# Wright State University Lake Campus/2018-9/Phy2410/Equation sheet

**Also available as File:Wsul file pdf 04.pdf**

### T1

**2.5 Electric charges and fields (https://cnx.org/contents/eg-XcBxE@14.1:Ai7EWAra@5/Introduction)**

$\varepsilon_0 = 8.85\times10^{-12}$ F/m = vacuum permittivity.

e = $1.602\times10^{-19}$C: negative (positive) charge for electrons (protons)

$k_e = \frac{1}{4\pi\varepsilon_0} =$ = $8.99\times10^9$ m/F

$\vec{F} = Q\vec{E}$ where $\vec{E} = \frac{1}{4\pi\varepsilon_0}\sum_{i=1}^{N}\frac{q_i}{r_{Pi}^2}\hat{r}_{Pi}$

$\vec{E} = \int \frac{dq}{r^2}\hat{r}$ where $dq = \lambda d\ell = \sigma da = \rho dV$

$E = \frac{\sigma}{2\varepsilon_0}$ = field above an infinite plane of charge.

Find E

$\vec{E}(\vec{r}) = \dfrac{1}{4\pi\varepsilon_0}\sum_{i=1}^{N}\dfrac{\widehat{\mathcal{R}}_i Q_i}{|\vec{\mathcal{R}}_i|^2} = \dfrac{1}{4\pi\varepsilon_0}\sum_{i=1}^{N}\dfrac{\vec{\mathcal{R}}_i Q_i}{|\vec{\mathcal{R}}_i|^3}$ is the electric field at the field point, $\vec{r}$, due to point charges at the source points,$\vec{r}_i$ , and $\vec{\mathcal{R}}_i = \vec{r} - \vec{r}_i$, points from source points to the field point.

### T2

**2.6 Gauss's law (https://cnx.org/contents/eg-XcBxE@14.1:xakXl9gb@5/Introduction)**:

$\Phi = \vec{E}\cdot\vec{A} \to \int \vec{E}\cdot d\vec{A} = \int \vec{E}\cdot\hat{n}\, dA$ = electric flux

$q_{enclosed} = \varepsilon_0 \oint \vec{E}\cdot d\vec{A}$

$d\,\mathrm{Vol} = dxdydz = r^2 dr dA$ where $dA = r^2 d\phi d\theta$

$A_{\text{sphere}} = r^2\int_0^{\pi}\sin\theta d\theta\int_0^{2\pi}d\phi = 4\pi r^2$

Surface Integrals

Calculating $\int f dA$ and $\int f dV$ with angular symmetry

Cyndrical: $dA = 2\pi r\, dz$; $dV = dA\, dr$. Spherical: $\int dA = 4\pi r^2,\ dV = 4\pi r^2\, dr$

More Gauss Law

Calculating $\int f dA$ and $\int f dV$ with angular symmetry

Cyndrical: $dA = 2\pi r\, dz$; $dV = dA\, dr$. Spherical: $\int dA = 4\pi r^2,\ dV = 4\pi r^2\, dr$

**T3**

**2.7 Electric potential (https://cnx.org/contents/eg-XcBxE@14.1:bMxnTeM5@6/Introduction)** The alpha-particle is made up of two protons and two neutrons.

$\Delta V_{AB} = V_A - V_B = -\int_A^B \vec{E}\cdot d\vec{\ell}$ = electric potential

$\vec{E} = -\frac{\partial V}{\partial x}\hat{i} - \frac{\partial V}{\partial y}\hat{j} - \frac{\partial V}{\partial z}\hat{k} = -\vec{\nabla}V$

$q\Delta V$ = change in potential energy (or simply $U = qV$)

$Power = \frac{\Delta U}{\Delta t} = \frac{\Delta q}{\Delta t}V = IV = e\frac{\Delta N}{\Delta t}$

Electron (proton) mass = 9.11×10$^{-31}$kg (1.67× 10$^{-27}$kg). Elementary charge = e = 1.602×10$^{-19}$C.

$K = \frac{1}{2}mv^2$ =kinetic energy. 1 eV = 1.602×10$^{-19}$J

$V(r) = k\frac{q}{r}$ near isolated point charge

Many charges: $V_P = k\sum_1^N \frac{q_i}{r_i} \to k\int \frac{dq}{r}$.

