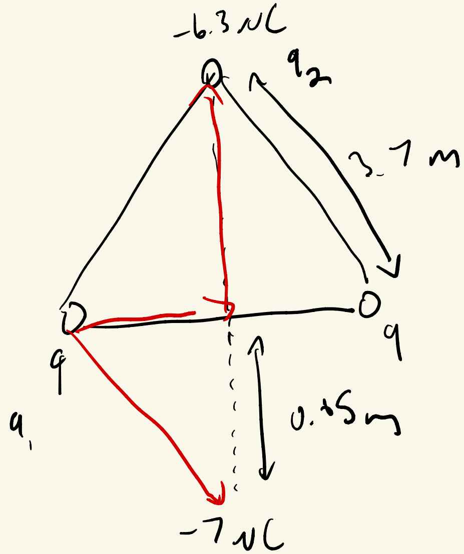
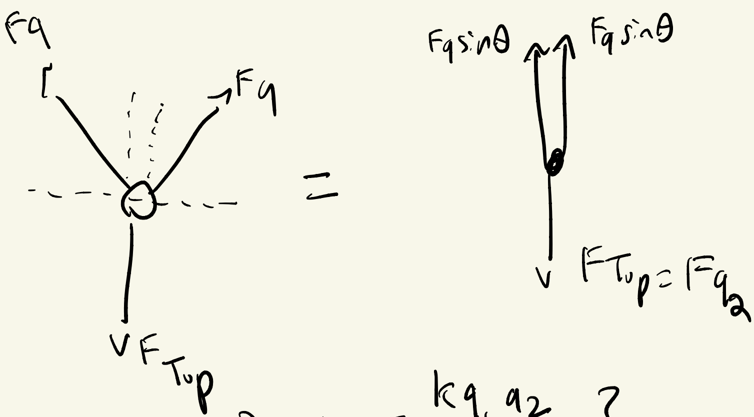
Three Charges



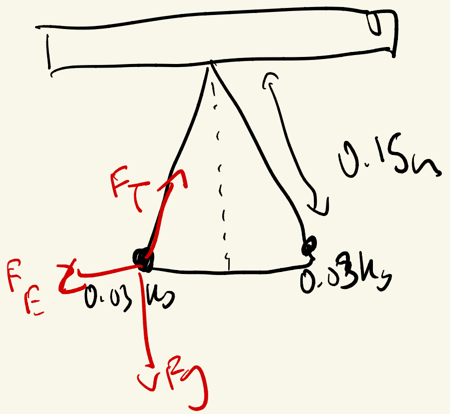


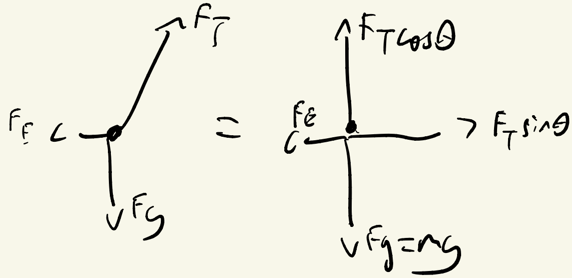
1) $F_2 = \frac{k q_1 q_2}{r^2} = ?$

2) $F_{q_2} = 2 F_q \sin\theta \Rightarrow F_q = ?$

3) $F_q = \frac{k q q_2}{r^2}$

Two Hanging Spheres





$$\Sigma F_y = F_T\cos\theta - F_g$$

$$\Sigma F_x = F_T\sin\theta - F_E$$

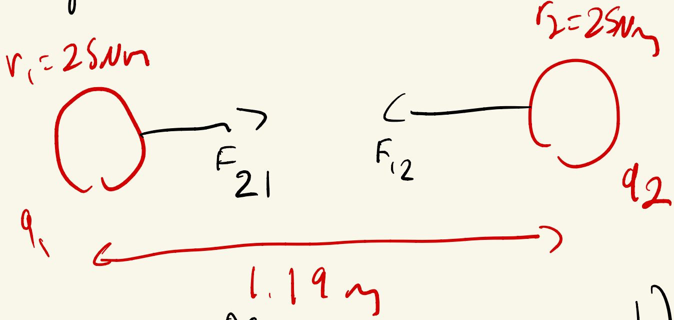
$$y: \ mg = F_T\cos\theta$$

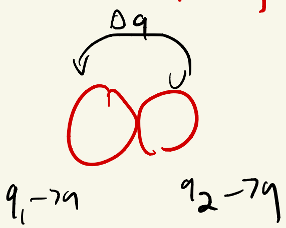
$$x: \ F_E = F_T\sin\theta$$

$$F_E = \frac{kq_1q_2}{r^2}$$

$$F_E = \frac{kq^2}{r^2}$$

Two spheres

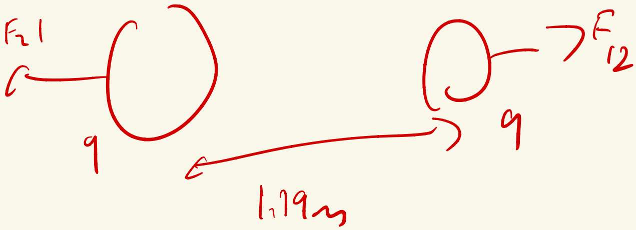




$q_1 = q_2$

1) $F = \frac{kq_1q_2}{r^2} = \frac{kq^2}{r^2}$

$$\sqrt{\frac{Fr^2}{k}} = q$$



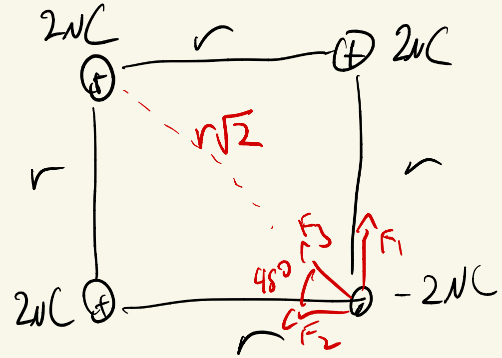
B) $q_1 + q_2 = 2q \Rightarrow q_2 = 2q - q_1$

