte Potential (§ 170) ga naritatu.

Nazekanareba, Sitten ga P kara sore ni kiwamete tikai P' made susumu aidano Sigoto wa, — O wo Tyûsin to si, $OP=r$, $OP'=r+dr$, $\angle(K, PP')=\theta$ to sureba —

$$dW=K \cos \theta ds=f(r) PP' \cos \theta =f(r) \overline{PQ}=f(r) dr.$$

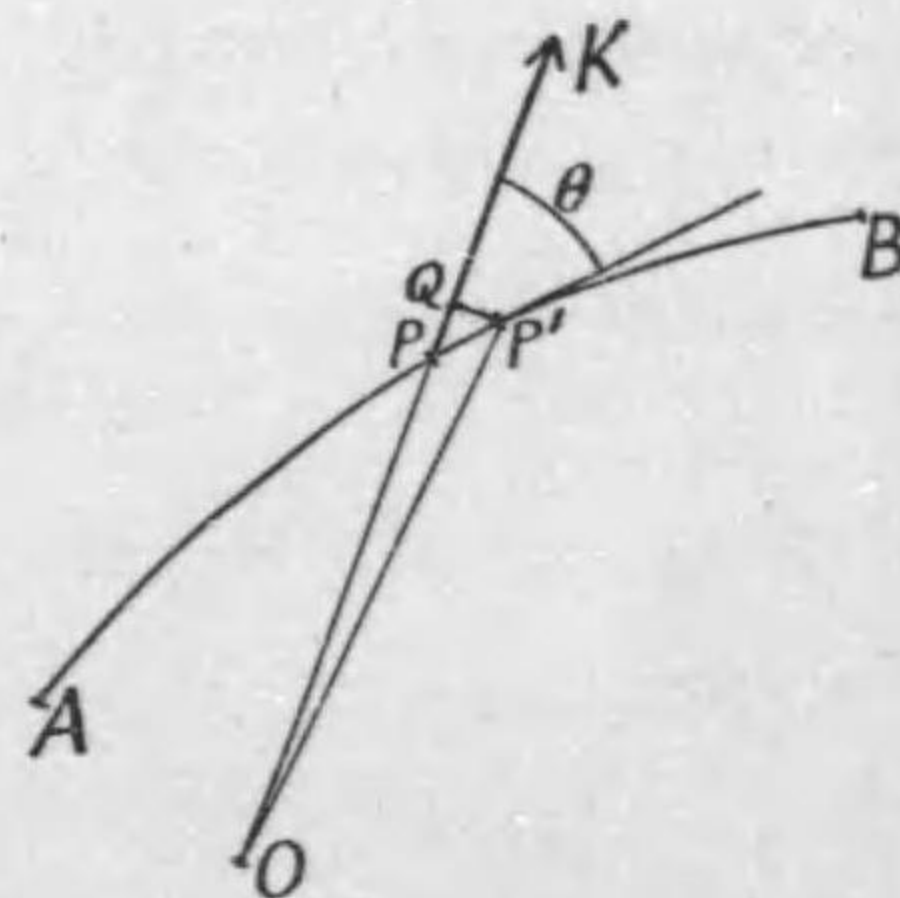
Soreyueni, Sitten ga A ($OA=r_1$) kara B ($OB=r_2$) ni yuku madeniwa,

$$W=\int_{r_1}^{r_2} f(r) dr=F(r_2)-F(r_1);$$

tadasi $F(r)$ wa $f(r)dr$ no Hutei-sekibun (§ 261). Kore wa A to B to no Iti ni nomi yotte, Totyû no Mitisudi niwa yoranai Ryô de aru. Kore wo § 169 de mita yōna Katati ni suru niwa,

$$W=[-F(r_1)]-[-F(r_2)]$$

to kaku koto ga hituyō de aru. Sosite, Potential wa



Du 196.

$$\Phi=-F(r)=-\int f(r) dr$$

to naru.

§ 192 no Daen-sindô dewa, $f(r)=-kr$; sitagatte,

$$\Phi=\int kr dr=\frac{1}{2} kr^2.$$

[Φ no Hakarihazime ga $r=0$ no Ten ni totte aru.]

Kantanna Sindô wa Daen-sindô no tokubetuna Baai de aru kara, Φ mo onazi Siki ni naru.

§ 190 no Ban'yû-inryoku dewa, “Ban'yû-inryoku no Zyôsû” wo f to si, hiku Buttai no Situryō wo m , hikareru Buttai no Situryō wo 1 to totte,

$$K=-\frac{fm}{r^2},$$

sitagatte,

$$\Phi=-\frac{fm}{r}.$$

[Φ no Hakarihazime ga $r=\infty$ ni totte aru.]

Korerano Φ wa Potential de aru to dôzini *Iti-sciryoku* de aru koto wa maeni (§ 170) nobeta tôri de aru.

Rensyû-mondai VI.

1. Kantanna Sindô no Syûki ga $T=0.5$ byô, Hurihaba ga 2 cm. de aru tokini, Sitten no saidaino Hayasa wa ikura ka?
2. Hitotuno kantanna Sindô de, Tyûsin karano Kyori s_1 ni okeru Hayasa ga v_1 , s_2 ni okeru Hayasa ga v_2 de aru tokini, $s_1^2-s_2^2$ to $v_2^2-v_1^2$ to no aidani kimatta Kwankei ga okonawareru koto wo syômeisei!
3. Aru Tihô de Nagasa 1 m. no Sitten-huriko no Syûki ga 2'01 s. da to sureba, soko no Dyûryoku no Tuyosa wa ikura ka?
4. Syûki ga 1 s. no Huriko wo motta Tokei ga itiniti ni 30 byô dutu susumu. Ima kono Huriko wo Sitten-huriko to dôto

to mite, Susumi-okure wo nakusuru niwa, Huriko wo ikura sagereba yoi ka?

5. Rasenbane no ueno Hazi wo koteisi, sitano Hazi ni 1 kg. no Omori wo kaketa tokini, Bane ga 3 cm. hodo nobite turiau. Ima kono Bane ga Omori 100 g. ni taisite 5 mm. dutu nobiru to sureba, Omori 1 kg. wo kaketa mono wo nao sukosi nobasite hanasu tokini donna Undô wo suru ka? [Kataku maite aru Rasenbane wa, sore wo hiku Tikara ga aru Bunryô wo koenai aida, sukosimo nobinai no ga hutû de aru. Kono Mondai no Bane wa, Omori 400 g. made nobinakatta wake de aru.]

6. Mondai 5 to onazi Bane nihon wo, 1 kg. no Omori no ue to sita to ni tunagi, nihon tomoni entyokuna Iti ni oite hiki-nobasita Katati de, ueno Bane no ueno Hazi to sitano Bane no sitano Hazi to wo koteisi, Omori wo uesitani huraseru tokini okoru Sindô no Syûki wa ikura ka?

7. 1 kg. no Tikara de Nagasa 24 cm. ni hikinobasarete iru Rasenbane nihon wo tunaide, suiheina Iti de Ryôhazi wo koteisi, mannakano Ten ni 1 kg. no Omori wo kaketa tokini, sono Ten ga 10 cm. orite turiatte iru. Kono Omori wo sukosi sitani hiite hanasu tokini, sore ga donna Syûki wo motte sindôsuru ka?

8. Massuguna hosoi haganenô Bô ga, sitano Hazi wo sikkarisita Dai ni kataku sasikonde sasaete aru. Bô no ueno Hazi wo yokoni hiku tokini, 100 g. no Omosa ni hitosii Tikara de 5 mm. ugoku. Ima Bô no ueno Hazi ni 500 g. no Omori wo toritukete yokoni huraseru to sureba, Sindô no Syûki wa ikura ka? [Kono Mondai dewa, Undô ga osoi tameni, hosoi Bô wa itudemo ueno Hazi wo yokoni hikarete turiatte iru Baai to onazi Katati wo nasite iru to minasu.]

9. x -Diku no ue wo ugoku Sitten no Iti ga

$$x = ae^{-\lambda t} \cos(nt + \epsilon)$$

de ataerareru tokini, $x=0$ ni naru tugitugino Zikoku no Kwankai, oyobi x no tugitugino saidai-, saisyôno Atai no Kwankai wo sirabe, katu kono Sitten no Undô wo (t, x) no Kyokusen ni yotte arawase!

[Ueno Siki de arawasareru Undô wo "otoroeru Sindô" to iu.]

10. Ueno Mondai no Sitten ga ukeru Tikara ga itumo

$$X = -kx - c \frac{dx}{dt}$$

no Katati ni kakareru koto wo syômeisi, katu k, c oyobi Sitten no Situryô m ga ataete aru tokini, kono Tikara ni yotte okoru "otoroeru Sindô" no λ oyobi n no Atai wo keisansei!

11. Hitotuno Heimen de, Tyokkaku-zahyô

$$x = 5 \cos\left(\frac{\pi}{6}t + \frac{\pi}{3}\right), y = 3 \cos\left(\frac{\pi}{4}t - \frac{3\pi}{4}\right)$$

de ataerareru Ten no Undô wo Du ni arawase!

12. Hitotuno Heimen de, Tyokkaku-zahyô

$$x = 5 \cos \frac{2\pi t}{2'01} \text{ cm.}, y = 5 \sin \frac{2\pi t}{2'00} \text{ cm.} \quad [t \text{ no Tan'i wa Byô}]$$

de ataerareru Ten no Undô wo sirabei!

13. Itudemo Zahyô-genten ni mukatte, soko karano Kyori r cm. ni hireisuru Tikara kr dyne ($k=90$) de hikareru Sitten (Situryô=10 g.) ga aru. $x=2$ cm., $y=1$ cm. no Ten de $+y$ no Hôkô ni 4 cm./s. de nagedasarete okoru Undô wo sirabei!

14. Onazi Takasa ni aru hutatuno ugokanai Ten A, B ni, sorera no Hedatari yorimo nagai nobinai Ito no Ryôhazi wo musubituke, Ito no mannakano Ten C ni betuno nobinai Ito wo musubitukete, sore no sitano Hazi P ni Omori wo torituketa Sôti wo "Blackburn no Huriko" to tonaeru. Kono Sôti wa AB -Sen wo hukumu Entyokumen dewa PC dake no Sitten-huriko no Undô wo si, AB -Sen ni suityokuna Entyokumen dewa PD (D wa AB no mannakano Ten) dake no Sitten-huriko no Undô wo suru. Ima, $PC=80$ cm., $PD=180$ cm. to site, tiisai Kuiki no Sindô wo saseru tokini, Huriko wa donna Undô wo suru ka?

15. Mondai 5 ni okeru to onazi (100g. ni taisite 5 mm. nobiru) Rasenbane A no ueno Hazi wo koteisite, sitano Hazi ni 900 g. no Omori wo torituke, sore no sitani mohitotuno dôyôna Rasenbane B wo tunaide, kono Rasenbane B no sitano Hazi ni 600 g. no Omori wo toritukeru. Kono Sikake zentai ga Entyokusen ni sôte sindôsuru Undô wo sirabei!

16. Koteisita Ten kara Nagasa l cm. no nobinai Ito wo sagete, sore no sitano Hazi ni 1500 g. no Sitten wo torituke, sore kara mata l cm. no nobinai Ito wo sagete, itiban sitani 500 g. no Sitten wo torituketa Sôti (Nidyû-huriko) ga aru. Kore ga hitotuno Entyokumen de nasu tiisai Sindô wo sirabei!

17. Tikyû ga Taiyô no mawari wo, Hankei 149 500 000 km. no En wo egaite 365.3 niti ni hitomawarisi, Tuki wa Tikyû no mawari wo Hankei 385 000 km. no En wo egaite 27.32 niti ni hitomawarisuru to kateisureba, Taiyô no Situryô wa Tikyû no Situryô no nanbai aru ka?

18.* Tikyû no ue kara donna Sokudo wo motte Taihô no Tama wo utidaseba, sore ga Dimen wo eikyûni hanareru ka? Tadasî, Tikyû wo kwaitensinai itiyôna Kyû (Hankei 6370 km.) to mi, mata Kûki no Teikô ga nai to kateisuru.

19. Namerakana Bô ga sore no hitotuno Ten wo Tyûsin to site, itiyôna Kakusokudo ω de suiheini mawatte iru. Sore ni hamatte iru Wa wo, saisyô Tyûsin kara Kyori a ni sasaete oite hanaseba, sore no Tyûsin karano Kyori ga

$$r = \frac{1}{2} a(e^{\omega t} + e^{-\omega t})$$

ni sitagau yôni ugoku koto wo syômeisei!

20. Ueno Mondai de Kwaiten no Tyûsin ga Bô wo hadureta Tokoro ni attemo, mosimo Tyûsin kara Bô ni hiita Suisen no Asi kara r wo hakaru to sureba, onazi Kwankei ga naritatu koto wo syômeisei!

21. Suiheina namerakana Kuda no nakani aru Sitten ga gomuno Ito de Kuda no nakano hitotuno Ten O ni musunde aru. Kono Kuda wo, O -Ten wo tôru Entyokusen wo Diku to site, kimatte Hayasa de mawasu tokini, Sitten ga donna Undô wo suru ka? [Gomuno Ito no Tyôryoku wa sore no Nobî ni hireisuru mono to suru.]

22. Heimen no ue wo ugoku Sitten ga, itumo zibun no susumu Hôkô kara hidarini 60° katamuita Hôkô ni kimatta Ooisa no Tikara de hikareru to sureba, Sitten no Undô no Mitisudî wa dô naru ka?

Daisanno Oowake.

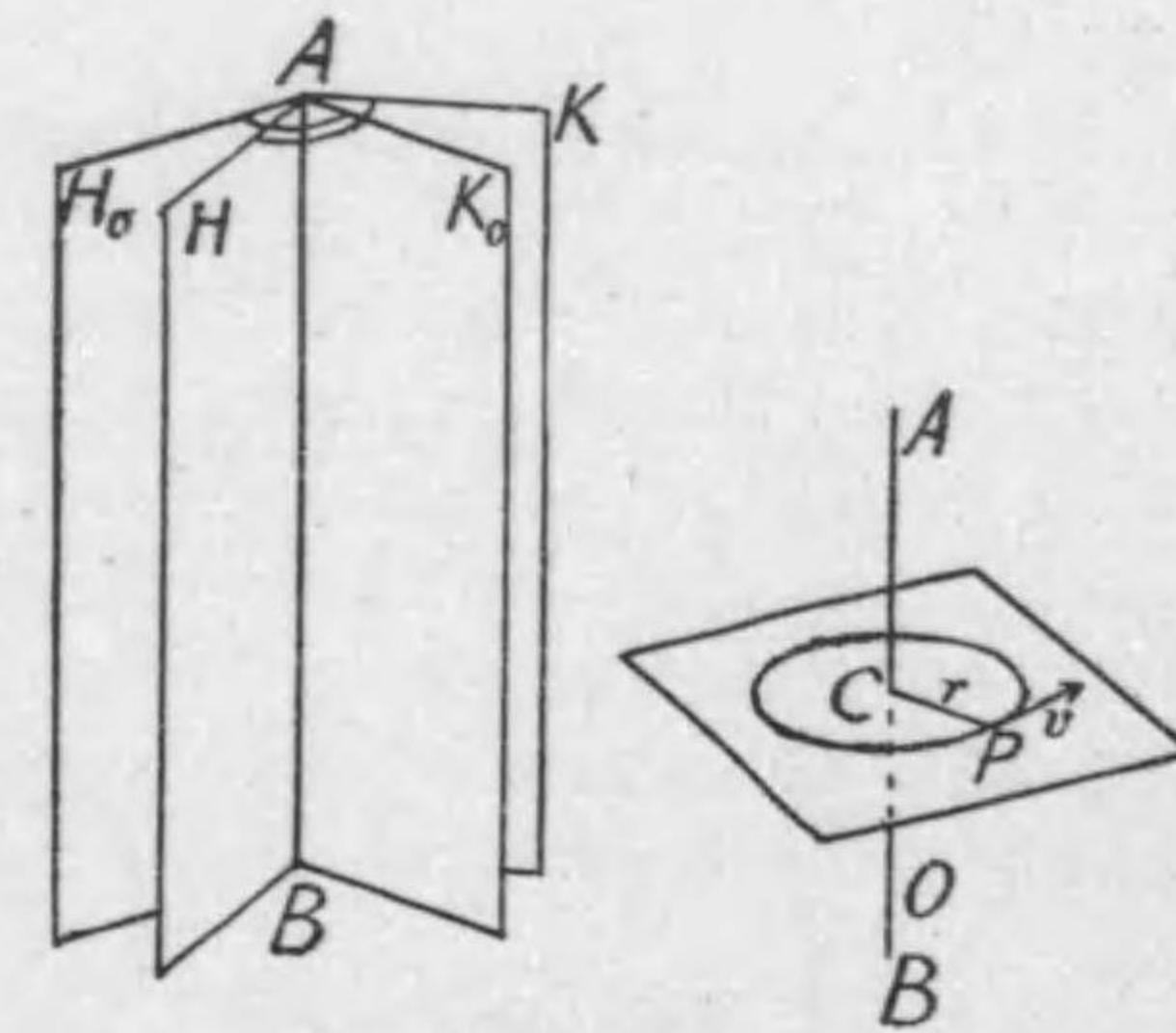
GÔTAI NO UNDÔ.

SYOO VII.

Kimatta Diku no mawarino Undô.

201. Gôtai no Kwaiten-undô. Gôtai no utino hitotuno Tyoku-

sen AB (Du 201) ga Iti wo kaenai yôni natte iru Baai niwa, Gôtai wa kono Tyokusen wo Diku to site *kwaitensuru* dake de aru. Hitotuno konoyôna Hen'i (*Kwaiten-hen'i* matawa *Kaku-hen'i*) no tameni AB wo hukumu Gôtai ni koteisita iroirona Heimen no Uturikata wo miru. Hazime H_0AB ni atta Heimen ga HAB ni, K_0AB ni atta Heimen ga



Du 201

KAB ni kita to sureba, $\angle H_0AH = \angle K_0AK$ no Kwankei ga aru ($\angle HAK = \angle H_0AK_0$ da kara). Sunawati, Diku wo hukumu subetono Heimen wa mina onazi Kaku dake mawatte iru. Kono Kaku ga "Gôtai zisin no *Kwaiten no Kaku*" de aru. Ima kore wo φ de arawasu.

Gôtai no hazimeno Iti wo kimete, sore kara mawatta Kaku φ wo hakaru to sureba, $\frac{d\varphi}{dt}$ ga "Gôtai no *Kwaiten-sokudo* matawa *Kakusokudo*" de aru. Tûzyô sore wo ω de arawasu.

Gôtai no kattena Ten P wa, sore wo hukumu AB ni sui-tyokuna Heimen no ue de, kono Heimen to AB to no Kiraiten C wo Tyûsin to suru En no ue wo ugoku. Sore no ugoku Hayasa v wa, $PC=r$ to sureba,

$$v = r \frac{d\varphi}{dt} = r\omega$$

de aru.

202. Undô no Hôteisiki. Kimatta Kwaitendiku wo motta Gôtai ni Tikara ga hataraku tokini, Gôtai no Undô no Arisama wa dô naru ka wo siraberu.

Kwaitendiku no kattena Ten wo Zahyô-genten to si, Kwaitendiku wo *z*-Diku ni tori, *x*-Diku to *y*-Diku wa sore ni suityokuni zuini toru.