**2.8 Capacitance (https://cnx.org/contents/eg-XcBxE@14.1:FYJxWFC_@6/8-1-Capacitors-and-Capacitance)**

$Q = CV$ defines capacitance.

$C = \varepsilon_0\frac{A}{d}$ where A is area and d<<A$^{1/2}$ is gap length of parallel plate capacitor

**Series :** $\frac{1}{C_S} = \sum\frac{1}{C_i}$. **Parallel:** $C_P = \sum C_i$.

$u = \frac{1}{2}QV = \frac{1}{2}CV^2 = \frac{1}{2C}Q^2$ = stored energy

$u_E = \frac{1}{2}\varepsilon_0 E^2$ = energy density

**T4**

**2.9 Current and resistors (https://cnx.org/contents/eg-XcBxE@14.10:WS3a1YbB@5/Introduction)**

Electric current: 1 Amp (A) = 1 Coulomb (C) per second (s)

Current=$I = dQ/dt = nqv_dA$, where

$(n, q, v_d, A)$ = (density, charge, speed, Area)

$I = \int \vec{J}\cdot d\vec{A}$ where $\vec{J} = nq\vec{v}_d$ =current density.

$\vec{E} = \rho\vec{J}$ = electric field where $\rho$ = resistivity

$\rho = \rho_0\left[1 + \alpha(T - T_0)\right]$, and $R = R_0\left[1 + \alpha\Delta T\right]$,

where $R = \rho\frac{L}{A}$ is resistance

$V = IR$ and Power=$P = IV = I^2R = V^2/R$

**2.10 Direct current circuits (https://cnx.org/contents/eg-XcBxE@14.1:BRLHpZ5e@6/Introduction)**

$V_{terminal} = \varepsilon - Ir_{eq}$ where $r_{eq}$=internal resistance and $\varepsilon$=*emf*.

$R_{series} = \sum_{i=1}^N R_i$ and $R_{parallel}^{-1} = \sum_{i=1}^N R_i^{-1}$

Kirchhoff Junction: $\sum I_{in} = \sum I_{out}$ and Loop: $\sum V = 0$

Charging an RC (resistor-capacitor) circuit: $q(t) = Q\left(1 - e^{t/\tau}\right)$ and $I = I_0e^{-t/\tau}$ where $\tau = RC$ is RC time, $Q = \varepsilon C$ and $I_0 = \varepsilon/R$.

Discharging an RC circuit: $q(t) = Qe^{-t/\tau}$ and $I(t) = -\frac{Q}{RC}e^{-t/\tau}$

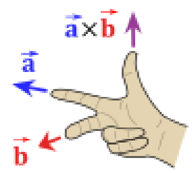
**T5**

**2.11 Magnetic forces and fields (https://cnx.org/contents/eg-XcBxE@14.1:-cf9Ogkt@5/Introduction)**

$|\vec{a}\times\vec{b}| = ab\sin\theta \Leftrightarrow$

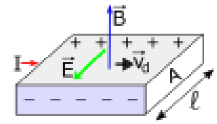
$(\vec{a}\times\vec{b})_x = (a_yb_z - a_zb_y)$,

$(\vec{a}\times\vec{b})_y = (a_z b_x - a_x b_z)$,
$(\vec{a}\times\vec{b})_z = (a_x b_y - a_y b_x)$
Magnetic force: $\vec{F} = q\vec{v}\times\vec{B}$, $d\vec{F} = I\vec{d\ell}\times\vec{B}$.
$\vec{v}_d = \vec{E}\times\vec{B}/B^2$ =EXB drift velocity
Circular motion (uniform B field): $r = \frac{mv}{qB}$. Period=$T = \frac{2\pi m}{qB}$.



cross product

Dipole moment=$\vec{\mu} = NIA\hat{n}$. Torque= $\vec{\tau} = \vec{\mu}\times\vec{B}$. Stored energy=$U = \vec{\mu}\cdot\vec{B}$.
Hall field =$E = V/\ell = Bv_d = \frac{IB}{neA}$