$$F = \frac{kq_1q_2}{r^2} \Rightarrow \frac{Fr^2}{k} = q_1q_2$$

$$\frac{Fr^2}{k} = 2qq_1 - q_1^2 \Rightarrow q_1^2 - 2qq_1 + \frac{Fr^2}{k} = 0$$

$$\Rightarrow q_1 = \frac{1}{2}\left[2q \pm \sqrt{4q^2 + 4\frac{Fr^2}{k}}\right]$$

4 Charges in Square



$r = 0.10\,m$

$F_1 = F_2 > F_3$

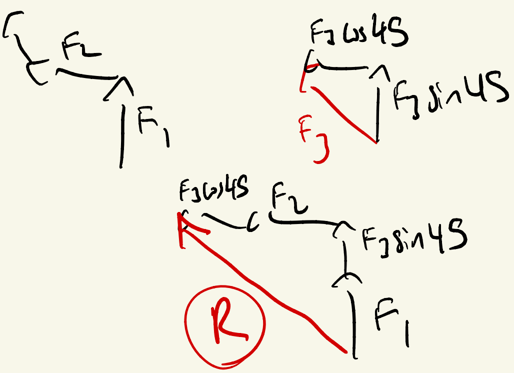
1) Solve for F_1, F_2, F_3

F_1 & F_2

$$F = \frac{k q_1 q_2}{r^2} = \frac{(9\cdot10^9)(2\cdot10^{-6})(2\cdot10^{-6})}{(0.10)^2} = F_1 \text{ and } F_2$$

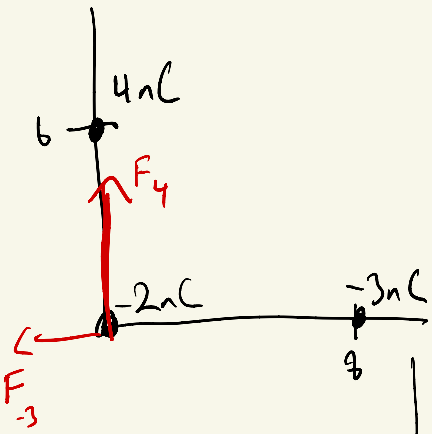
F_3

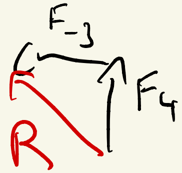
$$F = \frac{k q_1 q_2}{r^2} = \frac{(9\cdot10^9)(2\cdot10^{-6})(2\cdot10^{-6})}{(0.1(\sqrt{2}))^2}$$



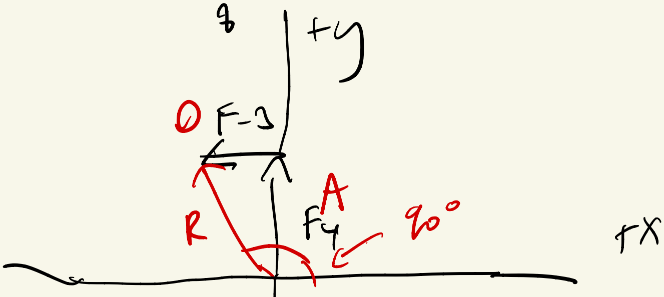
Three Charges in Plane

$1\,nC = 1 \times 10^{-9}\,C$





$$F = \frac{kq_1q_2}{r^2}$$



$$\tan\theta = \frac{O}{A}$$

$$\tan^{-1}\left(\frac{O}{A}\right) = \theta = \tan^{-1}\left(\frac{F_{-3}}{F_4}\right)$$

Electrons in Nickel

molar mass of Ni = 58 g/mol

a)

$$\frac{\text{\# of g}}{g/mol} = \frac{mass}{\text{molar mass}} = \frac{5g}{58} = \text{\# of mols}$$

g / g/mol = mol

b) 1 mol = 6.02×10^{23} atoms

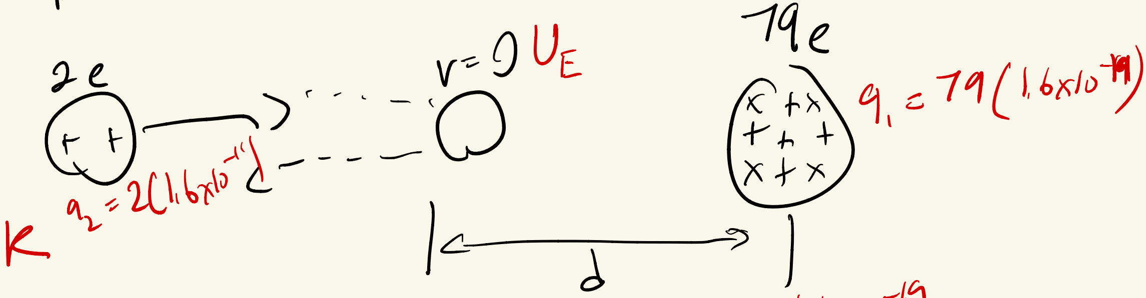
1) # of atoms

2) multiply by 28

# of mols (6.02×10^{23}) = # of atoms × 28 = # of e^-

c) $1 e = 1.6 \times 10^{-19}$ C

Alpha Particle Fired at Nucleus



q of 1 $e^- = 1.6\times10^{-19}$

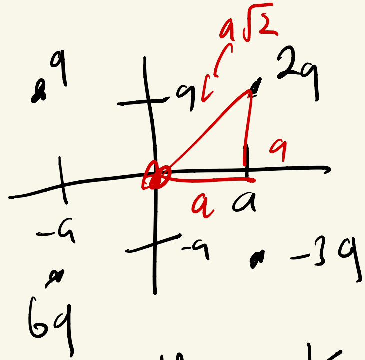
$k = 9\times10^{9}$

m of $e^- = 9.11\times10^{-31}$ kg

$K = U_E$

$$\frac{1}{2}mv^2 = \frac{kq_1q_2}{r}$$

Four Charges in a Square



(x, y)