Gôtai wo musûno Sitten no Atumari to mite, sore no onôno ni hataraku Tikara wo kangaereba, Gôtai no soto kara hataraite iru Tikara, sunawati "sotono Tikara (Gwairyoku)" to, Gôtai no utino hokano Sitten kara hataraite iru Tikara sunawati "utino Tikara (Nairyoku)" to hutasyurui aru.

Onônono Sitten *P* (Du 202) ni tuite, sore no Situryô wo *m* to si, sore ni hataraku sotono Tikara no *x*-, *y*-Seibun wo *X*, *Y* to si, utino Tikara no *x*-, *y*-Seibun wo *X_u*, *Y_u* to sureba, tugino Hôteisiki ga naritatu:—

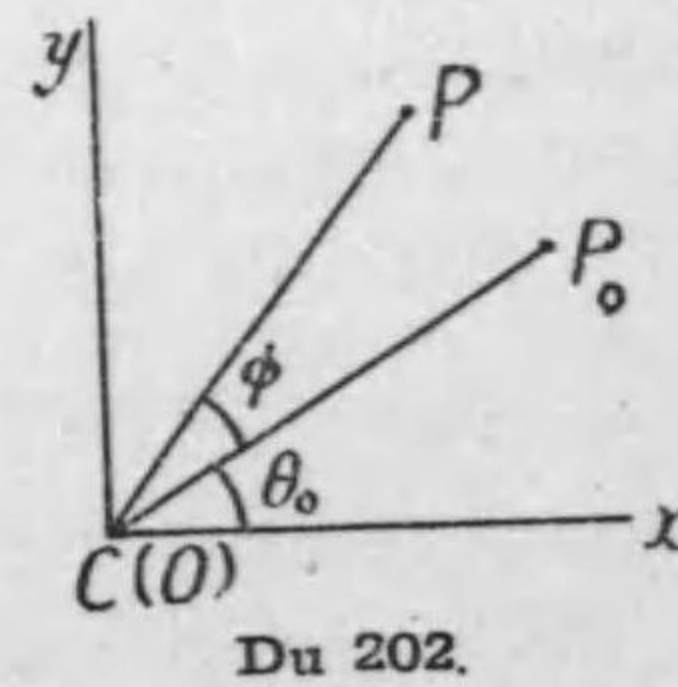
$$\left. \begin{aligned} m \frac{d^2x}{dt^2} &= X + X_u, \\ m \frac{d^2y}{dt^2} &= Y + Y_u \end{aligned} \right\} \dots\dots(1).$$

Korera ni sorezore $-y$ to x wo kakete kuwaereba,

$$x \cdot m \frac{d^2y}{dt^2} - y \cdot m \frac{d^2x}{dt^2} = x(Y + Y_u) - y(X + X_u),$$

sunawati,

$$\frac{d}{dt} \left[m \left(x \frac{dy}{dt} - y \frac{dx}{dt} \right) \right] = x(Y + Y_u) - y(X + X_u) \dots\dots(2).$$



Du 202.

P kara Kwaitendiku ni orosita Suityokusen *PC* ga *x*-Diku to tukururu Kaku wo θ to sureba, $\theta = \theta_0 + \varphi$ (θ_0 wa θ no hazimeno

Atai, φ wa hazime kara ima madeno Gôtai no Kwaiten-kaku); nao $PC=r$ to site,

$$\begin{aligned} x &= r \cos \theta = r \cos (\theta_0 + \varphi), \quad y = r \sin \theta = r \sin (\theta_0 + \varphi), \\ \frac{dx}{dt} &= -r \sin (\theta_0 + \varphi) \frac{d\varphi}{dt} = -y\omega, \quad \frac{dy}{dt} = r \cos (\theta_0 + \varphi) \frac{d\varphi}{dt} = x\omega \\ &\dots\dots(3). \end{aligned}$$

Kore wo tukatte keisansuruto, tugino yôni naru:—

$$x \frac{dy}{dt} - y \frac{dx}{dt} = (x^2 + y^2)\omega = r^2\omega.$$

Kore wo (2) ni ireruto, *r* wa kawaranai kara,

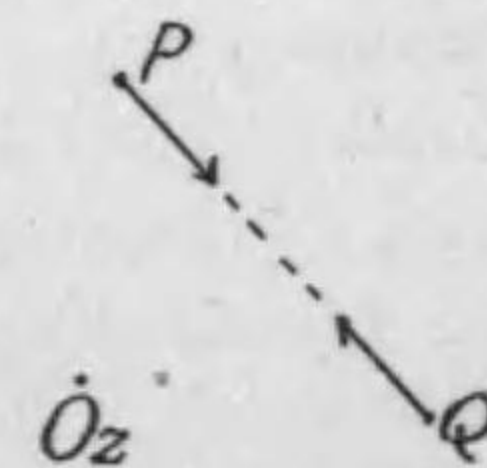
$$mr^2 \frac{d^2\varphi}{dt^2} = mr^2 \frac{d\omega}{dt} = x(Y + Y_u) - y(X + X_u).$$

Subeteno Sitten ni tuite kono Kwankei ga okonawareru kara, sorera wo mina kuwaeruto, ω wa subete ni kyôtû de aru kara,

$$(\Sigma mr^2) \frac{d\omega}{dt} = \Sigma \{ x(Y + Y_u) - y(X + X_u) \},$$

sunawati, $(\Sigma mr^2) \frac{d\omega}{dt} = \Sigma (xY - yX) + \Sigma (xY_u - yX_u) \dots\dots(4).$

Koko de Migigawa ni aru Siki wa § 38 de mita "*z*-Diku no mawarino Tikara no Moment" de aru. Kotoni, saigono Kô wa, Sitten dôsi ga tagaini oyobosu Tikara no Moment no Wa de atte, Sitten *P* (Du 203) ga *Q* kara ukeru Tikara no Moment to *Q* ga *P* kara ukeru Tikara no Moment to no yôna ittui dutu ni natte iru Ryô no Wa de aru. Sika-runi, kôiu ittuino Tikara wa, § 151 no Hôsoku ni yotte, kyôtûna Sayôsen ni sôte hantaino Muki ni hataraite ka-tu Ooisa ga hitosii tameni, sorera no Moment no Wa wa o de aru. Sitagatte, sôiu Ryô wo kuwaeta Ryô de aru tokorono



Dn 203.

$$\Sigma (xY_u - yX_u) = 0 \dots\dots(5)$$

Yueni, $(\Sigma mr^2) \frac{d\omega}{dt} = \Sigma (xY - yX) \dots\dots(6).$

Kokoni, $\Sigma mr^2 = \Sigma m(x^2 + y^2)$ wa "*z*-Diku no mawarino Gôtai no *Kwansei* no Moment matawa *Kwansei-moment*" to tonaeru

Ryô de, tûzyô sore wo I de arawasu. Mata, onazi Siki no Migigawa wa *soto kara Gôtai ni hataraite iru Tikara no Kwaitendiku no mawarino Moment no Wa* de atte, ima sore wo G de arawasuto, ueno Siki wa tugino yôni naru:—

$$I \frac{d\omega}{dt} = G \dots\dots\dots(7)$$

$\frac{d\omega}{dt}$ no kawarini $\frac{d^2\varphi}{dt^2}$ to kaitemo yoi.

Tyûi 1. Ueno Siki ni aru $I = \sum m(x^2 + y^2)$ wa, Gôtai wo Sitten ni wakete kangaeru sono Wakekata niwa yorazu, hakkiri Keisan no dekiru Ryô de aru koto wa, notini noberu yôyôna Baai ni taisuru Keisan no Rei wo mitemo wakarû.

Tyûi 2. Ueno Siki (7) wa

$$\frac{d}{dt}(I\omega) = G$$

to kakeru. Kono

$$I\omega = \omega \sum mr^2 = \sum m \left(x \frac{dy}{dt} - y \frac{dx}{dt} \right)$$

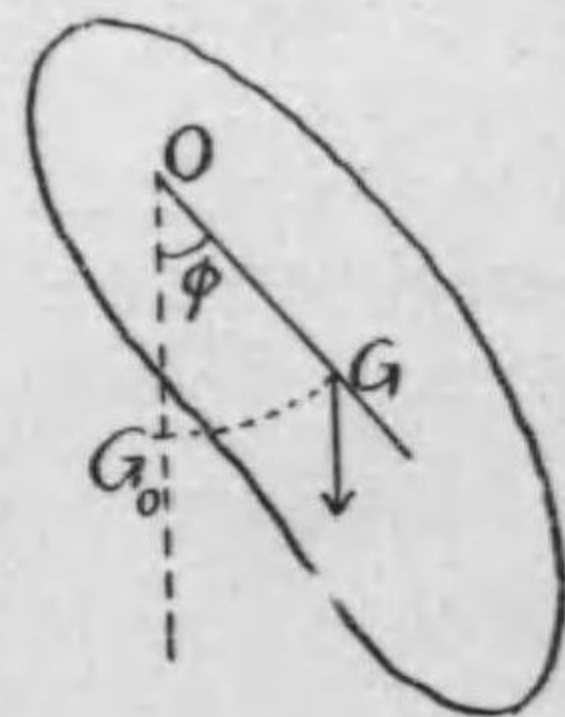
wa, notini motto ippanno Baai ni tokiakasu “Kaku-undôryô” de aru.

Tyûi 3. $G = \sum(xY - yX)$ no Keisan dewa, Gôtai wo Sitten no Atumari to miru koto wa hituyô de nai; soko ni aru (x, y) wa tanni Tikara (X, Y) no hataraite iru Ten no Zahyô de aru.

203. Rei. Zittai-huriko. Gôtai no Dyûsin wo tôranai Tyokusen wo kimatta suiheina Iti ni sasaete, Gôtai ga sore wo Kwaitendiku to site sindôsuru mono wo *Zittai-huriko* (matawa *Hukusinsi*) to tonaeru.

Dyûsin G (Du 204) wo tôte, Kwaitendiku ni suityokuna Heimen $G_0 OG$ wo Du no Heimen to si, Kwaitendiku wa O wo maesironi turanuku mono to suru.

Gôtai no Situryô wo M , $OG = h$ to si, OG ga sitamukino Entyokusen to tukuru Kaku wo φ to sureba, Diku O no mawarino Tikara no Moment wa,



Du 204.

$$- Mgh \sin \varphi$$

de aru; (-)-Kigô wo tuketa no wa, kono Moment ga φ wo *herasu* hô ni multe iru kara de aru. Soreyueni, Undô no Hôteisiki wa

$$I \frac{d^2\varphi}{dt^2} = -Mgh \sin \varphi \dots\dots\dots(1).$$

Kono Hôteisiki wo Sitten-huriko no Undô no Hôteisiki (§ 186)

$$\frac{d^2\theta}{dt^2} = -\frac{g}{l} \sin \theta$$

to kurabete mireba, $\frac{g}{l}$ no kawarini $\frac{Mgh}{I}$ ga aru dakeno Tigai de aru. Soreyueni, kono Zittai-huriko no Undô wa, Nagasa

$$L = \frac{I}{Mh} \dots\dots\dots(2)$$

no Sitten-huriko no Undô to mattaku onazikoto de aru. Sosite, Sinpuku no tiisai Baai ni,

$$\varphi = \alpha \cos \left(\sqrt{\frac{Mgh}{I}} t + \varepsilon \right)$$

ni nari, Syûki wa

$$T = 2\pi \sqrt{\frac{L}{g}} = 2\pi \sqrt{\frac{I}{Mgh}} \dots\dots\dots(3)$$

ni naru.

Ueno $L = \frac{I}{Mh}$ wo “dôtôna Sitten-huriko no Nagasa” to

tonaeru.

Zittai-huriko no yôyôna Seisitu ga nao § 211 ni aru.

204. Seiryoku no Hôteisiki. Kwaitensite iru Gôtai wo Sitten no Atumari to mi, sorerano Sitten no Situryô wo m_1, m_2, \dots to site, sore kara Kwaitendiku madeno Kyori wo sorezore r_1, r_2, \dots to sureba, Gôtai ga Kakusokudo ω de mawatte iru tokino sorerano Sitten no Hayasa wa sorezore $r_1\omega, r_2\omega, \dots$ de aru (§ 201). Soreyueni, Gôtai ga motte oru Undô-seiryoku wa

$$\begin{aligned} & \frac{1}{2}m_1r_1^2\omega^2 + \frac{1}{2}m_2r_2^2\omega^2 + \dots \\ &= \frac{1}{2}(\Sigma mr^2)\omega^2 \\ &= \frac{1}{2}I\omega^2 \dots \dots \dots (1) \end{aligned}$$

de arawasareru.

Tugini, Gôtai no ueno Ten P (Diku madeno Suisen-kyori $PC=r$) ni hataraku sotonon Tikara wo K to site, P ga egaku En no Sessen no Hôkô ni okeru sore no Bunryoku wo K' to si, Ten P no ugoita Kyori wo s to sureba, Gôtai ga Kaku φ dake mawaru aidani, K no nasita Sigoto wa,

$$\int_0^s K' ds = \int_0^p K' r d\varphi.$$

Soreyue, konoaidani Gôtai ni hataraku subeteno Tikara no nasita Sigoto wa,

$$W = \Sigma \int_0^p K' r d\varphi = \int_0^p (\Sigma K' r) d\varphi = \int_0^p G d\varphi \dots (2).$$

Koko de $\Sigma K' r$ wo G to suru koto wa, Tikara ga Diku ni suityokuna Heimen ni aru Baai ni tuite § 36 de mita Koto kara wakaru. [Tikara ga Kwaitendiku ni heikôna Seibun wo motu Baai demo, § 68 ni yotte kono Seibun wa G ni mukwankei da kara, $\Sigma K' r = G$ no Kwankei wa yahari okonawareru.]

Sigoto W to Undô-seiryoku $\frac{1}{2}I\omega^2$ to no Kwankei wa Undô no Hôteisiki (7) (§ 202) kara erareru. $\omega dt = d\varphi$ de aru kara, (7) no Hidarigawa ni ωdt , Migigawa ni $d\varphi$ wo kakete, hazime kara ima made sekibun sureba,

$$\int_0^\omega I\omega d\omega = \int_0^p G d\varphi,$$

sunawati, I ga kawaranai kara,

$$\frac{1}{2}I\omega^2 - \frac{1}{2}I\omega_0^2 = \int_0^p G d\varphi = W \dots \dots (3).$$

Kore ga Seiryoku no Hôteisiki de aru.

Rei. Maeno § no Rei ni ueno Toriatukai wo sureba, $\frac{1}{2}I\omega^2 = \frac{1}{2}I\omega_0^2 - Mgh(1 - \cos \varphi)$ wo eru; tadasi, ω_0 wa OG -Sen ga entyokuni sitani muita Baai no ω no Atai.

205. Kwansai-moment. Gôtai wo ikutu kano tiisai Bubun kara naru yôni kangae, onônono Bubun no Situryô wo m , sore kara ataereta Tyokusen (Diku) AB ni itaru Suisen-kyori wo r to suru tokini,

$$I = \Sigma mr^2 \dots \dots \dots (1)$$

wo "Tyokusen AB no mawarino Kwansai-no-Moment matawa Kwansai-moment" to tonaeru koto wa maeni mita. Hutûno Gôtai dewa, Bussitu ga renzokutekini hirogatte oru node, sore no Situryô-element wo dm , Taiseki-element wo $d\tau$ to si, soko no Mitudo wo ρ de arawaseba,

$$I = \int r^2 dm = \int r^2 \rho d\tau \dots \dots \dots (2)$$

de aru.

Kotoni, x -, y -, z -Zahyôdiku no mawarino Kwansai-moment wa

$$\left. \begin{aligned} I_x &= \int (y^2 + z^2) \rho d\tau, \\ I_y &= \int (z^2 + x^2) \rho d\tau, \\ I_z &= \int (x^2 + y^2) \rho d\tau \end{aligned} \right\} \dots \dots \dots (3).$$

206. Kwaiten-hankei. Gôtai no zentaino Situryô wo M to site,

$$I = Mk^2 \dots \dots \dots (4)$$

to oku tokini, kono k wo, "Tyokusen (Diku) AB no mawarino Gôtai no Kwaiten-hankei" to tonaeru.

Kotoni Zahyôdiku no mawarino mono wo k_x, k_y, k_z to kaku. Gôtai no Mitudo ga itiyô de aru Baai niwa

$$I = \rho \int r^2 d\tau, \quad M = \rho \int d\tau;$$

sitagatte,
$$k^2 = \frac{\rho \int r^2 d\tau}{\rho \int d\tau} = \frac{\int r^2 d\tau}{\int d\tau} \dots\dots\dots(5)$$

wa Mitudo ni kwankeisinai, tada Gôtai no Katati to *AB* Sen no Iti ni nomi yoru Ryô de aru. Mata, ueno Siki kara mieru tôri, Kwaiten-hankei *k* wa *r* no issyuno heikinno Atai de aru.

207. *Kiwamete usui tairana Ita* ni kwansuru Teiri. Buttai ga kiwamete usukute katu heimenna Ita de aru Baai niwa, sore no Menseki-mitudo wo σ , Menseki-element wo dS to site, kono Heimen wo *xy*-Zahyômen to kimereba,

$$\left. \begin{aligned} I_x &= M k_x^2 = \int y^2 \sigma dS, \\ I_y &= M k_y^2 = \int x^2 \sigma dS, \\ I_z &= M k_z^2 = \int (x^2 + y^2) \sigma dS \end{aligned} \right\} \dots\dots(6);$$

soreyueni,

$$I_z = I_x + I_y \dots\dots\dots(7),$$

mata
$$k_z^2 = k_x^2 + k_y^2 \dots\dots\dots(8)$$

no Kwankei ga aru. Sunawati,

Heimen no ue de tagaini suitiyokuna hutatuno Diku ni taisuru Kwansei-moment no Wa wa, korerano Diku no Maziwari no Ten wo tôte, kono Heimen ni suitiyokuna Diku ni taisuru Kwansei-moment ni hitosii.

Tyûi. Ueno Siki (6) de, $\sigma=1$ to oïta Baai no I_x, I_y, I_z wo "Menseki no Kwansei-moment" to yobu.

