PH2200 Formula Sheet Knight

Electric Charges and Forces

$$F_{1\text{ on }2} = F_{2\text{ on }1} = \frac{K|q_1||q_2|}{r^2}$$

$$q = (N_\text{p} - N_\text{e})e$$

$$\vec{E} = \vec{F}_{\text{on q}}/q$$

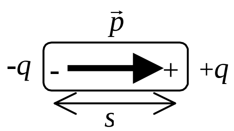
$$\vec{F}_{\text{on B}} = q_\text{B}\vec{E}$$

$$\vec{E} = \frac{1}{4\pi\varepsilon_0}\frac{q}{r^2}\hat{r} \quad \text{point charge}$$

The Electric Field

$$\vec{E}_{net} = \sum_i \vec{E}_i$$

Electric dipole:



$$\vec{p} = (qs,\ \text{from negative to positive})$$

Field on axis $\vec{E} = \frac{1}{4\pi\varepsilon_0}\frac{2\vec{p}}{r^3}$

Field in bisecting plane $\vec{E} = -\frac{1}{4\pi\varepsilon_0}\frac{\vec{p}}{r^3}$

Uniform infinite line of charge:

$$\vec{E} = \left(\frac{1}{4\pi\varepsilon_0}\frac{2\lambda}{r},\ \text{perpendicular to line}\right)$$

Uniform infinite plane of charge:

$$\vec{E} = \left(\frac{\eta}{2\varepsilon_0},\ \text{perpendicular to plane}\right)$$

Uniformly charged sphere:

$$\vec{E} = \frac{Q}{4\pi\varepsilon_0 r^2}\hat{r} \quad \text{for } r \ge R$$

Parallel-plate capacitor:

$$\vec{E} = \left(\frac{\eta}{\varepsilon_0},\ \text{from positive to negative}\right)$$

$$(E_\text{ring})_z = \frac{1}{4\pi\varepsilon_0}\frac{zQ}{(z^2+R^2)^{3/2}}$$

$$(E_\text{disk})_z = \frac{\eta}{2\varepsilon_0}\left[1 - \frac{z}{\sqrt{z^2+R^2}}\right]$$

$$\vec{a} = (q/m)\vec{E}$$

$$\tau = pE\sin\theta$$

Gauss's Law

$$\Phi_\text{e} = \vec{E}\cdot\vec{A} = EA\cos\theta \quad \text{constant field}$$

$$\Phi_\text{e} = \int_\text{surface} \vec{E}\cdot d\vec{A}$$

$$\Phi_\text{e} = \oint \vec{E}\cdot d\vec{A} = \frac{Q_\text{in}}{\varepsilon_0}$$

$\vec{E}$ at surface of a charged conductor:

$$E_\text{surface} = \begin{cases} \dfrac{\eta}{\varepsilon_0} \\ \text{perpendicular to surface} \end{cases}$$

Current and Conductivity

Electron current:

i = rate of electron flow

$N_\text{e} = i\Delta t$

$i = nAv_\text{d}$

$v_\text{d} = \frac{e\tau}{m}E$

Conventional current:

I = rate of charge flow $= ei$

$Q = I\Delta t$

Current density:

$J = I/A$

$J = nev_\text{d} = \sigma E$

$\sigma = \frac{ne^2\tau}{m} = \frac{1}{\rho}$

$\sum I_\text{in} = \sum I_\text{out}$

The Electric Potential

$$U_\text{elect} = U_0 + qEs \quad \text{(parallel-plate capacitor)}$$

$$U_{q_1+q_2} = \frac{1}{4\pi\varepsilon_0}\frac{q_1q_2}{r} \qquad U_\text{elect} = \sum_{i<j}\frac{1}{4\pi\varepsilon_0}\frac{q_iq_j}{r_{ij}}$$

$$U_\text{dipole} = -\vec{p}\cdot\vec{E} = -pE\cos\theta$$

$$U_{q+\text{sources}} = qV \qquad V = \frac{U_{q+\text{sources}}}{q}$$

$$V = Es \quad (\text{inside a parallel-plate capacitor})$$

$$\Delta V_\text{capacitor} = Ed \quad \text{(parallel plates)}$$

$$V = \frac{1}{4\pi\varepsilon_0}\frac{q}{r} \quad \text{point charge}$$

$$V = \sum_i \frac{1}{4\pi\varepsilon_0}\frac{q_i}{r_i}$$

Potential and Field

$$\Delta V = V(s_\text{f}) - V(s_\text{i}) = -\int_{s_\text{i}}^{s_\text{f}} E_s\,ds$$