1) Find V @ origin

$V = k \sum \frac{q}{r}$

$= k\left(\frac{q}{a\sqrt{2}} + \frac{2q}{a\sqrt{2}} - \frac{3q}{a\sqrt{2}} - \frac{6q}{a\sqrt{2}}\right)$

$U_E \to K$

$V = \frac{U_E}{q}$

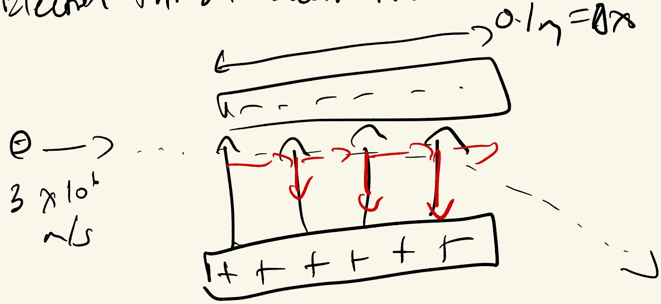
2) Multiply V b q

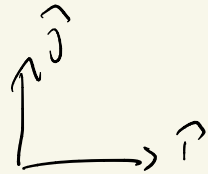
$V = \frac{U_E}{q} \Rightarrow U_E = Vq$

3) Convert $U_E \to K$

$Vq = \frac{1}{2}mv^2$ solve for v

Electron through Electric field





mass of $e^- = 9.11 \times 10^{-31}$ kg

q of $e^- = 1.6 \times 10^{-19}$ C

$a \propto F \qquad \Sigma F = ma$

a) $a = \frac{\Sigma \vec{F}}{m}$

$\vec{E} = \frac{F}{q} \Rightarrow \vec{F} = Eq$

b) $v_0 = 3 \times 10^6\ m/s = \frac{\Delta x}{\Delta t}$

c) $\Delta y = v_0 \Delta t + \frac{1}{2} a \Delta t^2$

$v_0 = 0$

Electrons thru Resistor

Ohm's Law

$V = IR$

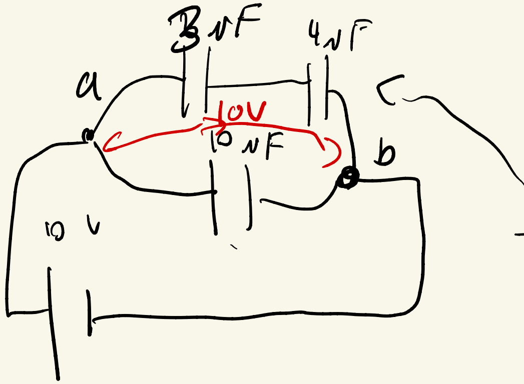
$I = \frac{\Delta Q}{\Delta t}$

$\Delta t = 10$ min $\rightarrow$ s

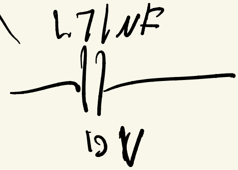
$\Delta Q =$ total # of e^- (1.6×10^{-19})

$1 e^- = 1.6 \times 10^{-19}$ C

Voltage across capacitor

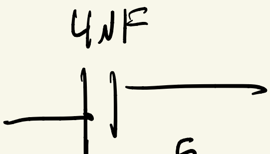


$$(3^{-1}+4^{-1})^{-1} = 1.71\,nF$$



$$C = \frac{Q}{\Delta V}$$

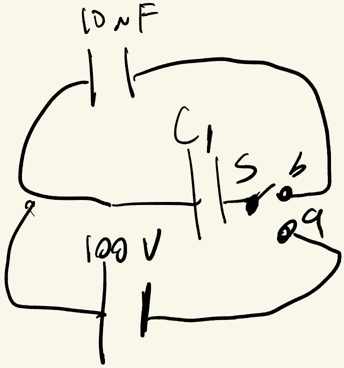
$$Q = C\Delta V$$
$$= 1.71\times10^{-6}(10) = 1.71\times10^{-5}\,C$$



$$Q = 1.71\times10^{-5}\,C$$

$$\Delta V = \frac{Q}{C} = \frac{1.71\times10^{-5}}{4\times10^{-6}} = 4.275V$$

Unknown Capacitance



@ A)

$$C = \frac{Q}{\Delta V} \Rightarrow C_1 = \frac{Q}{100V}$$

@ B)

$$C = \frac{Q}{\Delta V} \Rightarrow (C_1 + 10) = \frac{Q}{30V}$$

$$30(C_1 + 10) = Q$$

$$30C_1 + 300 = Q$$

$$C_1 = \frac{30C_1 + 300}{100}$$

$$\Rightarrow C_1 = \frac{300}{70} = 4.286\, nF$$

Drift velocity

$$I = nqV_dA$$

n = charge density

V_d = drift velocity

A = area

of e^- = # of atoms

cm → m

x100

6 places

$\frac{m}{M} \times n_A = \#$ of atoms

$\rho = \frac{m}{V}$

$$n = \frac{\rho}{M} \times n_A = \frac{2.7\times10^{-6}}{26.98}(6.02\times10^{23})$$