208. *Heikôna Diku no mawarino Kwansei-moment.* Aru Tyokusen no mawarino Gôtai no Kwansei-moment I wo motomeru tameni, kono Tyokusen wo *s*-Diku ni toreba, Gôtai no utino tiisai Bubun P no Situryô wo m, x, y -Zahyô wo x, y to site,

$$I = \sum m(x^2 + y^2).$$

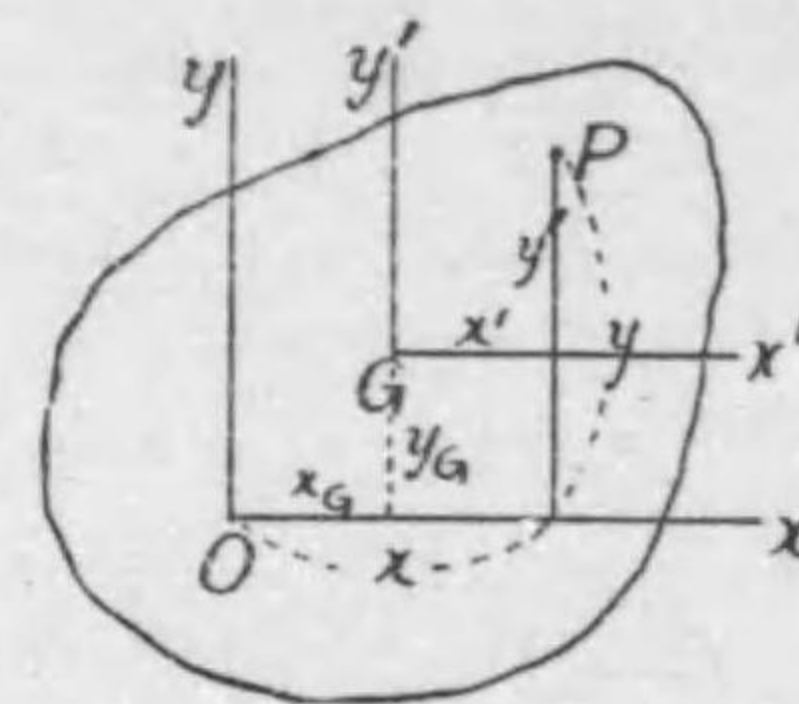
Ima, Gôtai no Dyûsin G (Du 205) no x, y -Zahyô wo x_G, y_G to si, Dyûsin wo Genten to site motono Zahyôdiku ni heikôna Zahyôdiku wo môkete, kore ni taisuru P no x, y -Zahyô wo x', y' to sureba,

$$\begin{aligned} x &= x_G + x', \\ y &= y_G + y' \end{aligned}$$

de aru. Kore wo ueno Siki ni irereba,

$$\begin{aligned} I &= \sum m \{ (x_G + x')^2 + (y_G + y')^2 \} \\ &= \sum m (x_G^2 + y_G^2) + \sum m (x'^2 + y'^2) + \\ &\quad 2x_G \sum m x' + 2y_G \sum m y', \end{aligned}$$

Sikaruni,
$$x_G = \frac{\sum m x}{\sum m} = \frac{\sum m (x_G + x')}{\sum m} = x_G + \frac{\sum m x'}{\sum m},$$



Du 205.

de aru kara,

$$\sum m x' = 0; \quad \text{dôyôni} \quad \sum m y' = 0.$$

Soreyueni,
$$I = (\sum m) (x_G^2 + y_G^2) + \sum m (x'^2 + y'^2).$$

Kono Siki de, $\sum m (x'^2 + y'^2)$ wa Dyûsin wo tôru heikôna Diku no mawarino Kwansei-moment de aru kara, kore wo I' to kaki, mata Gôtai no Situryô wo $\sum m = M, \sqrt{x_G^2 + y_G^2} = OG = h$ to kakeba,

$$I = Mh^2 + I'$$

to naru. Sunawati,

Hitotnno Tyokusen ni taisuru Gôtai no Kwansei-moment wa, Dyûsin ni zentaino Situryô ga atumatta to sôzôsita Baai no Kwansei-moment to, Gôtai no Dyûsin wo tôte motono Tyokusen ni heikôna Tyokusen ni taisuru Kwansei-moment to no Wa ni hitosii.

Mata, $I = Mh^2, I' = Mk'^2$ to kakeba, tugino Kwankei ga aru.

$$k^2 = k'^2 + h^2.$$

209. *Omodatta Baai no Kwansei-moment no Keisan.* Tugini, kisokutadasii Katati wo motta, Mitudo no itiyôna Gôtai no Kwansei-moment wo keisansuru.

(i) Kiwamete hosoi massuguna itiyôna Bô (Nagasa= l). Diku: Tyûsin wo tôte Bô ni suitiyokuna Sen.

Senmitudo= σ to sureba, $dm=\sigma dx$, $M=\sigma l$ de aru kara,

$$I = \int_{-\frac{l}{2}}^{\frac{l}{2}} x^2 \sigma dx = \frac{\sigma l^3}{12} = M \frac{l^2}{12}.$$

Yueni, $k_z^2 = \frac{l^2}{12}.$

(ii) Kiwamete usui kukei-no itiyôna Ita (Hen no Nagasa= a, b). Menseki-mitudo wo σ to site, $M=\sigma ab$.

a. Diku: Dyûsin wo tôte b no Hen ni heikôna Sen; kore wo y -Diku to suru.

$$I_y = \int_{-\frac{a}{2}}^{\frac{a}{2}} x^2 b \sigma dx = \sigma b \frac{a^3}{12} = M \frac{a^2}{12},$$

sitagatte, $k_y^2 = \frac{a^2}{12}.$

Dôyôni, $I_x = M \frac{b^2}{12}, \quad k_x^2 = \frac{b^2}{12}.$

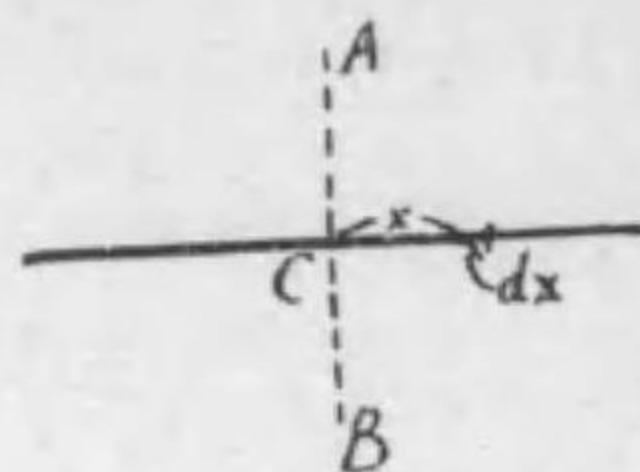
b. Diku: Dyûsin wo tôte Ita ni suitiyokuna Sen (z -Diku).

$$I_z = I_x + I_y = M \frac{a^2 + b^2}{12},$$

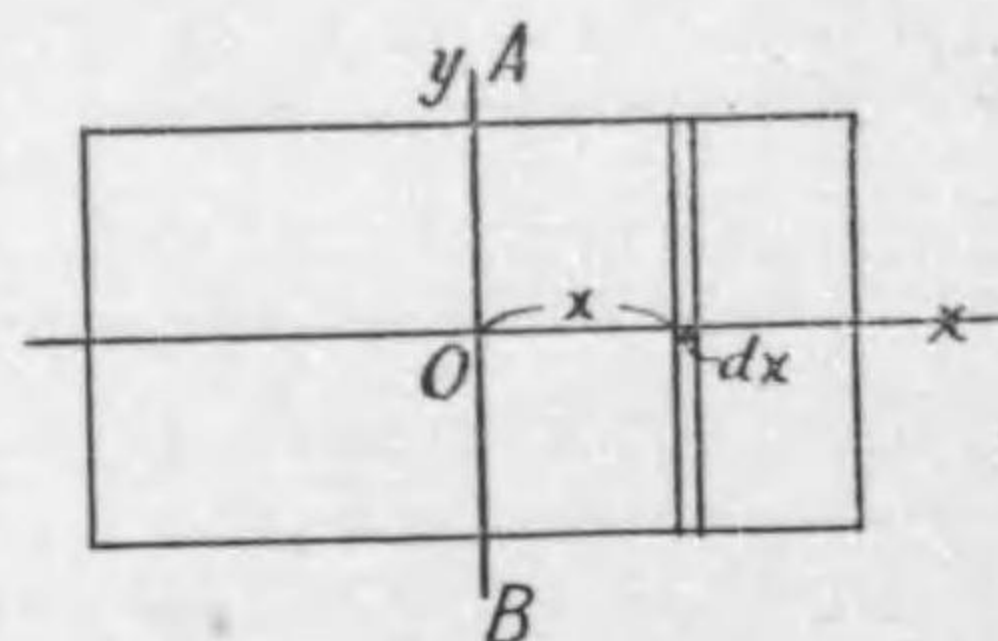
$$k_z^2 = k_x^2 + k_y^2 = \frac{a^2 + b^2}{12}.$$

(iii) Itiyôna Tyokurokumentai (Hen no Nagasa= a, b, c). Diku: Dyûsin wo tôte Hen a, b no Men ni suitiyokuna Sen (z -Diku).

z -Diku ni suitiyokuna usui kukei-no Ita ni wakete kangaereba,



Du 206.

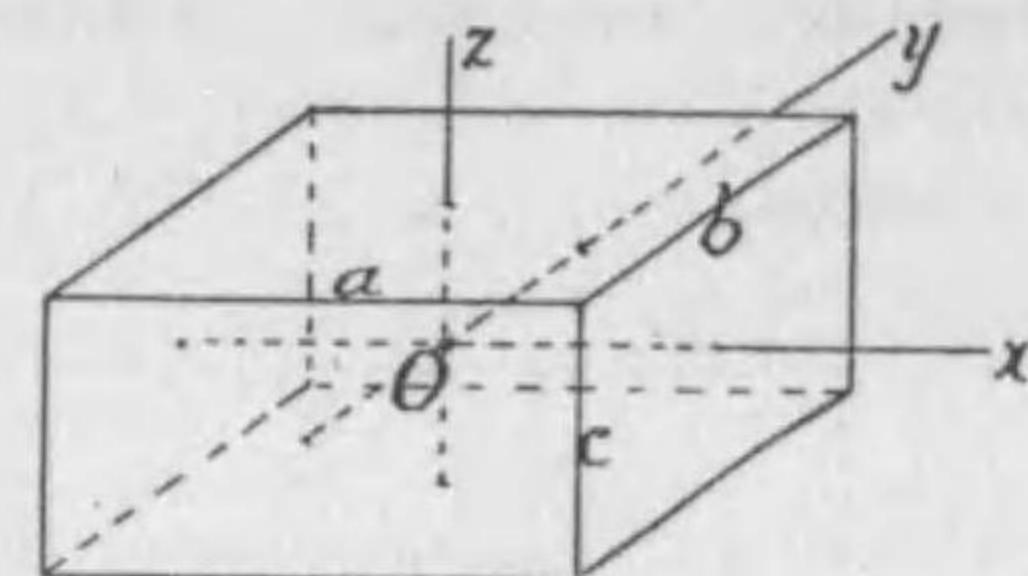


Du 207.

korerano Ita no z -Diku ni taisuru (Kwaiten-hankei)² wa, subete

$$\frac{a^2 + b^2}{12}$$

de aru. Soreyue, Tyokurokumentai z -Diku ni taisuru Kwaiten-hankei mo sore ni hitosii; sunawati,



Du 208.

$$I_z = M \frac{a^2 + b^2}{12}, \quad k_z^2 = \frac{a^2 + b^2}{12},$$

Dôyôni, $I_y = M \frac{c^2 + a^2}{12}, \quad k_y^2 = \frac{c^2 + a^2}{12},$

$$I_x = M \frac{b^2 + c^2}{12}, \quad k_x^2 = \frac{b^2 + c^2}{12}.$$

(iv) Hosoi enkeino itiyôna Harigane (Hankei= a). Tyûsin O wo Zahyô-genten to site, En no Heimen ni x, y -Diku wo toru.

a. Diku: Tyûsin wo tôte En no Heimen ni suitiyokuna Sen (z -Diku).

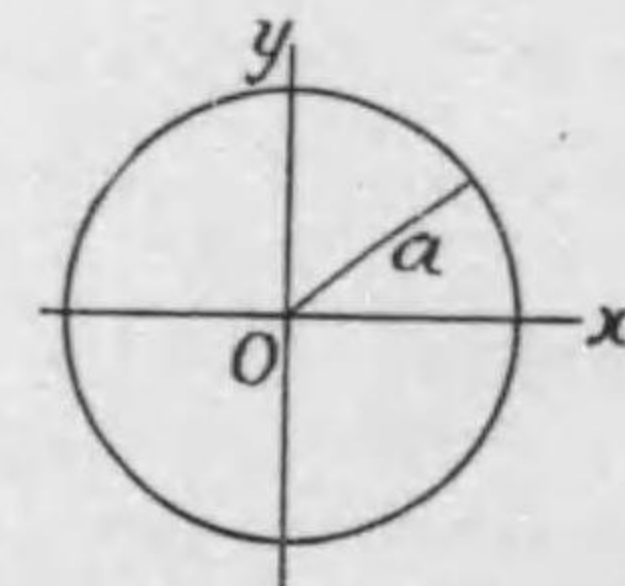
$$I_z = \int a^2 dm = Ma^2$$

Yueni, $k_z^2 = a^2.$

b. Diku: Tyokkei (x -Diku demo y -Diku demo). $I_z = I_x + I_y$ de aru noni, $I_x = I_y$ de aru kara,

$$I_x = I_y = \frac{1}{2} I_z = \frac{1}{2} Ma^2,$$

yueni, $k_x^2 = k_y^2 = \frac{a^2}{2}.$



Du 209.

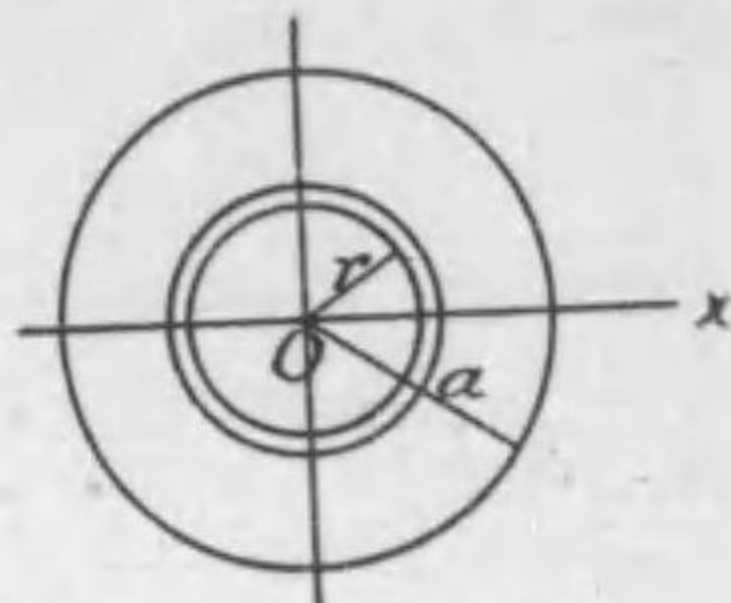
(v) Usui enkeino itiyôna Ita (Hankei= a). Menseki-mitudo wo σ to site, $M=\sigma \pi a^2$.

a. Diku: En no Tyûsin O wo tôte En no Heimen ni suitiyokuna Sen (z -Diku).

O wo Tyûsin to suru Dôsin-en de Ita wo hosoi enkeina ôkuno Wa ni wakeru. Ima Dôsin-en no hitotuno Hankei wo r to sureba,

$$I_z = \int_0^a r^2 \sigma 2\pi r dr = \sigma \frac{1}{2} \pi a^4 = M \frac{a^2}{2}.$$

Sitagatte, $k_z^2 = \frac{a^2}{2}.$



Du 210.

b. Diku : kattena Tyokkei (x -Diku). (iv) no (b) to dôyôna Riyû de,

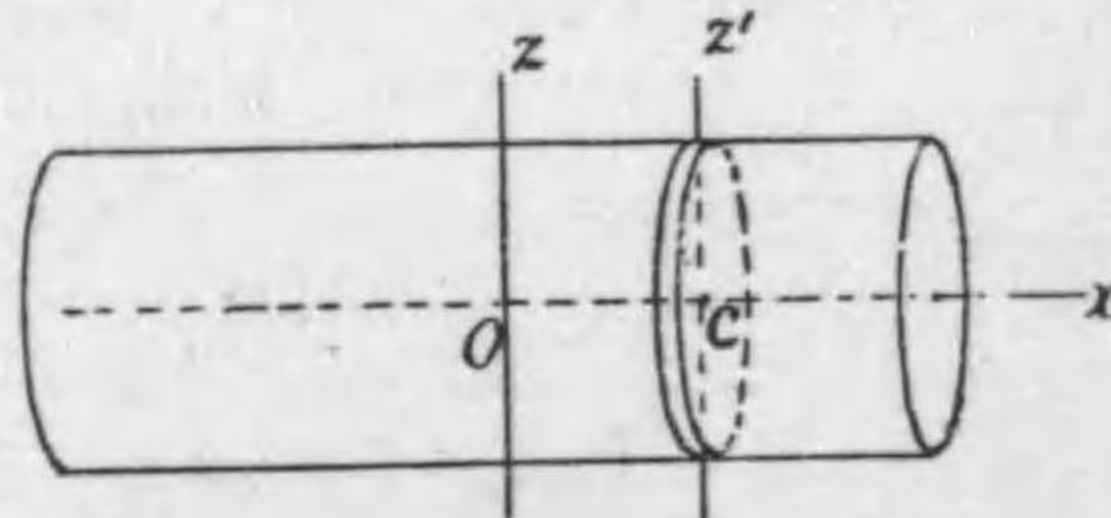
$$I_x = \frac{1}{2} I_z = M \frac{a^2}{4}, \quad k_x^2 = \frac{a^2}{4}.$$

Mondai : Hutatuno Dôsin-en (Hankei= a_1, a_2) ni kakomareta itiyôna Ita. [x, y, z wo ue to dôyôni totte, $k_z^2 = (a_1^2 + a_2^2)/2$, $k_x^2 = (a_1^2 + a_2^2)/4$.]

(vi) Itiyôna Marubasira (Hankei= a , Nagasa= l). Mitudo wo ρ to site, $M = \rho \pi a^2 l$.

a. Diku : Dyûsin O wo totte Nagasa ni suitiyokuna Sen (z -Diku).

x -Diku wo Nagasa no Hôkô ni totte, sore ni suitiyokuna Men de Marubasira wo musûno usui Ita ni wakeru to sureba,



Du 211.

$$I_z = \Sigma(\text{usui Ita no } I_z).$$

§ 108 no Teiri ni yotte,

$$\begin{aligned} &\text{Tyûsin ga } C (OC=x) \text{ ni aru Atusa } dx \text{ no usui Ita no } I_z \\ &= \text{usui Ita no Situryô} \times OC^2 \\ &+ C \text{ wo tôte } Oz \text{ ni heikôna Sen } Cz' \text{ no mawarino } I_z' \\ &= \rho \pi a^2 dx \cdot x^2 + \rho \pi a^2 dx \frac{a^2}{4}. \end{aligned}$$

Yueni,

$$\begin{aligned} I_z &= \int_{-\frac{l}{2}}^{\frac{l}{2}} \rho \pi a^2 x^2 dx + \int_{-\frac{l}{2}}^{\frac{l}{2}} \rho \frac{\pi}{4} a^4 dx \\ &= \rho \pi a^2 \left(\frac{l^3}{12} + \frac{a^2}{4} l \right) = \rho \pi a^2 l \left(\frac{l^2}{12} + \frac{a^2}{4} \right) \\ &= M \left(\frac{l^2}{12} + \frac{a^2}{4} \right). \end{aligned}$$

Sitagatte, $k_z^2 = \frac{l^2}{12} + \frac{a^2}{4}.$

b. Diku : Marubasira no Diku (x -Diku).

(v) no (a) to onaziku,

$$I_x = M \frac{a^2}{2}, \quad k_x^2 = \frac{a^2}{2}.$$

Mondai : Itiyôna Nikuatu wo motta, Mitudo no itiyôna Tutu (Nagasa l , utino Hankei r_1 , sotonô Hankei r_2) no, Dyûsin wo tôte Nagasa ni suitiyokuna Sen no mawarino Kwansci-moment wo keisansei!

(vii) Kiwamete usui kyûkeino itiyôna Kara (Hankei a). Diku : Tyokkei (x -Diku demo, y -Diku demo, z -Diku demo).