Hall effect

## 2.12 Sources of magnetic fields (https://cnx.org/contents/eg-XcBxE@14.1:BDvPdDpp@5/Introduction)

Free space permeability $\mu_0 = 4\pi\times10^{-7}$ T·m/A
Force between parallel wires $\frac{F}{\ell} = \frac{\mu_0 I_1 I_2}{2\pi r}$
Biot–Savart law $\vec{B} = \frac{\mu_0}{4\pi}\int_{wire}\frac{I\vec{d\ell}\times\hat{r}}{r^2}$

Ampère's Law: $\oint\vec{B}\cdot\vec{d\ell} = 4\pi\mu_0 I_{enc}$
Magnetic field inside solenoid with paramagnetic material = $B = \mu nI$ where $\mu = (1+\chi)\mu_0$= permeability

(we skip T6 because it was a review of previous chapters)

**T7**

## 2.13 Electromagnetic induction (https://cnx.org/contents/eg-XcBxE@14.1:az4UJL6l@6/Introduction)

Magnetic flux $\Phi_m = \int_S\vec{B}\cdot\hat{n}dA$
Motional $\varepsilon = B\ell v$ *if* $\vec{v}\perp\vec{B}$
Electromotive "force" (volts) $\varepsilon = -N\frac{d\Phi_m}{dt} = \oint\vec{E}\cdot\vec{d\ell}$

rotating coil $\varepsilon = NBA\omega\sin\omega t$

## 2.14 Inductance (https://cnx.org/contents/eg-XcBxE@14.1:gBxAb_6h@6/Introduction)

Unit of inductance = Henry (H)=1V·s/A

Mutual inductance: $M\frac{dI_2}{dt} = N_1\frac{d\Phi_{12}}{dt} = -\varepsilon_1$ where $\Phi_{12}$=flux through 1 due to current in 2. Reciprocity: $M\frac{dI_1}{dt} = -\varepsilon_2$

Self-inductance: $N\Phi_m = LI \to \varepsilon = -L\frac{dI}{dt}$

$L_{\text{solenoid}} \approx \mu_0 N^2 A\ell$, $L_{\text{toroid}} \approx \frac{\mu_0 N^2 h}{2\pi}\ln\frac{R_2}{R_1}$, Stored energy= $\frac{1}{2}LI^2$

$I(t) = \frac{\varepsilon}{R}\left(1-e^{-t/\tau}\right)$ in LR circuit where $\tau = L/R$.

$q(t) = q_0\cos(\omega t+\phi)$ in LC circuit where $\omega = \sqrt{\frac{1}{LC}}$

## 2.15 Alternating current circuits (https://cnx.org/contents/eg-XcBxE@14.1:6uMHjFiO@5/Introduction)

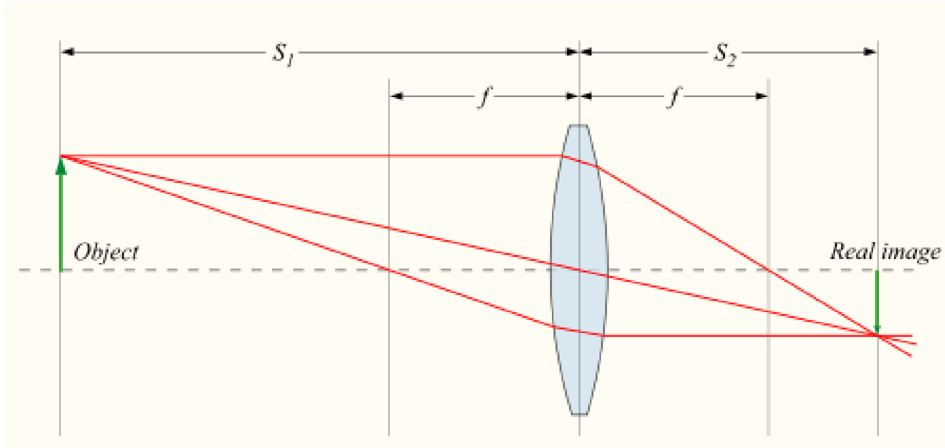
AC voltage and current $v = V_0\sin(\omega t-\phi)$ if $i = I_0\sin\omega t$.
RMS values $I_{rms} = \frac{I_0}{\sqrt{2}}$ and $V_{rms} = \frac{V_0}{\sqrt{2}}$
Impedance $V_0 = I_0 X$
Resistor $V_0 = I_0 X_R$, $\phi = 0$, where $X_R = R$
Capacitor $V_0 = I_0 X_C$, $\phi = -\frac{\pi}{2}$, where $X_C = \frac{1}{\omega C}$
Inductor $V_0 = I_0 X_L$, $\phi = +\frac{\pi}{2}$, where $X_L = \omega L$
RLC series circuit $V_0 = I_0 Z$ where $Z = \sqrt{R^2+(X_L-X_C)^2}$