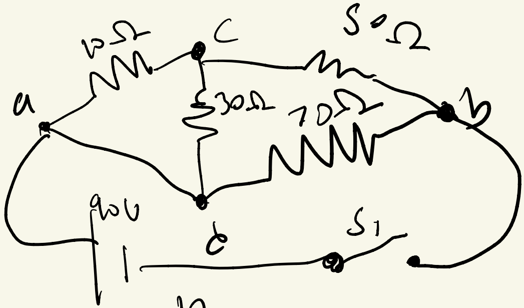
$$n = 6.02\times10^{28}\ \frac{e^-}{m^3}$$

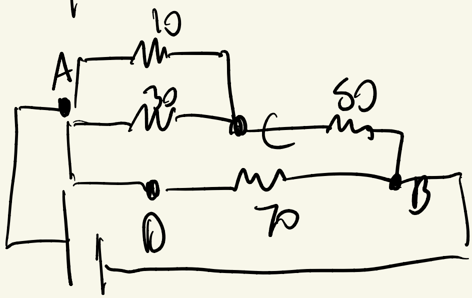
$$I = nqV_dA$$

$$V_d = \frac{I}{nqA} = \frac{5}{(6.02\times10^{28})(1.6\times10^{-19})(4\times10^{-6})}$$

$$= 1.2978\times10^{-4}\ m/s$$

Equivalent Resistance



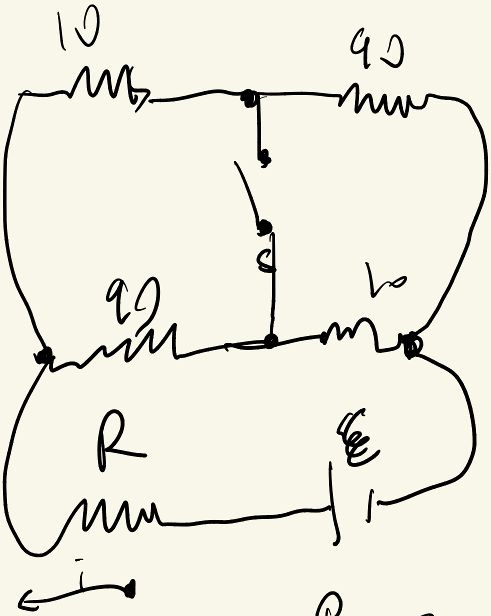


① A and C parallel

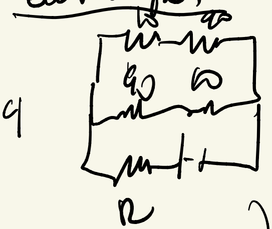
② A ~~to~~ B series

③ A to B parallel

Find R in Circuit with Switch

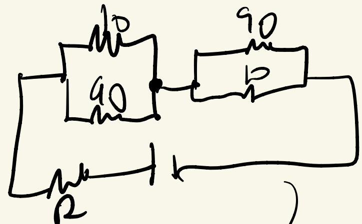


Switch open

R_{eq} 

$R_{eq} = R + ($

switch closed

$R_{eq} =$ 

$R_{eq} = R + ($

Current doubles -> R decreases by 2x

$$R_{closed} = \frac{R_{open}}{2}$$

$$R + \_\_\_\_ = \frac{1}{2}(R + \_\_\_\_)$$

Charge on Capacitor

$$C = \frac{Q}{\Delta V}$$

1) Find R_{eq}

2) Find $I_{total} = \frac{V_{batt}}{R_{eq}}$

3) $V_{3\Omega} = I_{total} R$

voltage across capacitor

$V = I\Omega$

long time = capacitor is "a break"

$R_{top} = 40\Omega$

$R_{bottom} = 40\Omega$

$I_{top} = \frac{V}{R} = 0.5A$ $\qquad 9 - 1 = 8V = \Delta V$

$I_{bottom} = 0.5A$

$V_{top} = IR = 9V$

$V_{bottom} = IR = 1V$

Two Loop Circuit

Loop 1 : $(8+4) = 1i_1 + 2i_1 + 6i_3$

$12 = 3i_1 + 6i_2$

Loop 2 : $4 = 2i_2 + 6i_3$

Junction Rule: $I_1 + I_2 = I_3$

$0 = I_1 + I_2 - I_3$

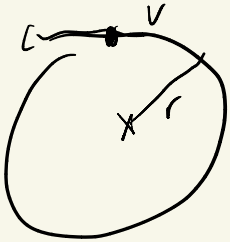
Subtract Loop 1 - Loop 2 => $8 = 3i_1 - 2i_2$

Loop 2 + Junction Rule => $4 = 6i_1 + 8i_2$

Combine => $36 = 18i_1$

$i_1 = 2$

Electron Orbiting Hydrogen



from C.M

1 circumference in 1 T

$$B = \frac{\mu_0 I R}{2\pi r}$$

$$T = \frac{2\pi r}{v}$$

$\rightarrow v = \frac{2\pi r}{T}$

$$I = \frac{\Delta Q}{\Delta t} \rightarrow q(1\ e^-) \times f = I$$

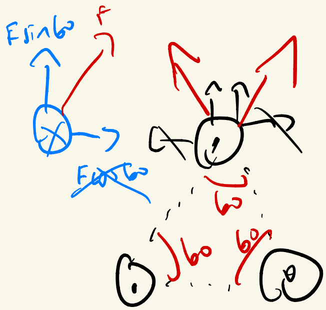
$$f = \frac{v}{2\pi r}$$

$$I = \frac{v}{2\pi r}(q e^-)$$

Three Parallel wires

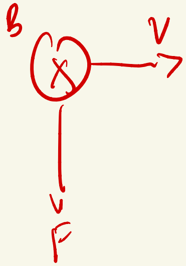
$$\frac{F}{l} = \frac{\mu_0 I_1 I_2}{2\pi d}$$