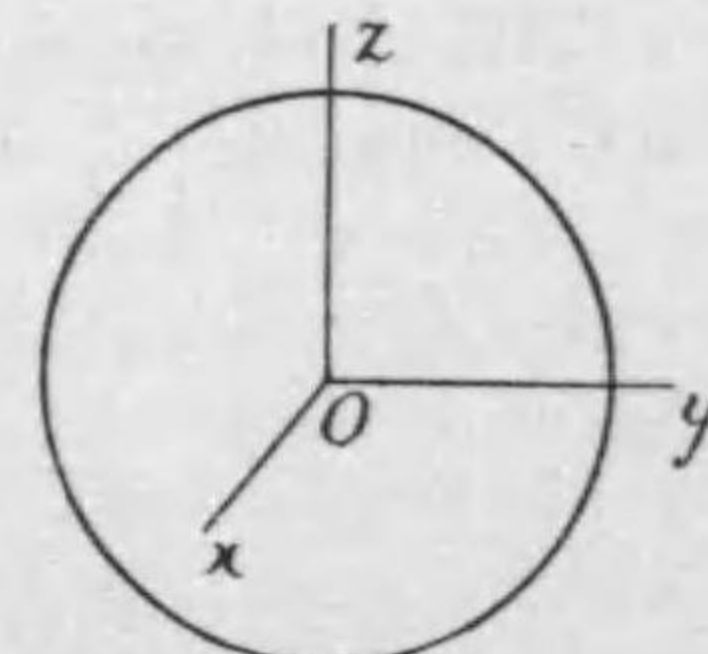
$I_x = I_y = I_z$ de aru koto wa motiron de aru kara, sore wo I to kakeba,

$$I = \frac{1}{3} (I_x + I_y + I_z).$$

Sikaruni, $I_x = \int (y^2 + z^2) dm,$

$$I_y = \int (z^2 + x^2) dm,$$

$$I_z = \int (x^2 + y^2) dm \quad *$$



Du 212.

de aru kara,

$$I = \frac{2}{3} \int (x^2 + y^2 + z^2) dm ;$$

sikaruni, dono dm ni taisitemo,

$$x^2 + y^2 + z^2 = a^2;$$

yueni,
$$I = M \frac{2a^2}{3}, \quad k^2 = \frac{2a^2}{3}.$$

(viii) Mitita itiyôna Kyû (Hankei= a). Diku : kattena Tyokkei. Mitudo wo ρ to site, $M = \rho \frac{4}{3} \pi a^3$.

Kyû ga ôkuno dôsinno Kara kara dekite oru to kangaereba, Hankei r , Atusa dr no Kara no Kwansei-moment wa

$$\frac{2r^2}{3} \rho \cdot 4\pi r^2 dr = \rho \frac{8\pi}{3} r^4 dr$$

de aru kara,

$$I = \rho \frac{8\pi}{3} \int_0^a r^4 dr = \rho \frac{8\pi}{3} \frac{a^5}{5} = \rho \frac{4}{3} \pi a^3 \frac{2}{5} a^2 = M \frac{2}{5} a^2;$$

yueni,
$$k^2 = \frac{2}{5} a^2.$$

210. Reidai (a). *Kwansei-moment no zikkentekino Kimekata.* Gôtai ni hosoi Harigane wo toritukete, ugokanai Ten kara turisageru. Sosite, sore ga seisisite iru Iti de, Harigane no Entyôsen wo Kwaitendiku to site Gôtai wo mawasite hanasu. Sôsûreba, nedireta Harigane no Dansei ni yotte, Gôtai ga Seisi no Iti no hô ni mawatte Seisi no Iti wo tôrisugi, ikutabimo kwaitentekino Sindô wo suru. Harigane no Toritukekata saemo tekitô de areba, kono Undô no aida Harigane ga yokoni ugokasareru koto ga naku, sitagatte, sore no Entyôsen de aru Gôtai no Kwaitendiku mo kawaranai.

Nedirareta Harigane ga Gôtai wo mawasô to suru Tikara no Moment (Gôtai no Kwaitendiku sunawati Harigane no Tyûsinsen no mawarino) wa, Harigane no Seisitu tosite, Nediri no Kaku θ ni hireisuru; kore wo

$$G = -k \cdot \theta$$

to kaku. Soreyue, Gôtai no Kwaitendiku no mawarino Kwansei-moment wo I to sureba,

$$I \frac{d^2\theta}{dt^2} = -k \cdot \theta.$$

Sitagatte, Sindô no Syûki wa

$$T = 2\pi \sqrt{\frac{I}{k}} \dots \dots \dots (1)$$

de aru.

Tugini, betuni Kwansei-moment wo (Keisan nado ni yotte) sitte oru Gôtai wo tori, ataerareta Gôtai ni sore wo kataku toritukeru; tadasi, zentai ga moto to onazi Sen wo Kwaitendiku to site kwaitentekino Sindô wo nasi eru yôni toritukeru.

Kono Kumiawase-gôtai no Kwaiten-sindô no Syûki wa, ma to doyôni,

$$T' = 2\pi \sqrt{\frac{I+I'}{k}}, \dots \dots \dots (2)$$

de aru; tadasi, I' wa tukekuwaeta Bubun no sirete iru Kwansei-moment.

Sôsûruto, (1) to (2) to kara,

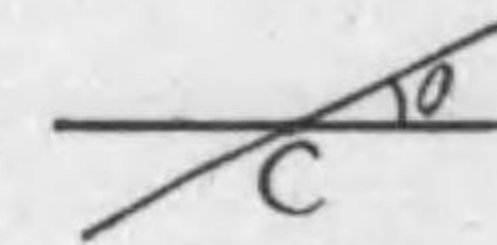
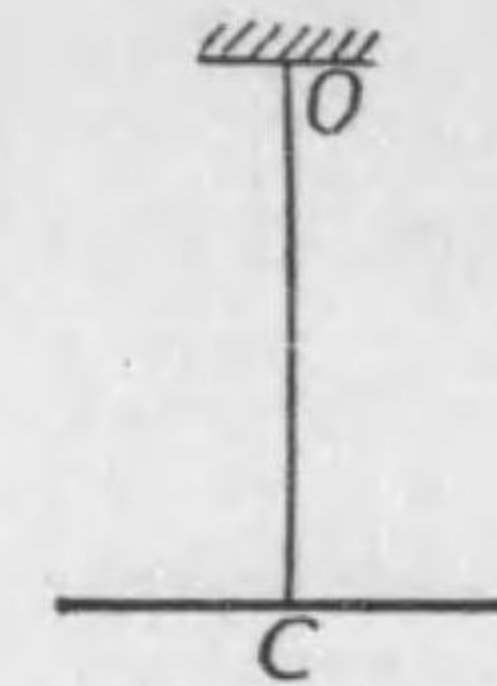
$$\frac{T^2}{T'^2} = \frac{I}{I+I'},$$

sitagatte,

$$I = \frac{T^2}{T'^2 - T^2} I'.$$

Sunawati, onônono Baai no Sindô no Syûki wo sokuteisureba, ataerareta Gôtai no Kwansei-moment I wo siru koto ga dekiru.

211. Reidai (b). *Hikkurikaesareru Huriko.* Zittai-huriko no Baai (§ 203) ni, Kwaitendiku no mawarino Kwansei-moment wo I to si, Dyûsin G wo tôru heikôna Diku ni taisuru Kwansei-moment wo I' Kwaiten-hankei wo k' to sureba, $OG = h$ to oite,



Di 213.

$$I = Mh^2 + I' = M(k^2 + k'^2)$$

de aru; sosite kono Zittai-huriko to "dôtôna" Sitten-huriko no Nagasa L wa

$$L = \frac{I}{Mh} = \frac{h^2 + k'^2}{h} = h + \frac{k'^2}{h} \dots \dots (1)$$

Kono Siki de miruto, dôtona Sitten-huriko no Nagasa L (sitagatte Syûki T) wa, h no ôkii Baai ni ôkii bakari de uaku, h ga sutto tiisai Baai nimo ôkikute, h ni taisite Du 214 no yôna Kwankei wo nasu. Soreyueni, h no aru Atai h_1 no L to onazi L wo motte iru h no Atai h_2 ga hokani aru. Korerano h_1 to h_2 no Kwankei wa, (1) no Siki wo tukatte,

$$L = h_1 + \frac{k'^2}{h_1} = h_2 + \frac{k'^2}{h_2}$$

sunawati,

$$h_2 - h_1 - \frac{k'^2}{h_1 h_2} (h_2 - h_1) = 0,$$

sunawati,

$$(h_2 - h_1) \left(h_2 - \frac{k'^2}{h_1} \right) = 0$$

kara,

$$h_2 = h_1 \text{ matawa } \frac{k'^2}{h_1}$$

Mosimo $h_2 \neq h_1$ to wakatte oreba,

$$h_2 = \frac{k'^2}{h_1} = L - h_1,$$

sitagatte,

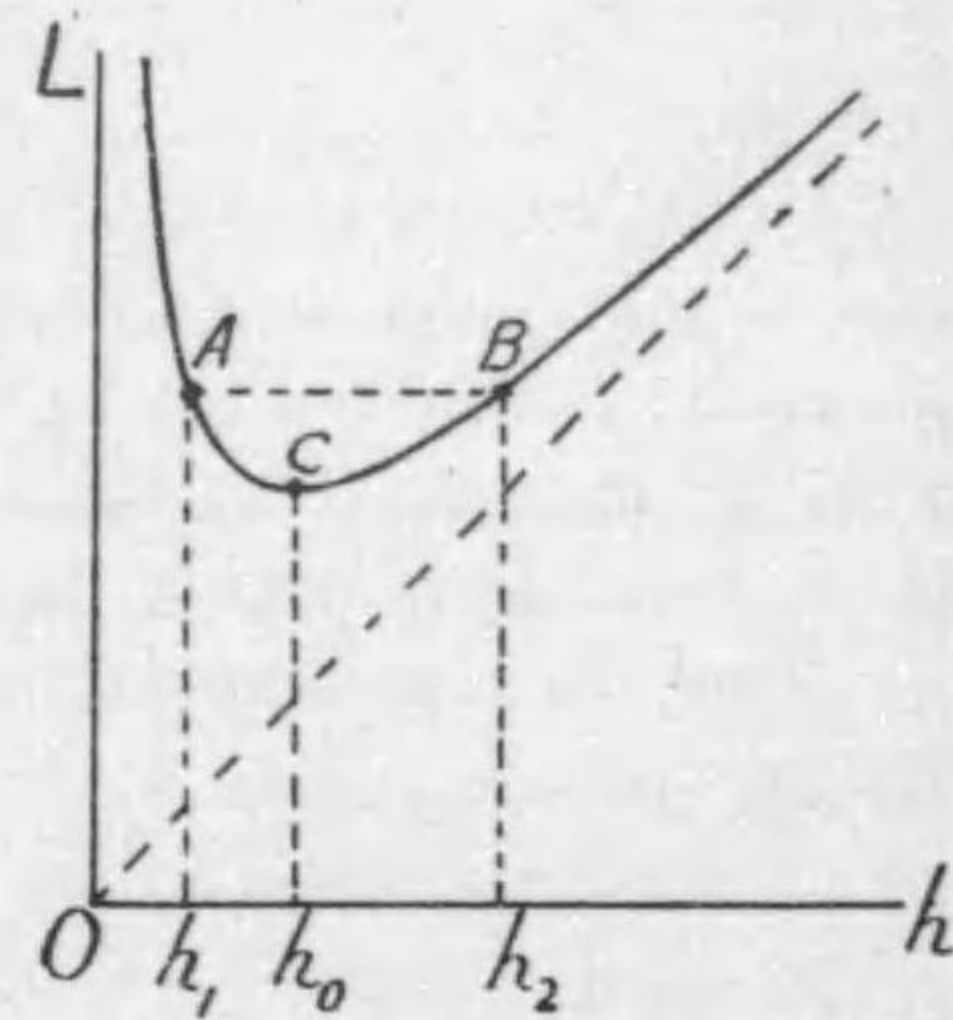
$$h_1 + h_2 = L.$$

Soreyueni,

Onazi L wo ataeru h no hutatuno (tagaini tigau) Atai h_1 h_2 wa

$$h_1 + h_2 = L \dots \dots \dots (2)$$

no Kwankei wo mitasu.



Du 214

Soreyueni, Gôtai no Dyûsin G (Du 215) wo tôru Tyokusen no ue de, G kara hantaino Gawa ni tigau Kyori h_1, h_2 ni aru Ten O to O' wo tôru tokorono, OO' ni suityoku de tagaini heikôna Sen wo Kwai-tendiku to site huraseru tokino Syûki ga hitosii naraba, OO' no Kyori wa sono Syûki wo motte huru Sitten-huriko no Nagasa ni hitosii.

Konoyôna Zittai-huriko wo "hikkurikaesareru Huriko" to iu.

212. Sitten-huriko de Dyûryoku no Tuyosa sunawati Rakutai no Kasokudo g no Atai wo sadameru koto wa § 187 de nobeta ga, nao seimituna Hôhō wa, hikkurikaesareru Huriko no ueno Seisitu wo tukau Hôhō de aru. Zissaini tukawareru Huriko wa, Du 216 no yôni ue-sita onaziyôna Katati ni natte ite, sikamo Dyûsin G ga ippô ni katayotte iruyôni site aru (A no Bubun ga garandôna Hako de, B no Bubun niwa omoi Bussitu ga tumete aru nado no Hôhō de); sosite, ueno Kwankei $h_1 h_2 = k'^2$ ni naru yôna (Dyûsin G no Ryôgawa ni aru) Ten O, O' ni Hasudi (Eigo no knife-edge) wo sôtisite oku.

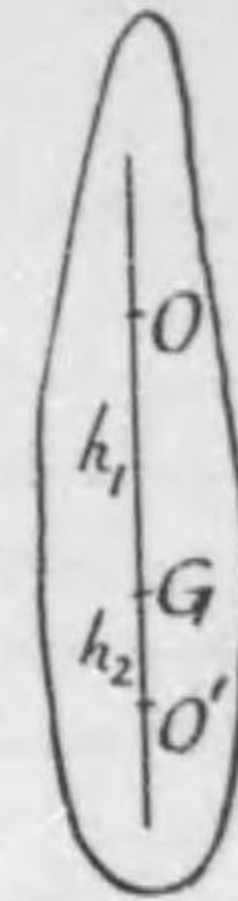
Hasudi no aidano Kyori L to Syûki T to wa zyûibun seimituni sokutei dekuru kara, Dûryoku no Tuyosa wo

$$g = \frac{4\pi^2 L}{T^2}$$

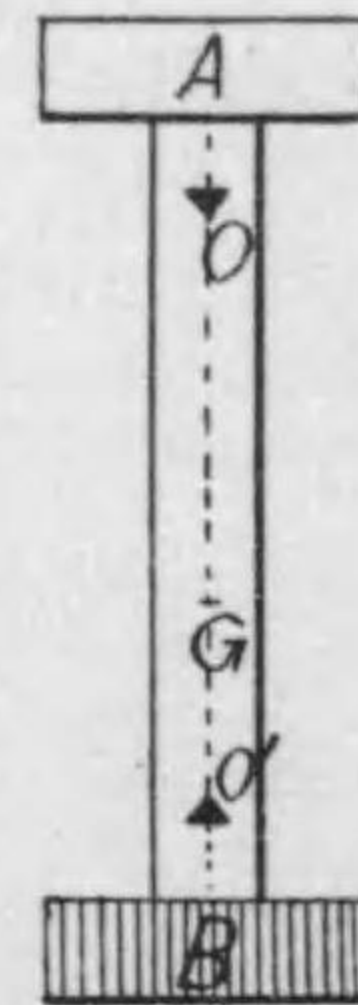
ni yotte kimeru koto ga dekuru.

213. Reidai (c). Atwood no Sôti. Diku no koteisita Kuruma K (Situryô M , Hankei R) ni karui nobinai Ito ga kakatte, sore no hutatuno Hazi ni onôno Situryô m no Omori A, B ga tuite iru. Nao sore no hitotu B ni Situryô m' no Ita wo tukekuwae matawa torisaru koto ga dekuru.

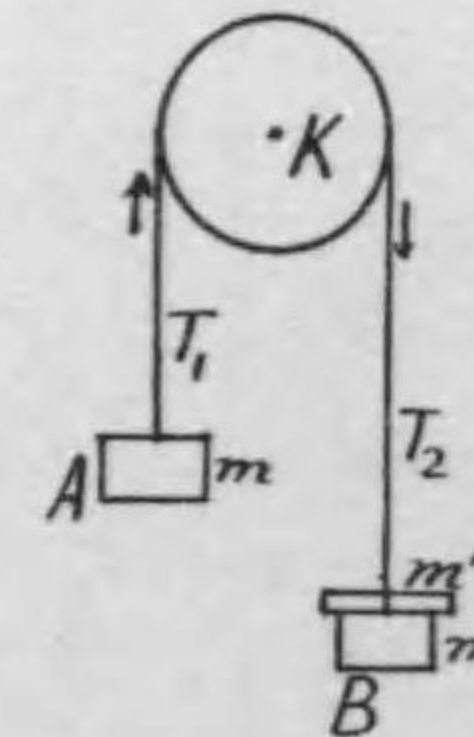
Ima, Kuruma no Sinbô ni Masatu nado



Du 215.



Du 216.



Du 217.

ga nai to site, m' no Ita ga notte oru Baai no Undô wo siraberu.

Kuruma no Kakusokudo wo ω to site, A no nobori B no kudaru Hayasa wo V to sureba,

$$V=R\omega, \quad \frac{dV}{dt}=R \frac{d\omega}{dt} \dots\dots\dots(1)$$

no Kwankei ga aru.

Kuruma no Ryôgawa no Ito no Tyôryoku wo T_1, T_2 to suru. Kuruma no, sore no Diku ni taisuru Kwansei-moment wo Mk^2 to kaite,

$$\left. \begin{aligned} &Mk^2 \frac{d\omega}{dt} = (T_2 - T_1)R, \\ &A \text{ ni tuitewa,} \\ &\quad m \frac{dV}{dt} = T_1 - mg, \\ &B \text{ ni tuitewa,} \\ &\quad (m + m') \frac{dV}{dt} = (m + m')g - T_2 \end{aligned} \right\} \dots\dots(2).$$

Korerano mittuno Siki to (1) to kara

$$\frac{dV}{dt} = \frac{m'}{2m + m' + M \frac{k^2}{R^2}} g,$$

$$\frac{d\omega}{dt} = \frac{m'}{2m + m' + M \frac{k^2}{R^2}} \frac{g}{R},$$

$$T_1 = \frac{2(m + m') + M \frac{k^2}{R^2}}{2m + m' + M \frac{k^2}{R^2}} mg,$$

$$T_2 = \frac{2m + M \frac{k^2}{R^2}}{2m + m' + M \frac{k^2}{R^2}} (m + m')g.$$

Mosi, Kuruma ga itiyôna Atusa no Ita naraba, $\frac{k^2}{R^2}$ wo $\frac{1}{2}$ to sureba yoi.

m' no Ita wo torisatta Baai no Undô wa, ueno Siki de $m'=0$ to okeba yoi node, $\frac{dV}{dt}=0, T_1=T_2=mg$ ni naru.