= the negative of the area under the E_s graph

$$E_s = -\frac{dV}{ds}$$

$$\Delta V_\text{loop} = \sum_i (\Delta V)_i = 0$$

$$\Delta V_\text{bat} = \frac{W_\text{chem}}{q} = \mathcal{E} \quad \text{(ideal battery)}$$

$$E_\text{wire} = \frac{\Delta V_\text{wire}}{L}$$

$$R = \frac{\rho L}{A} \qquad I = \frac{\Delta V_\text{wire}}{R}$$

$$C = \frac{Q}{\Delta V_\text{C}}$$

$$C = \frac{\varepsilon_0 A}{d} \quad \text{(parallel-plate capacitor)}$$

$$C_\text{eq} = C_1 + C_2 + C_3 + \ldots \quad \text{(parallel capacitors)}$$

$$C_\text{eq} = \left(\frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3} + \ldots\right)^{-1} \quad \text{(series capacitors)}$$

$$U_\text{C} = \frac{Q^2}{2C} = \frac{1}{2}C(\Delta V_\text{C})^2$$

$$u_\text{E} = \frac{\varepsilon_0}{2}E^2$$

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Fundamentals of Circuits

$I = \frac{\Delta V}{R}$

junction law: $\sum I_{\text{in}} = \sum I_{\text{out}}$

loop law: $\Delta V_{loop} = \sum_i (\Delta V)_i = 0$

$P_{\text{bat}} = I\mathcal{E}$

$P_{\text{R}} = I\Delta V_{\text{R}} = I^2 R = \frac{(\Delta V_{\text{R}})^2}{R}$

$R_{\text{eq}} = R_1 + R_2 + R_3 + ... + R_{\text{N}}$ (series)

$R_{\text{eq}} = \left(\frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + ... + \frac{1}{R_{\text{N}}}\right)^{-1}$ (parallel)

$Q = Q_0 e^{-t/\tau} \quad I = I_0 e^{-t/\tau} \quad \tau = RC$

The Magnetic Field

$\vec{B} = \frac{\mu_0}{4\pi}\frac{q\vec{v}\times\hat{r}}{r^2} = \left(\frac{\mu_0 |q| v\sin\theta}{4\pi r^2},\ \text{RHR}\right)$

$\vec{B} = \frac{\mu_0}{4\pi}\frac{I\Delta\vec{s}\times\hat{r}}{r^2} = \left(\frac{\mu_0 I(\Delta s)\sin\theta}{4\pi r^2},\ \text{RHR}\right)$

$B_{\text{long straight wire}} = \frac{\mu_0}{2\pi}\frac{I}{d} \quad B_{\text{coil center}} = \frac{\mu_0}{2}\frac{NI}{R}$

$\vec{\mu} = (AI,\ \text{from south pole to north pole})$

$\vec{B}_{\text{dipole}} = \frac{\mu_0}{4\pi}\frac{2\vec{\mu}}{z^3}$ (on axis of dipole)

$\oint \vec{B}\cdot d\vec{s} = \mu_o I_{\text{through}}$

$B_{\text{solenoid}} = \frac{\mu_o NI}{L}$

$\vec{F}_{\text{on q}} = q\vec{v}\times\vec{B} = (|q| vB\sin\theta,\ \text{RHR})$

$f_{\text{cyc}} = \frac{qB}{2\pi m} \quad r_{\text{cyc}} = \frac{mv}{qB}$

$\vec{F}_{\text{wire}} = I\vec{L}\times\vec{B} = (ILB\sin\theta,\ \text{RHR})$

$F_{\text{parallel wires}} = \frac{\mu_0 L I_1 I_2}{2\pi d}$

$\vec{\tau} = \vec{\mu}\times\vec{B} = (\mu B\sin\theta,\ \text{RHR})$

Electromagnetic Induction

$\mathcal{E} = vlB$

$\Phi_{\text{m}} = \vec{A}\cdot\vec{B} = AB\cos\theta$ (uniform $\vec{B}$-field)