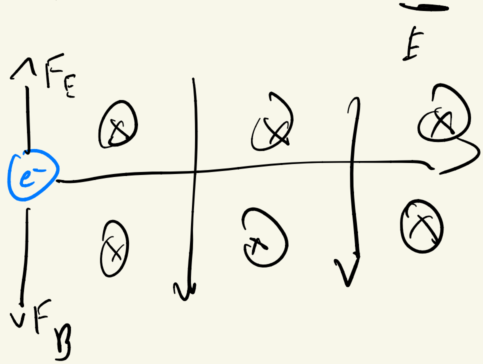
d = cm → m



$$2\left(\frac{F}{l}\right)\sin 60$$

Energy of Undeflected Electron





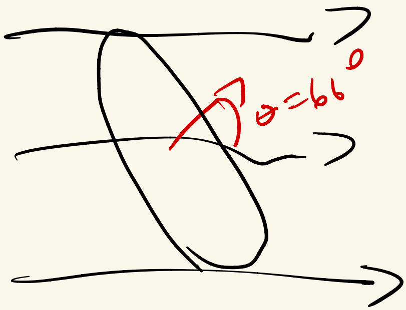
$$F_E = F_B$$

$$q\vec{E} = qv\vec{B} \Rightarrow v = \frac{\vec{E}}{B}$$

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

Joules $eV = \frac{J}{q_{e^-}} = \frac{J}{1.60 \times 10^{-19}}$

Torque on Circular Loop

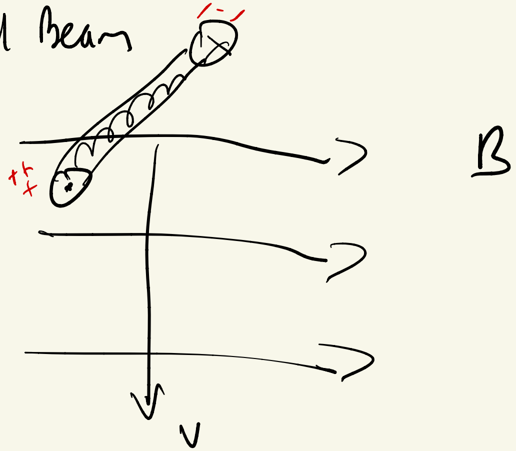


$\tau = \mu B \sin\theta$

μ = magnetic moment

$\mu = N I A \Leftarrow A = \pi r^2$

Dropped Steel Beam



$\theta = 90^\circ$

$v_0 = 0$

$a = g = 9.8$

$\Delta t = ?$

$\varepsilon = B l v \sin\theta$

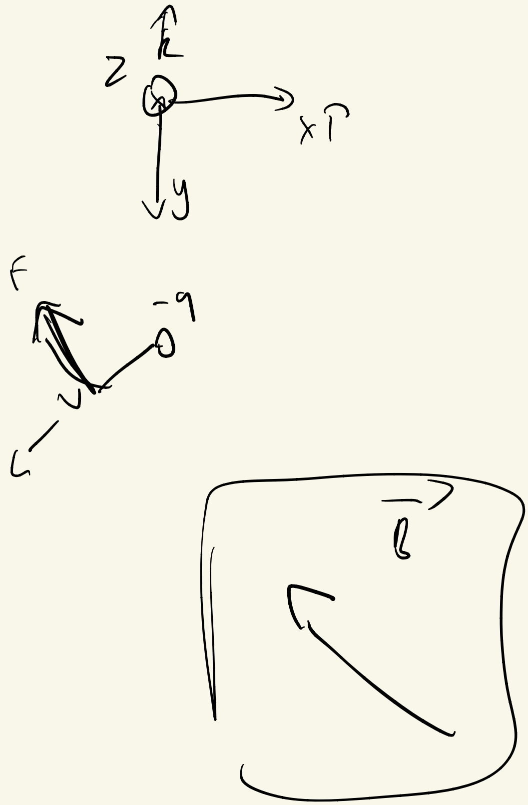
$v_f = ?$

$v_f = v_0 + g\Delta t$

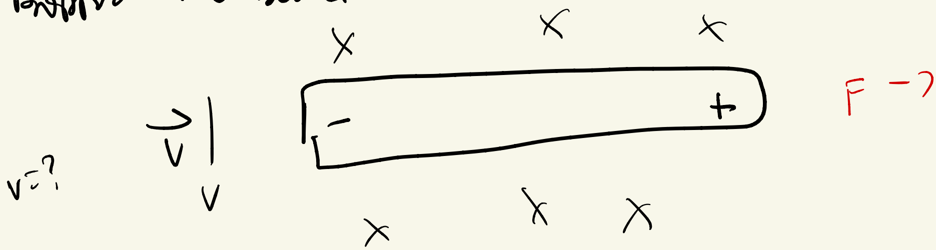
$\varepsilon = B l v$

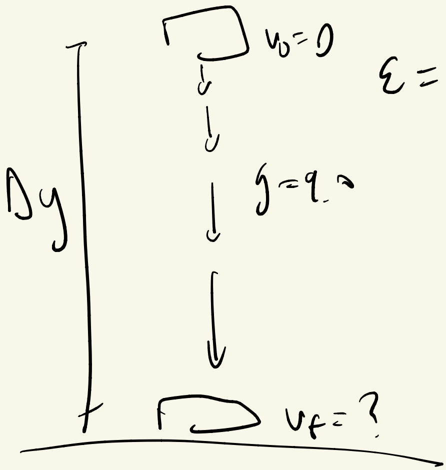
$\Delta t = \sqrt{\frac{2\Delta y}{g}}$

Right Hand Rule



Problem 2 Steel Beam





$\varepsilon = B\ell v$

$\Delta t = \sqrt{\frac{2\Delta y}{g}}$

$v_f = v_0 + a\Delta t$

$v_f = 0 + 9.8(\Delta t)$

$B = 9 \times 10^{-6}\ T$

Energy stored in Inductor

Find L $\Rightarrow$ $L = \frac{\mu_0 N^2 A}{l}$

L - inductance
l - length