Tatoeba, $m'=\frac{1}{10}m, M\frac{k^2}{R^2}=\frac{1}{5}m$ nareba, $\frac{dV}{dt}=\frac{1}{23}g$; sitagatte, $V=0$ de Undô wo okosasureba, 1 byô no aidani $980/46=21$ cm., 2 byô no aidani $4 \times 980/46=85$ cm. dake B ga kudaru. Mosi koko de m' no Ita wo torinokereba, sore kara notiwa $2 \times 980/23=85$ cm./s. no itiyôna Hayasa de kudaru.

Rensyû-Mondai VII.

1. Kuruma no Wa no Katati wo motta itiyôna Gôtai (utino Hankei= a , sotonô Hankei= b , Diku ni heikôni hakatta Atusa= c , Situryô= m) no, Diku no mawarino Kwansei-moment wo keisansei!

2. Uturona itiyôna Kyû (sotonô Hankei= r , Niku no Atumi= c , Situryô= m) no, Tyokkei no mawarino Kwansei-moment wo keisansei!

3. Atusa mo Mitudo mo itiyôna kukeino Ita (20 cm. \times 100 cm.) no Men ni suitokuni, Tyûsin kara 40 cm., 30 cm., 20 cm., 10 cm. no Kyori ni Kwaitendiku wo toritukete tukutta Zittai-huriko no Syûki wo sorezore keisansei! [$g=980$.]

4. Ongaku de Hyôsi wo hakaru ni tukau *Metronome* wa hitotuno Zittai-huriko de aru. Sore no itibun ga Kwaitendiku wo tôte entyokuni ueni muite iru Bô ni natte, sore ni hamaru tiisai Omori ga atte, sono Omori wo Bô no ue de, iroirona Takasa ni toritukeru koto ni yotte, Huriko no Syûki wo iroiro kaeru no de aru. Ippun-zikan ni nasareru Katahuri no Kazu sunawati Oohuku-sindôsû no *nibai*, (kore ga "Metronome no Kazu" de aru) to Omori no Iti to wa donoyôna Kwankei ni naru ka?

5. Itiyôna marui Ita (Hankei=20 cm.) no Men ni suityoku-ni, Tyûsin kara 2 mm. hanarete Kwaitendiku ga atte, Diku wo suiheini sasacte aru. Kono Zittai-huriko no Sindô no Syûki wa ikura ka?

6. Ueno Mondai no Gôtai ga itu mademo onazi Muki ni Kwaiten wo tudukeru Baai ni, Kakusokudo no saidaino Atai to saisyôno Atai to ni donna Kwankei ga aru ka?

7. Tenbin ni tukau yôna Sara ga suiheina Iti de ipponno massuguna Harigane de turusite aru. Harigane no ueno Hazi no Torituke ya, Sara to sore to no Torituke ga katai tameni Harigane no Entyôsen wo Diku to site Sara wo mawaseba, Harigane ga soresake nedireru. Sara ga kara de aru tokini, Nedire-sindô no Syûki ga 3 byô de ari, Sara no Tyûsin ni marui itiyôna Ita (Hankei=5 cm., Situryô=1 kg.) wo tairani nosereba, Syûki ga 5 byô ni naru. Sara dake no Kwansei-moment wa ikura?

8. Bô-zisyaku wo Ito de suiheini tutte, Tikyû-ziryoku no Suihei-bunryoku ni yotte tiisai Sindô (Ito wo Kwaitendiku to sita kwaitentekino Sindô) wo saseru tokino Syûki wa ikura ka? Tadasî, Bô-zisyaku wa Nagasa l cm., Haba b cm., Situryô m g.; Ziki-moment M c.g.s.-tan'i; Tikyû-ziryoku no Ba no Suihei-bunryoku ga H c.g.s.-tan'i da to suru. [Zisyaku no hutatuno *Kyoku no Tuyosa* ga q de, Kyori ga l nareba, Ziki-moment= ql ; mata, Ba no Tuyosa H no Tokoro de, Tuyosa q no Kyoku wa qH no Tikara wo ukeru.]

9. Itiyôna Ita de tukutta Tobira (tate 1.7 m., yoko 0.9 m., Situryô 5 kg.) ga Bane no Tyôtugai de sasaerete iru. Bane no Tuyosa wa, Tobira wo 30° hiraite sasaeru no ni, 0.9 m. no Ude de 0.5 kg. no Omosa ni hitosii Tikara wo yôsuru Teido de aru. Kono Tobira no Kwaiten-sindô no Syûki wa ikura ka?

10. Mondai 9 no Tobira wo, Tyôtugai wo suiheini si, Tobira ga sore ni sasaerete tarete iru yôni oku tokiniwa, Sindô no Syûki wa ikura ka?

11. Hikkurikaesareru Huriko no hutatuno Syûki, Dyûsin to Kwaitendiku to no Kyori h_1 ni taisuru T_1 to h_2 ($< h_1$) ni taisuru T_2 to ga sukosi tigau Baai ni, Nagasa h_1+h_2 no Sitten-huriko no Syûki T ga

$$T^2 = T_1^2 + (T_1^2 - T_2^2) \frac{h_2}{h_1 - h_2}$$

de ataerareru koto wo syômeisei!

12. Entyokusen ni taisite Kaku ε wo nasu Sen no ueni Tyôtugai wo motu Tobira ga Seisi no Iti no Kinzyo de sindô-suru tokino Syûki wo kimei!

13. Suiheina Kwaitendiku wo motu Rindiku to dôyôna Sôti no Wa no Bubun ga itiyôna Maruita (Hankei 50 cm., Situryô 10 kg.) de, Diku no Bubun ga Hankei 5 cm. de aru. Kono Diku ni Ito ga suberanai yôni maite atte, sore no hitotuno Hazi ni 1 kg. no Omori ga sagete aru. Diku no Sasae ga mattaku nameraka da to site kono Sôti ga Seisi no Iti kara ugokidasu tokini, t byô no aidani Omori no oriru Kyori wo kimei! Tadasî, Diku no Bubun no Situryô wa Kwansei-moment no Keisan niwa sutete yoi.

14. Suiheina Kwaitendiku no mawarini mawar iuru Rindiku to dôyôna Sôti (Kwansei-moment= I) no Diku no Bubun (Hankei= a) ni itiyôna Kusari (Nagasa= l , Sen-mitudo= σ) ga kakatte, sore no Ryôhazî ga tarete iru. Kwaitendiku ga nameraka de, Diku to Kusari to no aida wa suberanai to si, saisyo Seisi no Arisama ni aru to sureba, Kusari no Ryôhazî no Takasa no Sa ga, Zikan t ni taisite,

$$e^{\sqrt{\frac{2\sigma ga^2}{I+\sigma la^2}} t} + e^{-\sqrt{\frac{2\sigma ga^2}{I+\sigma la^2}} t}$$

ni hiresite masite yuku koto wo syômeisei!

15. Heikôna Kwaitendiku no mawarini namerakani mawaru hutatuno Kuruma A (Hankei= r_1 , Kwansei-moment= I_1), B (Hankei= r_2 , Kwansei-moment= I_2) ga onazi Heimen ni atte, Sirabekawa de renrakusite iru. Kuruma A ni Moment G no Tikara ga hataraku tokini, Kuruma B ga donna Kaku-kasokudo wo eru ka? Mata Sirabekawa no hutatuno Bubun no Tyôryoku no Sa wa ikura ka! Tadasî, Sirabekawa to Kuruma to no aida wo suberanai to si, mata Sirabekawa no Situryô wo kangaenai to suru.

SYOO VIII.

Hítotuno Heimen ní heikôna Undô.

221. Gôtai no Heimen-undô ni okeru Kwaiten no Tyûsin. Gôtai ga undôsuru tokini, dono Bubun mo subete aru kimatta hitotuno Heimen P ni heikôna Undô wo suru tokiniwa, Gôtai ga Heimen-undô wo suru to tonaeru.

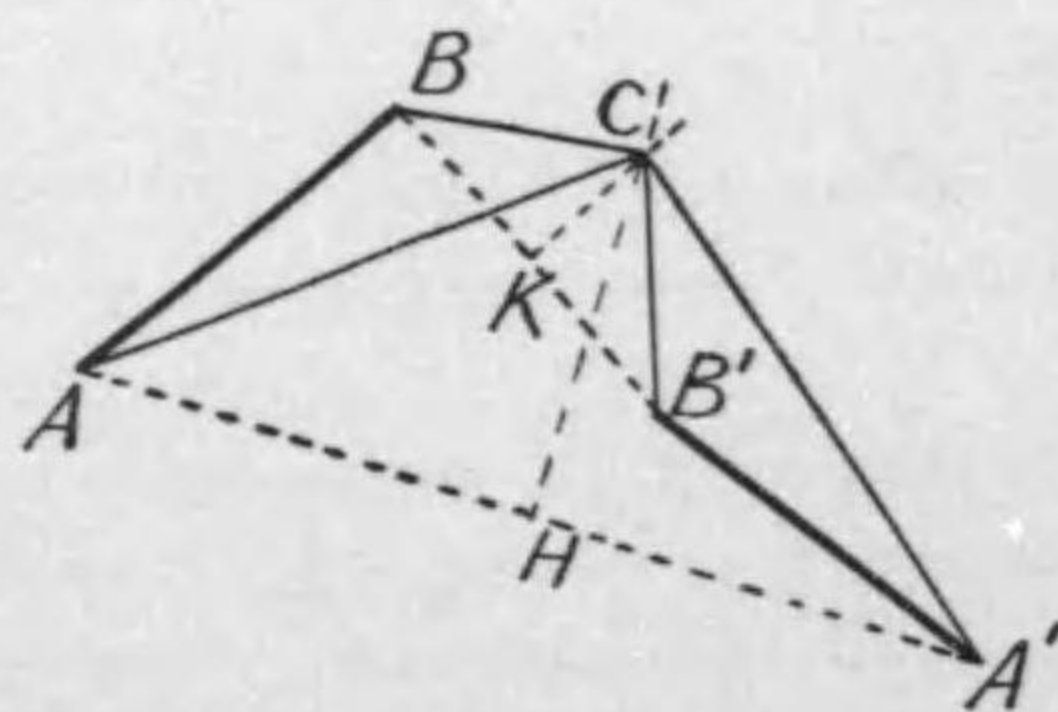
Konoyôna Undô wo suru Gôtai no Iti matawa Undô wo simesu niwa, P ni heikôna hitotuno (tatoeba Dyûsin wo tôru) Kirikuti no Iti matawa Undô wo simeseba yoi.

Konoyôna Gôtai ga aru hitotuno Zikoku ni ugoki tutu aru Arisama wo iarawasu ni mottomo kantanna Hôhô wa, sore ga aru Ten wo Tyûsin to site kwaitensi tutu aru to iu Iiarawasikata de aru. Kore wo ryôkaisuru niwa madu tugino Teiri wo siru ga yoi:—

222. Teiri. Heimen-undô wo suru Gôtai wo hitotuno Iti kara kattena hokano Iti e utusu koto wa, tekitôna Ten (nao tadasiku ieba, Undô no Heimen ni suityokuna Tyokusen) wo Tyûsin (Diku) to sita hitotuno Kwaiten de dekuru.

Syômei. Du wo Undô no Heimen ni heikôna Heimen no Du to si, kono Heimen no ue de Gôtai ni sirusiduketa hutatuno Ten A, B no Iti wo siruseba Gôtai zentai no Iti ga kimaru. Sore ga hazime AB no Iti ni, notini $A'B'$ no Iti ni aru to sureba wareware wa A wo A' ni, B wo B' ni utusu koto ga hitotuno Kwaiten de dekuru koto wo syômeisureba yoi no de aru.

A, A' wo musunde sore no Mannaka kara sore ni Suityokusen

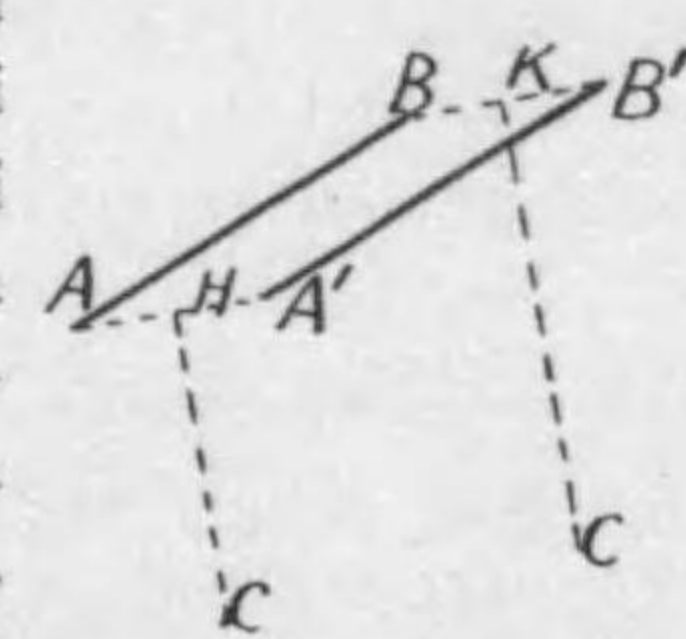


Du 221.

HC wo hiki, B, B' wo musunde sore no Mannaka kara sore ni Suityokusen KC wo hiki, hutatuno Suityokusen ga C -Ten de kiriau to suru. Sôsureba, $A'C=AC$, $B'C=BC$, mata $A'B'=AB$ wa Gôtai no Seisitu de sirete iru kara, Sankakukei $A'B'C$ to ABC wa mattaku onazimono de, $\angle A'CB' = \angle ACB$. Kyôtûna $\angle ACB'$ wo kuwaereba, $\angle ACA' = \angle BCB'$ no Kwankei ga aru. Soreyueni, C Ten wo Tyûsin tosite $\angle ACA'$ dake Gôtai wo mawasuto, A ga A' ni kuru to dôzini B ga B' ni kuru.

Kono Sakudu de C Ten no kimaranai no wa, hutatuno Suityokusen ga heikô de aru ka ittisuru ka no Baai de aru.

Heikô de aru Baai (Du 222) wa, Gôtai ga Kwaiten nasini ugoita Baai de aru ga, kore wa Kwaiten no Tyûsin ga kiwamete tôkute, Kwaiten no Kaku ga kiwamete tiisai



Du 222.

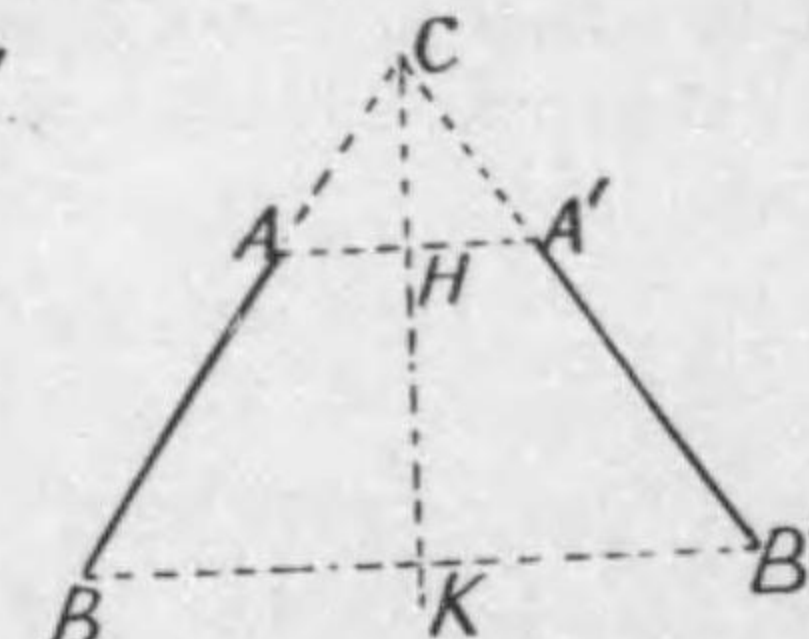
kyokutanno Baai da to itte yoi. Ittisuru Baai (Du 223) niwa, AB to $A'B'$ to no Kiriaiten C ga Kwaiten no Tyûsin de aru koto wa akiraka de aru.

223. Ueno Teiri wo kiwamete mizikai Zikan no aidani okoru Hen'i ni ôyôsureba, tugino Teiri ga sireru:—

Heimen-undô wo suru Gôtai wa, onônono Zikoku ni oite hitotuno Ten (kuwasiku ieba, Undô no Heimen ni suityokuna hitotuno Tyokusen) wo Tyûsin (Diku) to site mawari tutu aru.

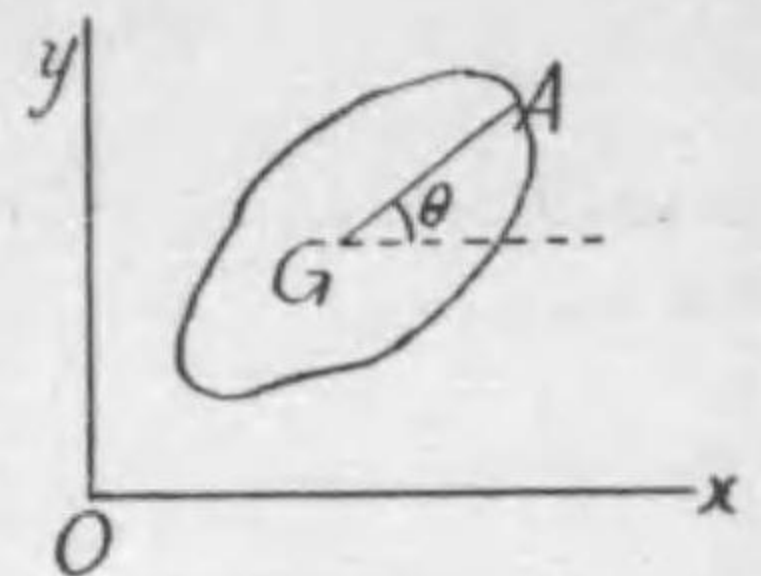
Tadasi, tokubetuna Baai tosite, Tyûsin ga kagirinaku tôkute, Kwaiten no Kakusokudo ga kagirinaku tiisai Baai niwa, Gôtai wa iwayuru Heisin-undô (sunawati sore no subeteno Bubun ga kyôtûna Sokudo wo motte ugoku Undô) wo suru.

224. Gôtai no Heimen-undô no kaisekitekinô Arawasikata. Gôtai no Heimen-undô wo kaisekitekini arawasu niwa, Kwaiten no Tyûsin wo tukau koto wa benri de nakute, tugino yôna Hôhô wo toru no ga yoi.



Du 223.

Dyûsin wo tôte Undô no Heimen ni heikôna Heimen de Gôtai wo kitta Kirikuti wo Du ni arawasu mono to si, x, y -Diku wo kono Heimen ni toru. Kono Kirikuti ni, Dyûsin wo tôru tekigina mezirusino Sen GA (Du 224) wo Gôtai ni sirusidukete okeba, kono Kirikuti no Iti, sitagatte Gôtai no Iti ga (1) Dyûsin G no Iti to (2) GA -Sen ga Ox to tukurû Kaku θ to de kimaru. Sunawati, x_G, y_G, θ no mittu ga Gôtai no Iti wo simesu Ryô de aru. Mata Gôtai no Undô wa, Dyûsin no Sokudo to Kwaiten no Kakusokudo, sunawati,



Du 224.

$$\frac{dx_G}{dt}, \quad \frac{dy_G}{dt}, \quad \frac{d\theta}{dt} = \omega$$

de ataerareru.