$\Phi_{\text{m}} = \int_{\text{area of loop}} \vec{B}\cdot d\vec{A}$

$\mathcal{E} = N\left|\frac{d\Phi_{\text{per coil}}}{dt}\right|$

$\mathcal{E}_{\text{coil}} = -\omega ABN\sin\omega t$

$V_2 = \frac{N_2}{N_1}V_1$

Electromagnetic Fields and Waves

$\oint \vec{E}\cdot d\vec{A} = \frac{Q_{\text{in}}}{\varepsilon_0}$

$\oint \vec{B}\cdot d\vec{A} = 0$

$\oint \vec{E}\cdot d\vec{s} = -\frac{d\Phi_{\text{m}}}{dt}$

$\oint \vec{B}\cdot d\vec{s} = \mu_0 I_{\text{through}} + \varepsilon_0\mu_0\frac{d\Phi_{\text{e}}}{dt}$

$\vec{F} = q(\vec{E} + \vec{v}\times\vec{B})$

$I_{\text{disp}} = \varepsilon_0\frac{d\Phi_{\text{e}}}{dt}$

$v_{\text{em}} = c = 1/\sqrt{\varepsilon_0\mu_0}$

$E = cB$

$\vec{S} = \frac{1}{\mu_0}(\vec{E}\times\vec{B})$

$I = \frac{P}{A} = S_{\text{avg}} = \frac{c\varepsilon_0}{2}E^2$

$p_{\text{rad}} = \frac{F}{A} = \frac{I}{c}$ (perfect absorber)

$I = I_0\cos^2\theta$

$I_{\text{transmitted}} = \frac{1}{2}I_0$ (incident light unpolarized)

Physical Constants

$K = 8.99\times10^9\ \text{N}\cdot\text{m}^2/\text{C}^2$

$\varepsilon_0 = 8.85\times10^{-12}\ \text{C}^2/\text{N}\cdot\text{m}^2$

$e = 1.60\times10^{-19}\ \text{C}$

$m_{\text{e}} = 9.11\times10^{-31}\ \text{kg}$

$m_{\text{p}} = 1.67\times10^{-27}\ \text{kg}$

$\mu_0 = 1.26\times10^{-6}\ \text{T}\cdot\text{m/A}$

$c = 3.00\times10^8\ \text{m/s}$

Useful Geometry

Circle

Area = πr^2

Circumference = $2\pi r$

Sphere

Surface area = $4\pi r^2$

Volume = $\frac{4}{3}\pi r^3$

Cylinder

Lateral surface area = $2\pi rL$

Volume = $\pi r^2 L$

PH2100 in Brief

$\vec{F}_{\text{net}} = \sum_i \vec{F}_i = m\vec{a}$

$\vec{F}_{\text{A on B}} = -\vec{F}_{\text{B on A}}$

Constant Acceleration:

$x_{\text{f}} = x_{\text{i}} + v_{\text{i}x}\Delta t + \frac{1}{2}a_x(\Delta t)^2$

$y_{\text{f}} = y_{\text{i}} + v_{\text{i}y}\Delta t + \frac{1}{2}a_y(\Delta t)^2$

$v_{\text{f}x} = v_{\text{i}x} + a_x\Delta t$

$v_{\text{f}y} = v_{\text{i}y} + a_y\Delta t$

$v_{\text{f}x}^2 = v_{\text{i}x}^2 + 2a_x(x_{\text{f}} - x_{\text{i}})$

$v_{\text{f}y}^2 = v_{\text{i}y}^2 + 2a_y(y_{\text{f}} - y_{\text{i}})$

Uniform Circular Motion:

$v = \frac{2\pi r}{T} \quad \omega = \frac{2\pi\ \text{rad}}{T}$

$\theta_{\text{f}} = \theta_{\text{i}} + \omega\ \Delta t$

$a_r = \frac{v^2}{r} = \omega^2 r$

Energy Conservation

$K = \frac{1}{2}mv^2$

$E_{\text{mech}} = K + U$

$K_{\text{f}} + U_{\text{f}} = K_{\text{i}} + U_{\text{i}}$

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