and $\phi = \tan^{-1}\frac{X_L-X_C}{R}$
Resonant angular frequency $\omega_0 = \sqrt{\frac{1}{LC}}$
Quality factor $Q = \frac{\omega_0}{\Delta\omega} = \frac{\omega_0 L}{R}$
Average power $P_{ave} = \frac{1}{2}I_0V_0\cos\phi = I_{rms}V_{rms}\cos\phi$
Transformer voltages and currents $\frac{V_S}{V_P} = \frac{N_S}{N_P} = \frac{I_P}{I_S}$

**T8**

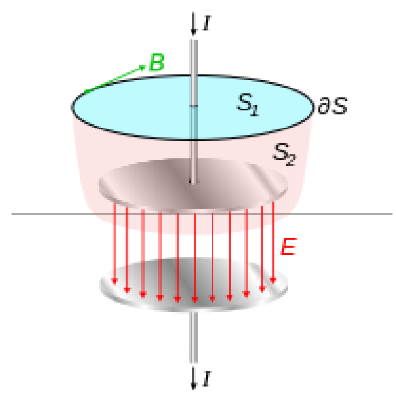
## 3.2 Geometric optics and image formation (https://cnx.org/contents/rydUIGBQ@10.14:-YlrAoNe@5/Introduction)

$\frac{1}{S_1}+\frac{1}{S_2}=\frac{1}{f}$ relates the focal length $f$ of the lens, the image distance $S_1$, and the object distance $S_2$. The figure depicts the situation for which ($S_1$, $S_2$, f) are all positive: (1)The lens is converging (convex); (2) The real image is to the right of the lens; and (3) the object is to the left of the lens. If the lens is diverging (concave), then f < 0. If the image is to the left of the lens (virtual image), then $S_2 < 0$ .




**T9**

## 2.16 Electromagnetic waves (https://cnx.org/contents/eg-XcBxE@14.10:-LQJwSUO@6/16-1-Maxwell-s-Equations-and-Electromagnetic-Waves)




Displacement current $I_d=\varepsilon_0\frac{d\Phi_E}{dt}$ where $\Phi_E=\int\vec{E}\cdot d\vec{A}$ is the electric flux.

Maxwell's equations: $\epsilon_0\mu_0=1/c^2$

$$\oint_S \vec{E}\cdot \mathrm{d}\vec{A}=\frac{1}{\epsilon_0}Q_{in}$$

$$\oint_S \vec{B}\cdot \mathrm{d}\vec{A}=0$$

$$\oint_C \vec{E}\cdot \mathrm{d}\vec{\ell}=-\int_S\frac{\partial\vec{B}}{\partial t}\cdot \mathrm{d}\vec{A}$$

$$\oint_C \vec{B}\cdot \mathrm{d}\vec{\ell}=\mu_0 I+\epsilon_0\mu_0\frac{\mathrm{d}\Phi_E}{\mathrm{d}t}$$

$\frac{\partial^2 E_y}{\partial x^2}=\varepsilon_0\mu_0\frac{\partial^2 E_y}{\partial t^2}$ and $\frac{E_0}{B_0}=c$

Poynting vector $\vec{S}=\frac{1}{\mu_0}\vec{E}\times\vec{B}$=energy flux

Average intensity $I=S_{ave}=\frac{c\varepsilon_0}{2}E_0^2=\frac{c}{2\mu_0}B_0^2=\frac{1}{2\mu_0}E_0B_0$

Radiation pressure $p=I/c$ (perfect absorber) and $p=2I/c$ (perfect reflector).