Tyûi. Gôtai no Iti wo simesu dakeno Mokuteki niwa, Dyûsin no kawarini kattena hokano Ten wo erande, ueno x_G, y_G, θ to dôyôna Ryô wo tukattemo yoi keredomo, Tikara to Undô to no Kwankei wo siraberu Ten de Dyûsin wo toru no ga yoi no de aru.

225. Dyûsin no Undô. Gôtai wo musûno Sitten no Atumari to mite, sorera no utino hitotuno Sitten no Situryô wo m , sore no Zahyô wo x, y , kore ni hataraku sotonô Tikara no Seibun wo X, Y , hokano Sitten ga sore ni sayôsuru utino Tikara no Seibun wo X_u, Y_u to sureba,

$$\left. \begin{aligned} m \frac{d^2x}{dt^2} &= X + X_u \\ m \frac{d^2y}{dt^2} &= Y + Y_u \end{aligned} \right\} \dots\dots\dots(1).$$

Subeteno Sitten ni tuite konoyôna Siki wo tukutte, sore wo mina kuwaereba,

$$\left. \begin{aligned} \Sigma m \frac{d^2x}{dt^2} &= \Sigma X + \Sigma X_u \\ \Sigma m \frac{d^2y}{dt^2} &= \Sigma Y + \Sigma Y_u \end{aligned} \right\} \dots\dots\dots(2).$$

Subeteno Sitten no ukeru utino Tikara wa Hôkô ga hantai de Ooisa ga hitosii mono ittui dutu no Atumari de aru kara,

$$\Sigma X_u = 0, \quad \Sigma Y_u = 0 \dots\dots\dots(3).$$

Sitagatte,

$$\left. \begin{aligned} \Sigma m \frac{d^2x}{dt^2} &= \Sigma X \\ \Sigma m \frac{d^2y}{dt^2} &= \Sigma Y \end{aligned} \right\} \dots\dots\dots(4).$$

Sikaruni, Dyûsin no Zahyô x_G, y_G wa

$$x_G \Sigma m = \Sigma mx, \quad y_G \Sigma m = \Sigma my$$

no Kwankei wo nasu kara, $\Sigma m = M$ to sureba,

$$\begin{aligned} \Sigma m \frac{d^2x}{dt^2} &= M \frac{d^2x_G}{dt^2}, \\ \Sigma m \frac{d^2y}{dt^2} &= M \frac{d^2y_G}{dt^2}; \end{aligned}$$

sitagatte,

$$\left. \begin{aligned} M \frac{d^2x_G}{dt^2} &= \Sigma X \\ M \frac{d^2y_G}{dt^2} &= \Sigma Y \end{aligned} \right\} \dots\dots\dots(5).$$

Sunawati, Gôtai no Dyûsin no Undô wa, Dyûsin ni Buttai zentai no Situryô ga atumatta mono to mite, kono Ten ni Buttai ni hataraku subeteno sotonô Tikara ga hataraku Baai no Undô to onazi de aru.

Kono Teiri wa mata Gôtai no Undoryo wo sihaisuru Teiri da to ieru. $\Sigma m \frac{d^2x}{dt^2} = \frac{d}{dt} \left(\Sigma m \frac{dx}{dt} \right)$ to kakeru; sosite, $\Sigma m \frac{dx}{dt}$ wa

Gôtai no subeteno Bubun no Undôryô no x -Seibun wo kuwaeta mono sunawati Gôtai no Undôryô no x -Seibun de aru. Hokano Seibun ni tuitemo dôyô de aru kara, tumari, Sitten no Baai (§ 143) to dôyôni,

Gôtai no Undôryô no Tan'i-zikan ni kawaru Wariai wa sore ni hataraku Tikara ni (vektortekini) hitosii.

226. Kaku-undôryô no Teiri. Aru Sen no mawarini totta Undôryô no Moment wo "sono Sen no mawarino Kaku-undôryô"

to tonacru.

Situryô m no Sitten ga (x, y) ni atte, $\left(\frac{dx}{dt}, \frac{dy}{dt}\right)$ no Sokudo wo motte iru tokini, sore ga Genten wo tôte xy -Men ni suitiyokuna Sen (z -Diku) no mawarini motu Kaku-undôryô wa, — § 38 de Tikara no Seibun X, Y wo atukatta no to dôyôni Undôryô no Seibun $m\frac{dx}{dt}, m\frac{dy}{dt}$ wo atukatte—tugino Siki de ataerareru :

$$x \cdot m \frac{dy}{dt} - y \cdot m \frac{dx}{dt} = m \left(x \frac{dy}{dt} - y \frac{dx}{dt} \right).$$

Sitagatte, konoyôna Sitten no kattena Atumari ni tuitewa,

$$H = \Sigma m \left(x \frac{dy}{dt} - y \frac{dx}{dt} \right) \dots \dots \dots (1)$$

ga Sitten-kumiai no z -Diku no mawarino Kaku-undôryô de aru. Sitagatte mata, sore no kawaru Wariai ni tuitewa, () no naka de $\frac{dx}{dt} \frac{dy}{dt} - \frac{dy}{dt} \frac{dx}{dt}$ ga kieru node,

$$\frac{dH}{dt} = \Sigma m \left(x \frac{d^2y}{dt^2} - y \frac{d^2x}{dt^2} \right) \dots \dots \dots (2)$$

no Siki wo eru.

Onônono Sitten no Undô no Hôteisiki,

$$\left. \begin{aligned} m \frac{d^2x}{dt^2} &= X + X_u, \\ m \frac{d^2y}{dt^2} &= Y + Y_u \end{aligned} \right\} \dots \dots \dots (3)$$

ni sorezore $-y$ to x to wo kakete kuwaereba,

$$m \left(x \frac{d^2y}{dt^2} - y \frac{d^2x}{dt^2} \right) = (xY - yX) + (xY_u - yX_u)$$

ni naru. Kore to onazi Kwankeisiki wo subteno Sitten ni tuite kuwaeruto,

$$\Sigma m \left(x \frac{d^2y}{dt^2} - y \frac{d^2x}{dt^2} \right) = \Sigma (xY - yX) + \Sigma (xY_u - yX_u) \dots (4).$$

Kono Hôteisiki de Hidarigawa wa (2) to onazimono de aru.

Migigawa dewa, owarino Kô wa, § 202 ni okeru to onazi Riyû ni yotte, rei ni naru ; mata hazimeno Kô wa hoka kara hataraite iru Tikara no z -Diku no mawarino Moment de, ima kore wo G de arawasu. Sôsuruto, (4) wa

$$\frac{dH}{dt} = G = \Sigma (xY - yX) \dots \dots \dots (5)$$

no Katati ni naru. Kore wa kattena Sitten-kumiai no (z -Diku no mawarino) Kaku-undôryô H ni tuite okonawareru Teiri de aru.

227. Gôtai ga kimatta Kwaitendiku wo motte iru Baai niwa, sore wo z -Diku to toreba,

$$H = I\omega \dots \dots \dots (6)$$

ni naru. Kore wa (1) no Siki ni § 202 ni okeru to onazi Keisan wo okonattemo sireru ga, mata tyokusetuni tugino yôni kangatemo sireru.

Tiisai Bubun P (Du 225) no Situryô wo m , sore kara Kwaitendiku ni itaru Suisen-kyori wo r to sureba, P no Sokudo wa $r\omega$, sore no Undôryô $mr\omega$ no z -Diku no mawarino Moment wa $mr^2\omega$ de aru. Sitagatte, Gôtai zentai no z -Diku no mawarino Kaku-undôryô wa

$$H = \Sigma mr^2\omega = I\omega$$

de aru.

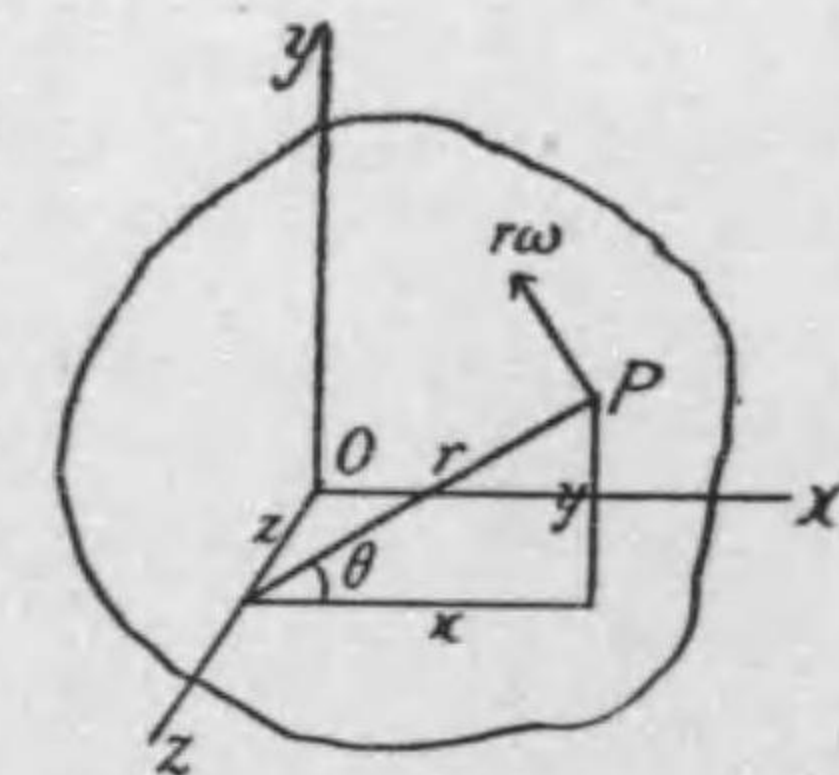
Kore wo (5) ni ireruto, I ga Zyôsû de aru tamenî,

$$I \frac{d\omega}{dt} = G \dots \dots \dots (7)$$

ni naru. Kore wa maeni § 202 de eta to onazimono de aru.

228. Dyûsîn no mawarino Kwaiten-undô. Gôtai ga ziyûni ugoku Baai ni Kaku-undôryô no Teiri

$$\frac{dH}{dt} = G \dots \dots \dots (1)$$



Du 225.

wo atehameru niwa, madu H wo kakikaeru koto ga hituyô de aru. Dyûsin wo Genten to site, moto to heikôna Zahyôdiku wo totte, kore ni taisuru Gôtai no utino tiisai Bubun no Zahyô wo (x', y') to sureba,

$$x = x_g + x', \quad y = y_g + y';$$

$$\frac{dx}{dt} = \frac{dx_g}{dt} + \frac{dx'}{dt}, \quad \frac{dy}{dt} = \frac{dy_g}{dt} + \frac{dy'}{dt}.$$

Korera wo H no Siki (maeno § no (1)) ni ireruto,

$$H = \sum m \left\{ x \frac{dy}{dt} - y \frac{dx}{dt} \right\}$$

$$= \sum m \left\{ (x_g + x') \left(\frac{dy_g}{dt} + \frac{dy'}{dt} \right) - (y_g + y') \left(\frac{dx_g}{dt} + \frac{dx'}{dt} \right) \right\}$$

$$= M \left(x_g \frac{dy_g}{dt} - y_g \frac{dx_g}{dt} \right) + \sum m \left(x' \frac{dy'}{dt} - y' \frac{dx'}{dt} \right)$$

$$+ \frac{dy_g}{dt} \sum m x' + x_g \sum m \frac{dy'}{dt} - \frac{dx_g}{dt} \sum m y' - y_g \sum m \frac{dx'}{dt}.$$

Sikaruni, owarino yottuno Kô wa mina rei de aru (§ 51 no Teiri); sitagatte,

$$H = M \left(x_g \frac{dy_g}{dt} - y_g \frac{dx_g}{dt} \right) + H' \dots \dots \dots (2);$$

tadasi,
$$H' = \sum m \left(x' \frac{dy'}{dt} - y' \frac{dx'}{dt} \right) \dots \dots \dots (3)$$

wa Dyûsin ni taisuru Undô ni tuite Dyûsin no mawarini totta Kaku-undôryô de aru. Sitagatte,

$$\frac{dH}{dt} = M \left(x_g \frac{d^2 y_g}{dt^2} - y_g \frac{d^2 x_g}{dt^2} \right) + \frac{dH'}{dt} \dots \dots \dots (4).$$

Mata,
$$G = \sum (xY - yX) = \sum (x_g Y - y_g X) + \sum (x' Y - y' X)$$

$$= x_g \sum Y - y_g \sum X + G' \dots \dots \dots (5);$$

tadasi,
$$G' = \sum (x' Y - y' X) \dots \dots \dots (6)$$

wa Dyûsin no mawarini totta Tikara no Moment de aru. (4) to (5) to wo (1) ni ireru Baai ni, maeno § no Kwankei

$$M \frac{d^2 x_g}{dt^2} = \sum X, \quad M \frac{d^2 y_g}{dt^2} = \sum Y$$

kara,
$$M \left(x_g \frac{d^2 y_g}{dt^2} - y_g \frac{d^2 x_g}{dt^2} \right) = x_g \sum Y - y_g \sum X$$

de aru kara, (1) no Kakikae tosite wareware wa tada

$$\frac{dH'}{dt} = G' \dots \dots \dots (7)$$

wo eru. Kono Hôteisiki wa hazimeno Hôteisiki (1) to onazi Katati wo motte iru ga, H' wa Dyûsin ni taisuru Undô ni tuite Dyûsin no mawarini totta Kaku-undôryô, G' wa yahari Dyûsin no mawarini totta Tikara no Moment de aru kara, (7) no Kwankei wo tugino yôni iiarawasu, koto ga dekiru:—

Dyûsin wo tôru Zahyômen ni suitiyokuna Diku no mawarino Kwaiten-undô wa, Dyûsin ga koteisite atte, onônono Ten ni moto to onazi Tikara ga hataraku Baai no Undô to onazi de aru.

Tyûi. § 225-228 no Teiri (Undôryô no Teiri to Kaku-undôryô no Teiri) wa, ueno Toriatukaikata de siseru tôri, Gôtai ni kagirazu, subeteno Buttai ya Buttai-kumiai ni okonawareru hiroi Teiri de aru.

229. Gôtai no Heimen-undô dewa, Dyûsin wo tôsite Undô no Heimen ni suitiyokuna Diku no mawarino Kwansei-moment wo I' to si, onazi Diku no mawarino Tikara no Moment wo G' , Kacusokudo wo ω to sureba,

$$H' = I' \omega,$$

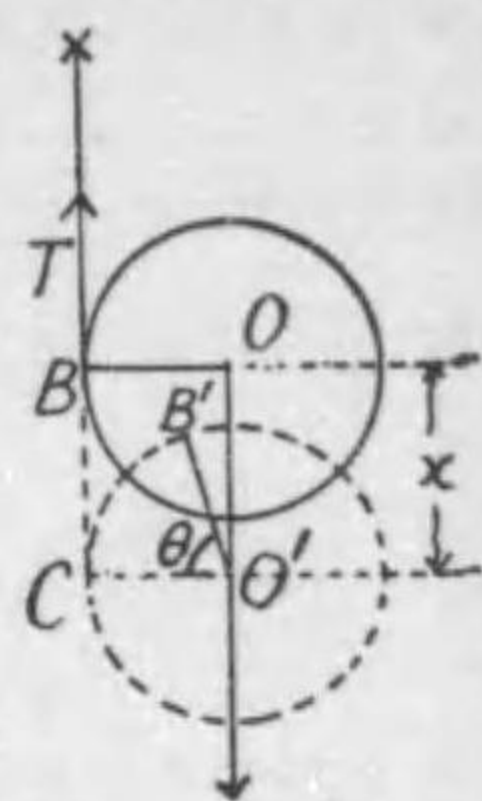
sitagatte,
$$I' \frac{d\omega}{dt} = I' \frac{d^2 \theta}{dt^2} = G' \dots \dots \dots (8).$$

Kono Hôteisiki (8) to Dyûsin no Undô wo kimeru Hôteisiki

$$\left. \begin{aligned} M \frac{d^2 x_g}{dt^2} &= \sum X, \\ M \frac{d^2 y_g}{dt^2} &= \sum Y \end{aligned} \right\} \dots \dots \dots (9)$$

to wa Gôtai no Heimen-undô wo kimeru dodaino Hôteisiki de aru.

230. Reî. Suiheini sasaerareta itiyôna Marubasira (Situryô M , Nagasa ni suitokuna Danmen no Hankei R) no mannakano enkeino Danmen no Huti ni sôte karui nobinai Ito ga makitukete atte, sore no hitotuno Hazi wa Marubasira ni toritukete ari, mohitotuno Hazi ni tikai Bubun wa entyokuni ueni muite, Hazi ga A Ten ni koteisite aru. Kono Marubasira wo hanaseba, donna Undô ga okoru ka?



Du 226.

Kono Marubasira ni sayôsuru Tikara wa Ito no Tyôryoku to Dyûryoku de aru ga, iduremo entyoku de aru kara, sore no Dyûsin ga suiheina Sokudo wo eru koto ga nai. Sitagatte, Marubasira no Dyûsin wa entyokuni kudari, Ito wa itu mademo entyokuni natte iru.

Ito no Tyôryoku wo T de, Dyûsin no otita Kyori wo x de arawasi, mata saisyô O kara suiheini, Gôtai ni sirusita Sen OB ga Kaku θ dake mawatte $O'B'$ ni kite iru to sureba, (C wo Du no yôni totte),

$$x = CB = CB' = R\theta$$

no Kwankei ga aru. Undô no Hôteisiki wa

$$M \frac{d^2x}{dt^2} = Mg - T, \dots \dots \dots (1)$$

$$I' \frac{d^2\theta}{dt^2} = TR \dots \dots \dots (2)$$

Kore to $x = R\theta \dots \dots \dots (3)$

to no mittu de T, x, θ ga kimaru. Mata,

$$I' = M \frac{R^2}{2}$$

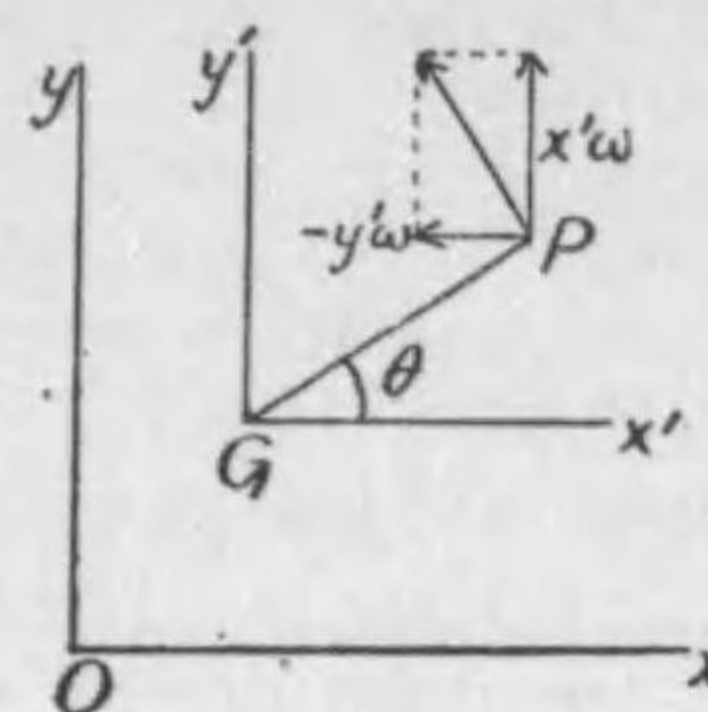
θ to T wo oidasite,

$$\frac{3}{2} \frac{d^2x}{dt^2} = g, \text{ sunawati } \frac{d^2x}{dt^2} = \frac{2}{3}g. \dots \dots (4)$$

Marubasira wa koredakeno Kasokudo de otiru. Saisyô $x=0$, $\frac{dx}{dt}=0$ de aru kara,

$$x = \frac{1}{3}gt^2 \dots \dots \dots (5)$$

231. Seiryoku no Hôteisiki. Dyûsin wo Genten to site, moto to heikôna Zahyôdiku wo tori, kore ni taisuru Gôtai no nakano hitotuno Ten P no Zahyô wo (x', y') to suru. Dyûsin wo tôte xy -Zahyômen ni suitokuna Diku G no mawarino Kakusokudo wo ω to sureba, P no G ni taisuru Sokudo wa $GP (=r')$ ni suitokuna $r'\omega$ de, sore no x -, y -Bun-sokudo wa sorezore $-r'\omega \sin \theta = -y'\omega$, $r'\omega \cos \theta = x'\omega$ de aru.