$V_L = \frac{1}{2} L I^2$

Force on a Bar

$$F = qvB = Il B$$

$$F = IlB$$

$$\mathcal{E} = Blv$$

$$V = IR \qquad \mathcal{E} = \Delta V$$

$$\mathcal{E} = IR$$

$$I = \frac{\mathcal{E}}{R}$$

Rate of Change of Current in Inductor

Definition of self inductance

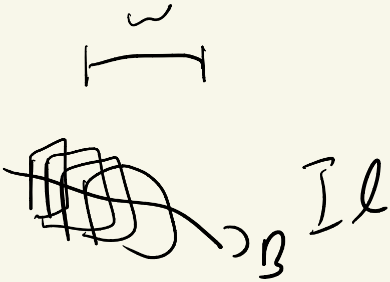
$$\Delta V = -L\left(\frac{\Delta I}{\Delta t}\right)$$

$$\frac{\Delta I}{\Delta t} = \frac{\Delta V}{L}$$

L = inductance

$$L = \frac{\mu_0 N^2 A}{l}$$

Change in Field of Rectangular Coil



(1) $A = l \times w$

$\Phi_B = B \cdot A$

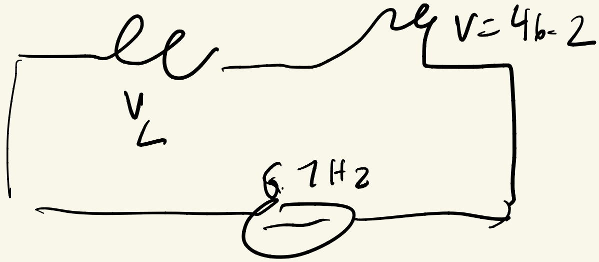
$$\mathcal{E} = -N \frac{\Delta \Phi}{\Delta t}$$

$$\mathcal{E} = -N \left(\frac{\Delta B \cdot \Delta A}{\Delta t} \right)$$

$$\frac{\Delta B}{\Delta t} = \frac{\mathcal{E}}{NA}$$

(2) $\mathcal{E} = IR$

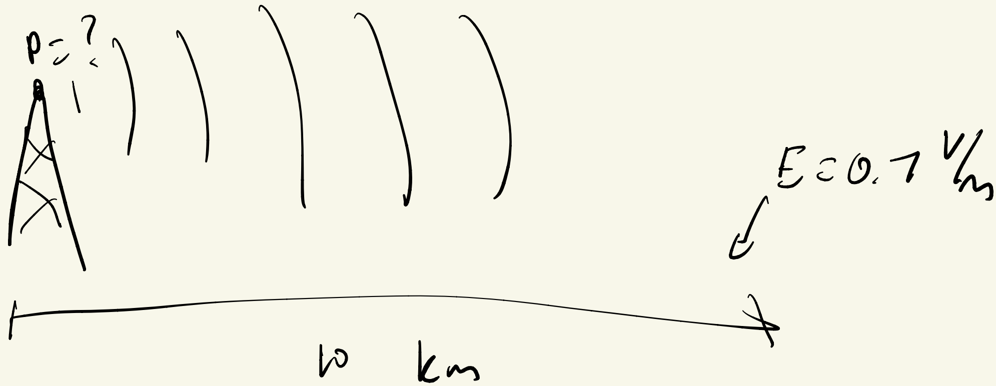
Inductor with Series in Loop



$V_L = I X_L$ and $X_L = 2\pi f L \Rightarrow I = \frac{V_L}{2\pi f L}$

$V^2 = V_r^2 + V_L^2 \Rightarrow V_L = \sqrt{V^2 - V_r^2}$

Power from a Radio



$$I = \frac{P}{A} \Rightarrow P = I \, 4\pi r^2$$

$$I = \langle S \rangle = \frac{1}{2n} |E^2| = \frac{1}{2(377)} |0.7| = \boxed{I}$$