Du 227.

Tugini Dyûsin no Sokudo wo V_G to site, sore no x -, y -Bun-sokudo wo u_G, v_G to suru. Sokudo no Gôsei de nobeta yôni, Ten P no Sokudo V no Seibun u, v wa, iduremo ueno hutatu dutuno Seibun wo awaseta mono de aru; sunawati,

$$u = u_G - y'\omega, \quad v = v_G + x'\omega.$$

Gôtai wo Sitten no Atumari to mite, Sitten no Situryô wo m to sureba, Gôtai no Undô-seiryoku wa, $\Sigma m = M$ to kaite,

$$\Sigma \frac{1}{2} m(u^2 + v^2) = \frac{1}{2} M(u_G^2 + v_G^2) + \left(\Sigma m \frac{x'^2 + y'^2}{2} \right) \omega^2 - u_G \omega \Sigma m y' + v_G \omega \Sigma m x'.$$

Sikaruni, § 51 ni yotte,

$$\Sigma m x' = 0, \quad \Sigma m y' = 0,$$

mata, $u^2 + v^2 = V^2, \quad u_G^2 + v_G^2 = V_G^2, \quad x'^2 + y'^2 = r'^2$

de aru kara, Undô-seiryoku wa

$$\frac{1}{2} \Sigma m V^2 = \frac{1}{2} M V_G^2 + \frac{1}{2} (\Sigma m r'^2) \omega^2.$$

Dyûsin no mawarino Kwansei-moment $\Sigma m r'^2$ wo I' to kaite,

$$\frac{1}{2} \Sigma m V^2 = \frac{1}{2} M V_G^2 + \frac{1}{2} I' \omega^2 \dots \dots \dots (1)$$

Sunawati, Heimen-undô wo suru Gôtai no Undô-seiryoku wa, Dyûsin to onazi Heisin-undô to Dyûsin ni taisuru Kwaiten-undô to ni yotte okoru Undô-seiryoku wo, betubetuni keisansite kuwaeta mono ni hitosii.

Tugini, kiwamete mizikai Zikan dt no aidani Tikara ga

nasu Sigoto wo keisansuru. Seibun X, Y no Tikara ga hataraite iru Ten (x, y) ga dt no aidani

$$\begin{aligned} dx &= udt = u_g dt - y' \omega dt = u_g dt - y' d\theta, \\ dy &= vdt = v_g dt + x' \omega dt = v_g dt + x' d\theta \end{aligned}$$

no Seibun dake ugoku kara, subetenô Tikara ga nasu sôtaino Sigoto dW wa

$$\begin{aligned} dW &= \Sigma(Xdx) + \Sigma(Ydy) \\ &= (\Sigma X)u_g dt + (\Sigma Y)v_g dt + \Sigma(x'Y - y'X)d\theta. \end{aligned}$$

Sikaruni, $u_g dt = dx_g$, $v_g dt = dy_g$, $\Sigma(x'Y - y'X) = G'$ de aru kara,

$$dW = (\Sigma X)dx_g + (\Sigma Y)dy_g + G'd\theta;$$

hazime kara ima madeni nasareta Sigoto wa

$$W = \int (\Sigma X)dx_g + \int (\Sigma Y)dy_g + \int G'd\theta \dots \dots \dots (2)$$

de aru.

Korerano Ryô, Undô-seiryoku (1) to Sigoto (2) to no Kwankei wa Undô no Hôteisiki kara dete kuru:—

§ 229 no (9) to (8) to wo

$$\left. \begin{aligned} M \frac{du_g}{dt} &= \Sigma X, & M \frac{dv_g}{dt} &= \Sigma Y, \\ I' \frac{d\omega}{dt} &= G' \end{aligned} \right\} \dots \dots \dots (3)$$

no Katati ni kaki, korera ni sorezore

$$u_g dt = dx_g, \quad v_g dt = dy_g, \quad \omega dt = d\theta \dots \dots \dots (4)$$

wo ((3) no Hidarigawa niwa (4) no Hidarigawa, Migigawa niwa Migigawa wo) kakete kuwaeruto,

$$M(u_g du_g + v_g dv_g) + I' \omega d\omega = (\Sigma X)dx_g + (\Sigma Y)dy_g + G'd\theta,$$

sunawati,

$$d\left(M \frac{u_g^2 + v_g^2}{2} + I' \frac{\omega^2}{2} \right) = (\Sigma X)dx_g + (\Sigma Y)dy_g + G'd\theta.$$

Kore wo sekibunsite, $u_g^2 + v_g^2 = V_g^2$ wo ire, mata V_g to ω to no saisyono Atai wo V_{g0} , ω_0 to sureba,

$$\begin{aligned} &\left(M \frac{V_g^2}{2} + I' \frac{\omega^2}{2} \right) - \left(M \frac{V_{g0}^2}{2} + I' \frac{\omega_0^2}{2} \right) \\ &= \int (\Sigma X)dx_g + \int (\Sigma Y)dy_g + \int G'd\theta. \end{aligned}$$

Kore ga kono Baai ni okeru Seiryoku no Hôteisiki de,

$$\text{Undô-seiryoku no Masidaka} = W \dots \dots \dots (4)$$

no Imi wo motte iru mono de aru.

232. Gekiryoku no hataraku Baai. Buttai wo utu Baai, matawa hutatuno Buttai ga syôtotusuru Baai nado niwa kiwamete mizikai Zikan, kiwamete ôkii Tikara ga hataraite, Buttai no Undôryô ga niwakani kawaru mono de aru. Konoyôni *kiwamete mizikai Zikan hataraku kiwamete ôkina Tikara* wo "Gekiryoku" to tonaeru (§ 144).

Gekiryoku wa, Tikara no Oisa K wa taihen ôkiku, sore no hataraku Zikan τ wa taihen tiisai ga, sore no Ryokuseki $K\tau$ (nao seimituni icba $\int_0^\tau K dt$) wa hutûno Oisa wo motte iru. Ima sore no Seibun wo $\Xi = X\tau (= \int_0^\tau X dt)$, $H = Y\tau (= \int_0^\tau Y dt)$ de arawasu.

Gôtai no Dyûsin no Sokudo no Seibun ga hazime u_{g0} , v_{g0} de, Gekiryoku wo uketa notini u_g , v_g ni nari, mata Kakusokudo wa hazime ω_0 de, notini ω ni natta to suru.

Undô no Hôteisiki

$$\left. \begin{aligned} M \frac{du_g}{dt} &= X, \\ M \frac{dv_g}{dt} &= Y, \\ I' \frac{d\omega}{dt} &= (x'Y - y'X) \end{aligned} \right\}$$

ni dt wo kakete $t=0$ kara $t=\tau$ made sekibunsuruto,

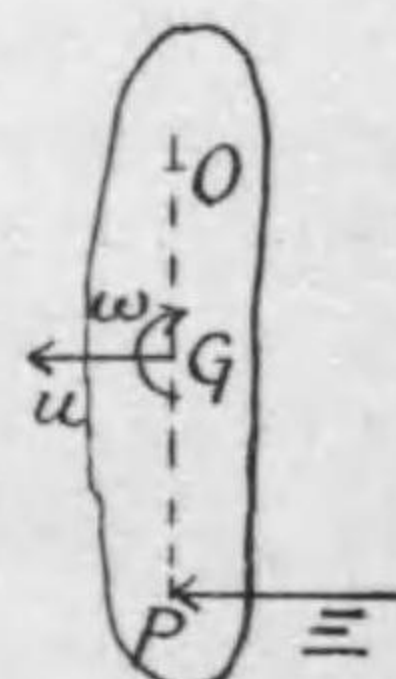
$$\left. \begin{aligned} M(u_G - u_{G0}) &= \int_0^{\tau} X dt = \Xi, \\ M(v_G - v_{G0}) &= \int_0^{\tau} Y dt = H, \\ I'(\omega - \omega_0) &= \int_0^{\tau} (x'Y - y'X) dt = x'H - y'\Xi \end{aligned} \right\} \dots (1).$$

Kono owarino Siki ni aru x', y' wa Gekiryoku no hataraku Ten no Dyûsin ni taisuru Zahyô de, $x'H - y'\Xi$ wa Dyûsin no mawari no Ryokuscki no Moment de aru.

Gôtai no hazimeno Undô wo arawasu Ryô (Dyûsin no Sokudo u_{G0}, v_{G0} , Kwaiten no Kakusokudo ω_0) to Gekiryoku no Sayôten x', y' oyobi Ryokuseki Ξ, H wo ataereba, ueno Hôteisiki ni yotte, Gekiryoku no hataraita notino Dyûsin no Sokudo u_G, v_G oyobi Kakusokudo ω wo motomeru koto ga dekiru.

233. Rei. Seisisite oru Gôtai (Situryô M) no hitotuno Ten P ni, sore wo Dyûsin G ni musubu Sen PG ni suityokuna Gekiryoku (Ryokuseki Ξ) ga hataraku.

Dyûsin G wo tôte, Ξ no Sayôsen to G to no Heimen ni suityokuna Diku ni taisuru Kwansai-moment wo I' , $PG = h$ to si, Gekiryoku ni yotte syôzuru Kakusokudo wo ω , Ξ to heikôni okorubeki G no Sokudo wo u to sureba, maeno § no Siki (1) kara



Du 228.

$$\left. \begin{aligned} Mu_G &= \Xi \\ I'\omega &= \Xi.GP \end{aligned} \right\} \dots (1)$$

de, Gekiryoku de syôzuru Undô ga kimaru.

PG wo entyôsita ueno kattena Ten O ga ugoki-hazimeru Sokudo wa, u_G to onazi Hôkô ni

$$u = u_G - \omega.GO$$

de aru. Kore ni ueno u_G, ω wo irekaereba,

$$u = \frac{\Xi}{M} - \frac{\Xi}{I'} . GP . GO.$$

$I' = Mk'^2$ to sureba,

$$u = \frac{\Xi}{M} \left(1 - \frac{GP . GO}{k'^2} \right).$$

Soreyueni, mosi Ten O ga

$$GP . GO = k'^2 \dots (2)$$

de ataerareru Atai wo motte oru naraba,

$$u = 0$$

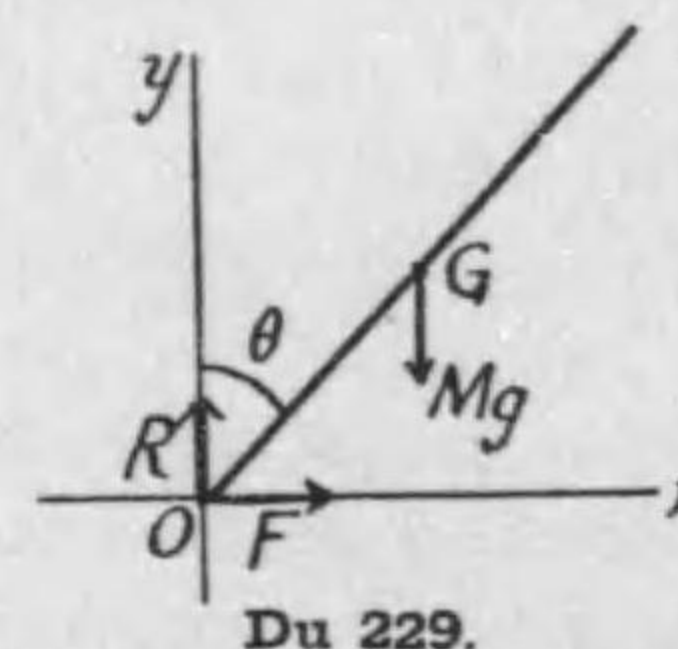
de aru. Sunawati, konoyôna Ten O wa, P ni Gekiryoku ga hataraita Syunkan ni okeru "Kwaiten no Tyûsin" de aru. Gyaku-ni, Ten P wo Ten O ni taisuru "Dageki no Tyûsin" to tonaeru.

Ten P to, Ten O to wa, Siki (2) de miru yôni, taisyôno Kwankei wo nasite oru kara, O Ten ga Dageki no Tyûsin to naru tokiniwa, P Ten ga Kwaiten no Tyûsin ni naru.

234. Reidai (a). Itiyôna Bô no hitotuno Hazi wo, kwanzenni arai Yuka no ueni suityokuni tatete hanasita to sureba, donoyôna Undô wo suru ka?

Bô no Nagasa wo a , sore no Situryô wo M to suru. Zikoku t ni, Bô to Entyokusen to no aidano Kaku wo θ to sureba, Dyûsin G no Zahyô wa

$$x = \frac{a}{2} \sin \theta, \quad y = \frac{a}{2} \cos \theta.$$



Du 229.

Yuka ga Bô ni oyobosu Entyoku-hankôryoku to Masaturyoku to wo sozore R, F to suru. Undô no Hôteisiki wa

$$M \frac{d^2x}{dt^2} = M \left\{ \frac{a}{2} \cos \theta \frac{d^2\theta}{dt^2} - \frac{a}{2} \sin \theta \left(\frac{d\theta}{dt} \right)^2 \right\} = F \dots (1),$$

$$M \frac{d^2y}{dt^2} = M \left\{ -\frac{a}{2} \sin \theta \frac{d^2\theta}{dt^2} - \frac{a}{2} \cos \theta \left(\frac{d\theta}{dt} \right)^2 \right\} = R - Mg \dots (2),$$

$$\frac{Ma^2 d^2\theta}{12 dt^2} = R \frac{a}{2} \sin \theta - F \frac{a}{2} \cos \theta \dots (3).$$

Korera kara F to R wo oidaseba,

$$\frac{d^2\theta}{dt^2} = \frac{3}{2} \frac{g}{a} \sin \theta \dots (4)$$

ni naru. $t=0$ no toki, $\theta=0$, $\frac{d\theta}{dt}=0$ de aru kara, (4) wo sekibunsite,

$$\left(\frac{d\theta}{dt}\right)^2 = 3\frac{g}{a}(1 - \cos\theta).$$

(1) to (2) ni $\left(\frac{d\theta}{dt}\right)^2$, $\frac{d^2\theta}{dt^2}$ no Atai wo irekaereba,

$$F = \frac{3}{4}Mg \sin\theta(3 \cos\theta - 2),$$

$$R = \frac{1}{4}Mg(3 \cos\theta - 1)^2.$$

Soreyue, $\cos\theta = \frac{1}{3}$ no toki, $R=0$ to naru, sunawati Bô ga Yuka wo osanaku naru keredomo, R ga Hugô wo kaenai kara, suguni mata Yuka wo osu yôni natte, Bô wa Yuka kara hanareru koto ga nai. Mata, $\cos\theta = \frac{2}{3}$ no toki, $F=0$ to natte, kore kara notiwa F wa hidarimukini hataraku.

Mata, $\frac{F}{R}$ wa $\cos\theta = \frac{1}{3}$ no toki, kagirinaku ôkiku naru kara,

Yuka ga kwanzenni araku nai naraba, kono toki yorimo ikuraka maeni suberi-hazimeru.

Tyûi. Kono Reidai dewa, Bô no sitano Hazi ga ugokanai kara, sore no Undô dake wo siraberu niwa, kimatta Kwaitendiku no Baai (§ 202) no Toriatukai wo site yoi. Sikasi, R ya F no Hatarakikata wo miru niwa kokoni kaita yôni suru no de aru.

Mondai. Yuka ga mattaku nameraka naraba, Bô ga donnani taoreru ka?

Mondai. Bô no ueno Hazi ni omoi tiisai Buttai ga toritukete atte, Yuka ga mattaku arai Baai niwa, $\cos\theta = \frac{1}{3}$ ni naru yorimo maeni Asi ga Yuka no Imi de aru koto wo syômeisei!

[Ueno Reidai no yôna Keisan wo site $R < 0$ ni naru no wa, Bô no Hazi no hanarenai tameni, Yuka ga sore wo hikutukeru koto ga hituyô de aru koto no Imi de aru kara, sore ga dekinai Baai niwa Bô ga Yuka wo hanareru.]

235. Reidai (b). Itiyôna Kyû ga arai Syamen no ue wo korogari-otiru tokiniwa donoyôna Undô wo suru ka?

(i) *Hureai ga zyûbuuni arakute, Kyû ga suberanaide korogari-otiru Baai.* Kyû no Situryô wo m , Hankei wo a , aru Zikoku ni okeru sore no Kakusokudo wo ω , Syamen ni sôta Dyûsin no Sokudo wo u_G to suru (Muki wa Du no yôni).

Kono Baai ni Kyû no Undô dake wo siru Mokuteki niwa, Seiryoku no Hôteisiki wo tukuru ga yoi.

Kyû no, G wo tôru suiheina Tyokkei ni taisuru Kwansei-môment wa $\frac{2}{3}ma^2$ de aru kara, Kyû no motte oru Undô-seiryoku wa,

$$T = \frac{1}{2}mu_G^2 + \frac{2}{3}ma^2\omega^2.$$

Tokoroga, Kyô wa itumo Syamen tono Hureaiten P no mawarini kwaitensite otiru [P no Sokudo $= 0$ karamo wakaruru] kara,

$$u_G = a\omega$$

de aru. Sitagatte,

$$T = \frac{1}{2}m(u_G^2 + \frac{2}{3}u_G^2) = \frac{7}{10}mu_G^2.$$

Mata, Kyû no Tyûsin no entyokuna Hôkô no Hen'i wo h to sureba, Dyûryoku ga nasita Sigoto wa mgh ni hitosii. Masaturyoku mo Suityoku-hankôryoku mo kono Baai niwa (sore no hataraku Ten P ga Sokudo $= 0$ de aru tameni), Sigoto wo site inai.

Soreyueni, u_G no hazimeno Atai wo u_{G0} to sureba,

$$\frac{7}{10}m(u_G^2 - u_{G0}^2) = mgh.$$

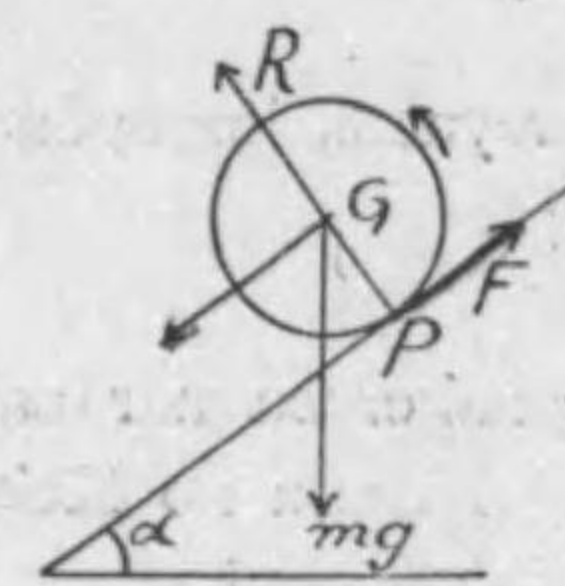
Kore wo

$$\frac{1}{2}m(u_G^2 - u_{G0}^2) = m \cdot \frac{5}{7}g \cdot h$$

to kaite, § 166 no (1) no Siki ni kuraberuto, Kyû no Tyûsin no Undô wa g no Atai ga $\frac{5}{7}$ ni hetta Basyo ni oite namerakana Syamen ni sôte suberi-otiru Sitten no Undô to dôto de aru.

Undô ga konoyôni okoru tameni, Men no Arasa ga ikura izyô de arubeki ka wo siru niwa, hutûno Undô no Hôteisiki wo tukatte, Masaturyoku no Ooisa nado wo dasaneba naranai.

Syamen no Suityoku-aturyoku wo R , Masaturyoku wo ueni F to suru. Dyûsin no Undô wo Syamen ni sôta Hôkô to, sore ni suityokuna Hôkô to ni bunkaisite kangaereba, suityokuno Hôkô niwa Dyûsin no Sokudo ga 0 da kara, Undô no Hôteisiki wa



Du 230.

$$m \frac{du_G}{dt} = mg \sin \alpha - F, \quad 0 = mg \cos \alpha - R, \quad m \cdot \frac{2}{3} a^2 \cdot \frac{d\omega}{dt} = Fa.$$

Kore ni $a\omega = u_G$ wo irete tokuto,

$$F = \frac{2}{3} mg \sin \alpha, \quad R = mg \cos \alpha, \quad u_G = u_{G0} + \frac{2}{3} g \sin \alpha \cdot t,$$

sitagatte,
$$\frac{F}{R} = \frac{2}{3} \tan \alpha.$$

Soreyueni, konoyôna Undô ga okoru tameniwa, Masatu no Keisû μ ga

$$\mu \geq \frac{2}{3} \tan \alpha$$

de nakereba naranai.

Masatu no Keisû μ no hô ga ataete aru to sureba, Syamen no Katamuki ga,

$$\tan \alpha_1 = \frac{2}{3} \mu$$

de ataerareru α_1 yorimo ôkiku nai Baai ($\alpha \leq \alpha_1$) niwa, (saisyono Undô no Ataekata ga Kyû no suberanai yôni natte oreba) Kyû wa suberazuni korogari-otiru (matawa korogari-agaru); $\alpha > \alpha_1$ nareba Kyû ga suberi nagara korogari-otiru (matawa -agaru).

(ii) *Kyû ga suberi-otiru Baai.* Kyû no Syamen ni hurete iru Tokoro ga *sitani* suberi tutu aru to kateisite siraberu. Kono Baai niwa, Kyû wa Hureaiten P no mawarini mawaranai kara, u_G to $a\omega$ to wa hitosiku nai. Undô no Masatukeisû wo μ' to sureba, Masaturyoku F wa $F = \mu' R$ de *ueni* multe hataraku.

Soreyueni, Undô no Hôteisiki wa

$$m \frac{du_G}{dt} = mg \sin \alpha - \mu' R, \quad 0 = mg \cos \alpha - R, \quad \frac{2}{3} m a^2 \frac{d\omega}{dt} = \mu' R a.$$

Kore kara tokuto,

$$\left. \begin{aligned} u_G &= u_{G0} + (\sin \alpha - \mu' \cos \alpha) g t, \\ a\omega &= a\omega_0 + \frac{2}{3} \mu' g \cos \alpha \cdot t. \end{aligned} \right\}$$

Kyû no Hureaiten no Sokudo wa *sitani*

$$u_G - a\omega = u_{G0} - a\omega_0 + (\sin \alpha - \frac{2}{3} \mu' \cos \alpha) g t$$

de aru.

Soreyueni, $u_{G0} - a\omega_0 > 0$, $\tan \alpha \geq \frac{2}{3} \mu'$ de aru Baai niwa, itu demo

$u_G - a\omega > 0$; sunawati, Hureai ga sitani subette iru to iu ueno Katei ga itu mademo atatte iru.

Mondai. Kono Reidai de Kyû no Syamen ni hurete iru Tokoro ga *ueni* suberi tutu aru Baai niwa dô naru ka?

Mondai. Ueno Reidai de,

$$\alpha = 30^\circ, \quad \mu = \mu' = 1, \quad a = 10 \text{ cm.}$$

$$u_{G0} = \text{sita e } 5 \text{ cm./s.}$$

$$\omega_0 = \text{korogari-agaru Muki ni } 5 \text{ radian/s.}$$

da to sureba, Undô ga donoyôni susumu ka?

Rensyû-mondai VIII.

1. Itiyôna Marubasira ga, Tyûsinsen wo suiheini site, arai Syamen (Keisya-no-Kaku= α) wo suberazuni korogari-otiru Kasokudo wa ikura ka? Kono Undô ga okoru tameniwa, Masatu-keisû no Dyôken wa dô ka?

2. Ueno Mondai de, Masatu-keisû (μ) ga tiisa-sugiru tokini, saisyô Marubasira ga tomatte iru to sureba, donna Undô ga okoru ka?

3. Niku no Atusa mo Mitudo mo itiyôna uturona Kyû ga arai Syamen (Keisya-no-Kaku= α) wo suberazuni korogari-otiru Kasokudo ga $\frac{2}{3} g \sin \alpha$ yoriwa ôkiku, $\frac{1}{3} g \sin \alpha$ yoriwa tiisai koto wo syômeisei!

4. Harigane wo En (Hankei= a) no Katati ni mageta Wa ga, itumo entyokuna Heimen no nakani atte, Masatu-keisû μ no Yuka no ue wo ugoite iru. Hazimeno Undô ga, Tyûsin no Sokudo ga migini V , Kakusokudo ga hidarimawarini ω de aru. $V < a\omega$ no Baai ni okeru Undô wo sirabei!

5. Marubasiragatano Sinbô (Hankei= r) no Ryôhazi ni, sore ni suityokuni muketa hutatuno dôiya itiyôna Maruita (Hankei= R) no Tyûsin wo koteisite tukutta Gôtai (Situryô= M) ga, Sinbô wo

suiheini site, suiheina Tukue no ueni nosete aru. Sinbô ni suberanaï yôni maita Ito no hitotuno Hazi ga Sinbô no *Sitagawa* kara, sore ni suityokuni suiheini dete, namerakana Bô ni kakatte sitani tarete, sore no Hazi ni Omori (Situryô= m) ga toritukete aru. Tukue ga zyûbunni arai tokini, kono Sôti ga saisyô seisisite iru to sureba, donna Undô ga okoru ka? Tadasî, Maruïta oyobi Sinbô no, Tyûsinsen no mawarino Kwansai-moment no Keisan niwa, Sinbô no Bubun wo sutete kangaeru.

6. Mondai 5 to dôyôna Sôti de, Ito no suiheina Bubun ga Sinbô no *Uwagawa* kara dete iru Baai niwa Undô ga dô naru ka?

7. Mondai 5 no Sôti de, Tukue no Masatu-keisû μ ga zyûbunni ôkiku nai tameni, Tukue no ue de Maruïta ga suberu Baai niwa, Undô ga dô naru ka?

8. Mondai 6 no Sôti de, Tukue no Masatu-keisû μ ga zyûbunni ôkiku nai tameni, Tukue no ue de Maruïta ga suberu Baai niwa, Undô ga dô naru ka? $r:R$ no Hi ni yotte donna Tigai ga aru ka?

9. Arai Tukue no ueni Marubasira (Hankei= r) ga korogatte iru. Sore no Mitudo wa hobo itiyô de aru keredomo, sukosino Kurui ga aru tameni, Dyûsin G ga Katati no Tyûsin C kara a dake hadurete iru. G no itiban hikui Iti no Kinzyo de okoru Sindô no Syûki wo dase! Tadasî, G no mawarino Kwansai-moment niwa Marubasira ga mattaku itiyôna Baai no Dyûsin no mawarino Atai wo tukatte yoi.

10. Gôtai ga sore no Dyûsin wo hanareta Tokoro ni, sore no Itibubun tosite marubasiragatano Bubun wo motte iru. Kono Marubasira wo arai suiheina ugokanai Ita ni sasaete, Gôtai ni Zittai-huriko to dôyôna Sindô wo saseru tokini, tiisai Sindô no Syûki ga

$$T = 2\pi \sqrt{\frac{k^2 + h^2}{(h+r)g}}$$

de ataerareru koto wo syômeisei! Tadasî, k wa Dyûsin (wo tôsite Marubasira ni heikôna Sen) no mawarino Kwaiten-hankei, h wa Dyûsin kara Marubasira no Men ni itaru Suisen-kyori, r wa Marubasira no Hankei.

11. Nagasa 1 m. no itiyôna hosoi Bô ga, hitotuno Hazi ni torituketa Ito (Nagasa 40 cm.) de koteisita Ten kara turisagete aru. Kono Sôti ga hitotuno entyokuna Heimen de nasu tiisai Sindô no Sikata oyobi Syûki wo sirabei! Tadasî, Ito no Situryô wa nai to suru.

12. Itiyôna hosoi Bô (Nagasa 1 m., Situryô 1 kg.) ga hitotuno Hazi wo Diku to site mawaru koto ga dekiru. Sore no sitano Hazi ni hokano itiyôna hosoi Bô (Nagasa 25 cm., Situryô 500 g.) no Hazi ga namerakana Tugime de tunaide aru. Kono Sôti ga hitotuno entyokuna Heimen de nasu tiisai Sindô no Sikata oyobi Syûki wo sirabei!

13. Itiyôna hosoi Bô ga, namerakana (suiheina) Yuka to namerakana (entyokuna) Kabe to no Kiriaisen ni suityokuna Heimen no nakani atte, Ryôhazi ga sorerano Men ni sasaerare tutu otite kuru. Kono Undô ni okeru Katamuki no Henkwa ga, onazi Bô ga hitotuno Hazi wo Diku to site entyokuna Heimen no naka de mawaru Undô ni okeru mono to onazi de aru koto wo syômeisei!

14. Itiyôna hosoi Bô no hitotuno Hazi ni tiisai Kagi ga tuite ite, ugokanai suiheina namerakana Yokobô ni kakatte iru. Kono Bô ga Yokobô wo hukumu Entyokumen ni oite nasu tiisai Sindô ni okeru Katamuki no Kawarikata ga, Dyûryoku ga 4-bai ôkii Tokoro de onazi Bô ga hitotuno Hazi wo Diku to site sindôsuru Baai to onazi de aru koto wo syômeisei!

15. Namerakana suiheina Men no ueni suiheina Iti de seisisite iru itiyôna kukeino Ita (Hen a, b , Situryô M) no, a no Hen no Mannaka kara c ($< \frac{1}{2}a$) dake hanareta Ten ni, sono Hen ni suityokuna Hôkô ni, Hayasa v de Men ni sôte tobu Teppôdama (Situryô m) ga atatte, Ita no Hutî ni kuttuita to sureba, sorekara noti Ita ga donna Undô wo suru ka? [Teppôdama no Ooisa wa kangaenai].

16. Itiyôna kukeino Ita ga, hitotuno Hen ga, suiheina Kwaitendiku ni natte, tarete iru. Kono Ita ni mukatte sore ni suityokuna Hôkô kara Teppôdama wo utta tokoro, Teppôdama ga Ita ni hamarikonde, Ita ga ugokidasi, entyokuna Iti kara

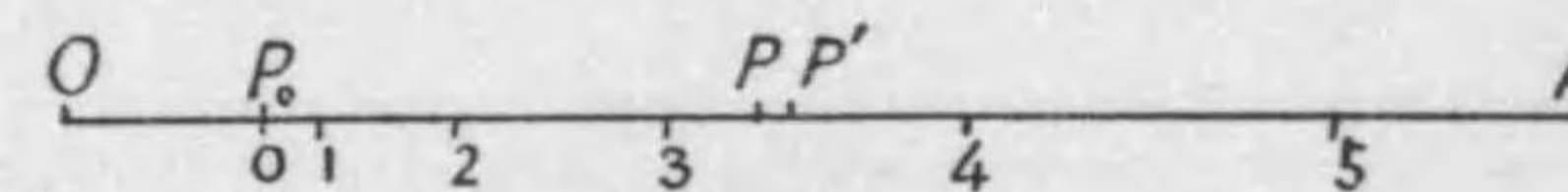
Kaku α dake katamuita Iti made agatte orita. Ita no tateno Nagasa l , Situryô M , Teppôdama no Situryô m , sore ga Ita^{wa}_{ni} atatta Basyo no Kwaitendiku karano Kyori c to, ueni dasita Kaku α to wo sitte Teppôdama no Sokudo wo kimeru Keisan wo simese!

HUROKU.

Bibungaku oyobi Sekibungaku no Keisansikata.

251. Bibunzan. Bibungaku no Keisansikata wo noberu no ni, madu hitotuno Rei ni tuite siraberu.

Tyokusen OA no ue wo ugoku Ten ga hazime P_0 ni ari,



Du 245.

sore kara t -byô tatta Zikoku ("Zikoku t " to iu) ni P ni aru to si, kono Iti P wo iarawasu no ni, kimatta Ten O kara soko made hakatta Kyori OP wo tukatte, sore wo s de arawasu. s wa t ga masu ni turete kawaru; ima, hitotuno Rei tosite, korera no aidano Kwankei ga

$$s = a + bt + ct^2 \dots\dots\dots(1)$$

de atarareru to suru. a wa $t=0$ ni taisuru s no Atai sunawati OP_0 de aru. [Du ni dasita no wa, Nagasa no Tan'i wo Miri-mêtoru (mm.) to site, $a=10$, $b=1$, $c=2$ no Baai de, Sen no sitani 0, 1, 2, 3, 4, 5 to sirusita no wa $t=0, 1, 2, 3, 4, 5$ no Zikoku ni Ten ga oru Iti de aru. Kono Du de wakaruru tôri, kono Undô wa *Hayasa ga sidaini masu Undô* de aru.]

Ten ga P ni aru Toki kara mizikai Zikan τ no notini P' ni kuru to si, $PP' = \sigma$ to sureba,

$$\begin{aligned} \sigma &= OP' - OP = \{a + b(t + \tau) + c(t + \tau)^2\} - \{a + bt + ct^2\} \\ &= b\tau + 2ct\tau + c\tau^2. \end{aligned}$$

Ten ga kono Aida wo tôru "heikinno Hayasa" wo $[V]$ de arawaseba,

$$[V] = \frac{\sigma}{\tau} = b + 2ct + c\tau \dots\dots\dots(2).$$

τ mo σ mo kiwamete tiisaku suru Baai ni, σ/τ no Atai wa $b + 2ct$ to iu kimatta (sunawati τ no Tiisasa ni mukwankeina) Atai ni naru. Kore ga sunawati P -Ten ni okeru (sunawati Zikoku t ni okeru) Sokudo V de aru; sunawati,

$$V = b + 2ct \dots\dots\dots(3).$$

252. P' ni taisuru s oyobi t no Atai wo s' oyobi t' de simeseba,

$$s' = s + \sigma \quad t' = t + \tau;$$

sunawati,

$$\sigma = s' - s, \quad \tau = t' - t.$$

Soreyueni, σ wa P kara P' ni kuru aidano s no Masidaka de ari, τ wa onazi aidano t no Masidaka de aru. " s no Masidaka," " t no Masidaka" wo arawasu Hugô tosite, tûzyô Δs , Δt no Sirusi wo tukau⁽¹⁾. Sitagatte,

$$\sigma = s' - s = \Delta s \quad \tau = t' - t = \Delta t;$$

mata (2) no Kwankei wa tugino yôni kakeru;—

$$[V] = \frac{\Delta s}{\Delta t} = b + 2ct + c\Delta t \dots\dots\dots(4).$$

253. Δs , Δt wo kagirinaku tiisaku totta mono wo ds , dt to kaku. "Kagirinaku tiisaku totta kyokugenno (dondumarimo) Atai" to iu Imi wo ippanno Narawasi ni sitagatte, "lim"⁽²⁾ to iu Hugô de simesuto, Ten P ni okeru (matawa Zikoku t ni okeru) Sokudo wa

$$V = \lim \left(\frac{\Delta s}{\Delta t} \right) = \frac{ds}{dt} = b + 2ct \dots\dots\dots(5).$$

de ataerareru.

⁽¹⁾ Δs ya Δt wa Δx , Δt no Imi no Ryô dewa nai: Δ (delta) wa Ryô demo Kazu demo nakute, tada uenô yôna Imi no Sirusi de aru. Tugini aru ds , dt no d mo dôyô.

⁽²⁾ Nao teineiniwa "lim" tomo kaku. *lim* wa Ratengo *limes*, Eigo *limit* ni ataru. $\Delta t = 0$

254. Ippanni, s ga t no kawaru ni turete kimatta Kwankei wo nasite kawaru Baai ni, " s ga t no Kansû de aru" to iu; sosite, s ga t no Kansû de aru koto wo

$$s = f(t), \quad s = F(t), \quad s = \varphi(t)$$

nado no yôna Siki de arawasu.

Ueno Rei de miru yôni, ippani

$$s = f(t) \dots\dots\dots(6)$$

de aru Baai ni,

$$\frac{ds}{dt} = \lim \left(\frac{\Delta s}{\Delta t} \right) = \lim_{\Delta t \rightarrow 0} \frac{f(t + \Delta t) - f(t)}{\Delta t} \dots\dots(7)$$

wa ononono t ni taisite kimatta Atai wo motu mono de, kore wo " t ni taisuru s no Bibun-keisû" to tonaeru.

s kara $\frac{ds}{dt}$ wo tukuru koto wo " s wo t ni taisite *bibun-suru*" to ii, $\frac{d}{dt}$ to iu Sirusi wo kono Tetuduki wo arawasu

Hugô to miru koto mo aru.

$f(t)$ wo t ni taisite bibunsite erareru Kansû wo tûzyô $f'(t)$ to kaki, " $f(t)$ no Yûdô-kansû" to tonaeru; sunawati,

$$f'(t) = \frac{d}{dt} f(t).$$

$\frac{ds}{dt}$ no t ni taisuru Bibunkeisû wo $\frac{d^2s}{dt^2}$ to kaku.

s ga x , y hutatuno Ryô no Kansû de aru tokini,

y wo kaenaide x nomi wo kaeru Baai no $\lim \frac{\Delta s}{\Delta x}$ wo $\frac{\partial s}{\partial x}$,

x wo kaenaide y nomi wo kaeru Baai no $\lim \frac{\Delta s}{\Delta y}$ wo $\frac{\partial s}{\partial y}$

to kaku. Korera wo *Bibun-bibun-keisû* to iu.

255. Yôyôna Bibun-keisû oyobi sore ni kwansuru Teiri wa tugino tôri:—(koko dewa, Kaku wa Kodohô sunawati *Radian* de arawasu; mata, s , t , u , v no hokano Ryô wa Zyôsû de aru.)