n = impedence of free space

Energy from Sun through Window

$$\frac{E/\Delta T}{A} = \frac{P}{A}$$

$$P = \frac{\Delta E}{\Delta t}$$

$$I = \frac{P}{A}$$

$A = 1.2 \times 1.4$

2h → seconds

kW → W

$$I = \frac{\Delta E}{A \Delta t}$$

MJ

$= 1 \times 10^6$ J

$$E = I A \Delta t$$

High Power Laser

a) $C = \frac{\vec{E}}{\vec{B}} \Rightarrow \vec{B} = \frac{\vec{E}}{C}$

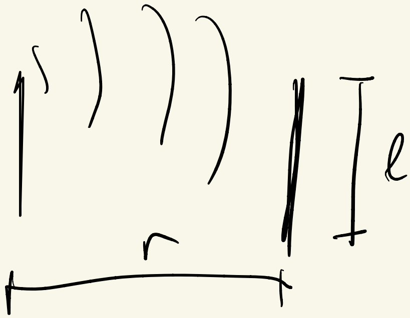
b) $I = \frac{E_{max} B_{max}}{2\mu_0}$

c) $I = \frac{P}{A} \Rightarrow P = IA$

diameter → area

$A = \pi r^2$

EMF in Receiving Antenna



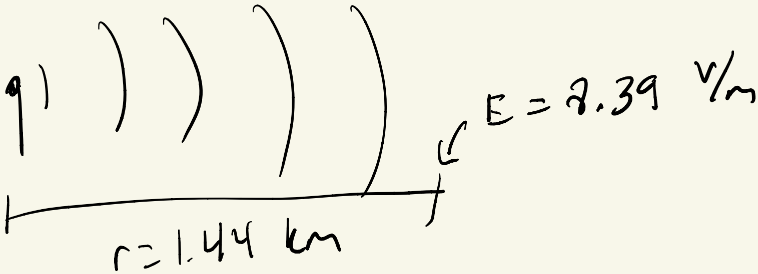
$$\varepsilon = V = \vec{E}\,\ell$$

$$I = \frac{P}{4\pi r^2} \quad \text{and} \quad I = \langle S \rangle = \frac{E_{max}^2}{2\mu_0 c}$$

$$\frac{P}{4\pi r^2} = \frac{E_{max}^2}{2\mu_0 c}$$

$$E_{max} = \sqrt{\frac{P\, 2\mu_0 c}{4\pi r^2}}$$

Microwave Transmitter



a) $c = \dfrac{\vec{E}}{\vec{B}} \Rightarrow \vec{B} = \dfrac{\vec{E}}{c}$

b) $I = \dfrac{P}{A} \Rightarrow P = IA$

$I = \langle S \rangle = \dfrac{E_{max}^2}{2\mu_0 c}$

$$P = \frac{E_{max}^2 (4\pi r^2)}{2\mu_0 c}$$

Three Polarizers

$\cos^2\theta = (\cos\theta)^2$

$$I = I_0 \cos^2\theta$$

$$I_1 = I_i \cos^2\theta$$

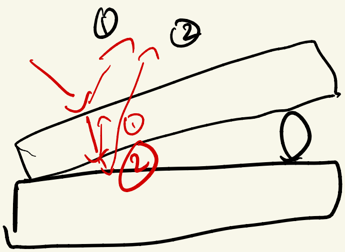
$$I_2 = I_1 \cos^2(\theta_2 - \theta_1)$$

$$\boxed{I_f} = I_2 \cos^2(\theta_3 - \theta_2)$$

Two Glass Plates

① no glass to air

② yes air to glass



0 1 2 3 4

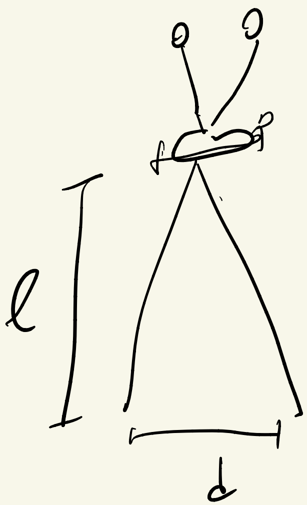
1) # of phase shifts = 1

m starts @ 0 → 120 bands = m = 119

whole multiple equation → $2t = \frac{m\lambda}{n}$

$t = \frac{m\lambda}{2n}$ $n_{air} = 1$

Satellite

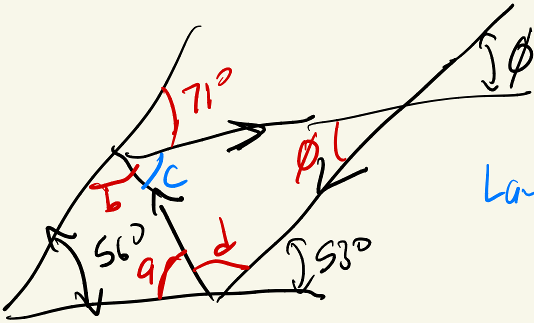


$$\theta = \frac{1.22\,\lambda}{D}$$

small angle approximation : $\theta = \frac{d}{\ell}$

$$\theta = \frac{d}{\ell} \implies \ell = \frac{d}{\theta}$$

Two Mirrors



Law of Reflection: $a = 53°$

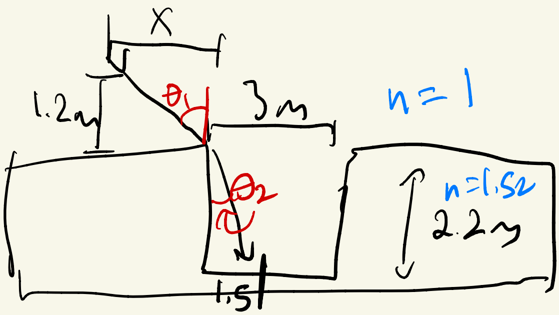
$b = 180 - 56 - 53 = 71°$

$c = 38°$

$d = 180° - 53° - 53° = 74°$

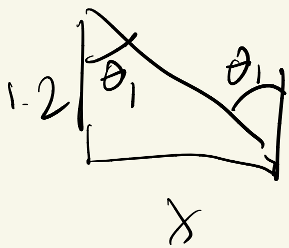
$\phi = 180° - 38° - 74° = 68°$

Liquid in a Cistern



$$n_1 \sin\theta_1 = n_2 \sin\theta_2 \Rightarrow \theta_1 = \sin^{-1}\left(\frac{n_2 \sin\theta_1}{n_1}\right)$$

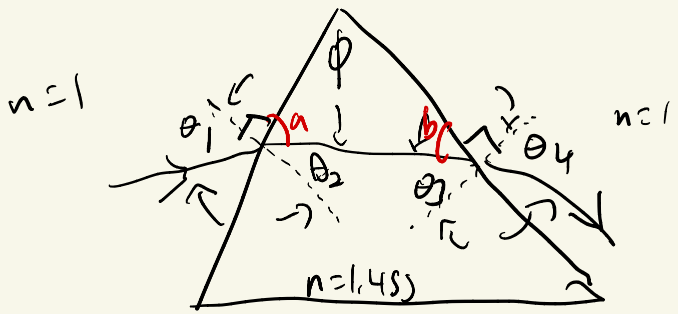
$$\theta_2 = \tan^{-1}\left(\frac{1.5}{2.2}\right)$$



$$\tan\theta_1 = \frac{x}{1.2}$$

$$\Rightarrow 1.2 \tan\theta_1 = x$$

Silica Prism



a) $n_1 \sin\theta_1 = n_2 \sin\theta_2$

$\sin^{-1}\left(\frac{n_1 \sin\theta}{n_2}\right) = \theta_2$

b) $\theta_2 + a = 90^\circ$ $\quad b = 180 - 60 - a$

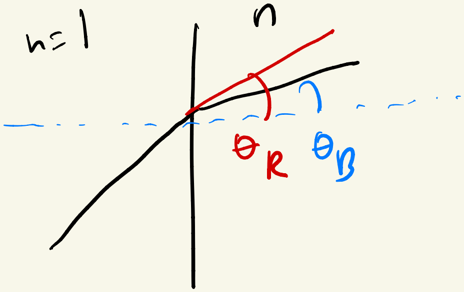
$a + b + 60 = 180$ $\quad \theta_3 + b = 90 \Rightarrow 90 - b = \theta_3$

c) $n_1 \sin\theta_3 = n_2 \sin\theta_4$

d) $\theta = 1 + 2$ $\quad 1: a - \theta_2$

$2: \theta_4 - b$

Two Beams in Glass



$$|\theta_R - \theta_B|$$

$$n_1 \sin\theta_1 = n_2 \sin\theta_2$$

$$\theta_2 = \sin^{-1}\left(\frac{n_1 \sin\theta_1}{n_2}\right)$$

$$\theta_R = \sin^{-1}\left(\frac{n_1 \sin\theta_1}{n_R}\right)$$

$$\theta_B = \sin^{-1}\left(\frac{n_1 \sin\theta_1}{n_B}\right)$$

Pulsed Laser

1) Find E of photon from laser

$E = pc$ $\quad P = \frac{\Delta E}{\Delta t}$ $\quad E = P\Delta t$

2) p of photon → K of pellet

$E = pc \Rightarrow p = \frac{E}{c}$

$K = \frac{p^2}{2m}$

3) Cons. of Energy

$K \rightarrow U_g$

$K = mg\Delta y$

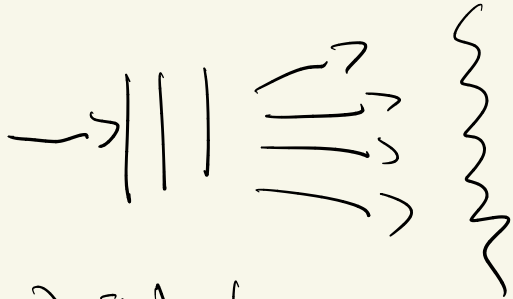
$1\,\mu m = 1 \times 10^{-6}\,m$

Solar Radiation

E of 1 photon : $E = \frac{hc}{\lambda}$

$I = \frac{W}{m^2} \Rightarrow \frac{I}{E \text{ of } 1 \text{ photon}} = \# \text{ of photons}$

Electron Beam Diffraction



$$X_m = \frac{m\lambda L}{d}$$

1) Find λ
2) use λ to get p
3) use p to get K
4) convert K from J → keV

① $\frac{X_m d}{mL} = \lambda$

③ $K = \frac{p^2}{2m}$

② $\lambda = \frac{h}{p}$

$$eV = \frac{J}{q \text{ of } 1e^-} = \frac{J}{1.6\times10^{-19}}$$

X-ray Tube

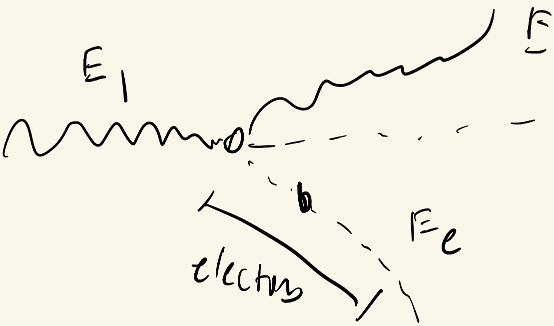
K of $e^- = q\Delta V = (1.6\times10^{-19})(70,000)$

a) $E = hf$

b) $E = pc$

c) E from part 1 & 2 = E

γ = photon

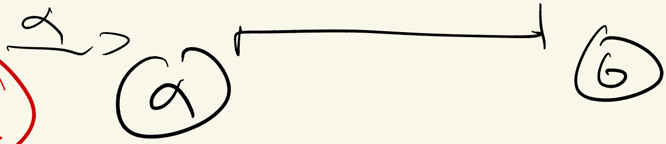


$E_1 = E_\gamma + E_e$

$E_e = E_1 - E_\gamma$

d) $K = \frac{p^2}{2m}$ $\quad m_e = 9.11\times10^{-31}$

Alpha Particle and Gold Nucleus



(a)

$$U_E = \frac{k q_1 q_2}{r}$$

$q_1 - \alpha = 2(1.6\times10^{-19})$

$q_2 - Au = 79(1.6\times10^{-19})$

$^{4}_{2}\alpha \quad {}_{79}Au$

$$U_E = \frac{9\cdot10^{9}\left[2(1.6\times10^{-19})\right]\left[79(1.6\times10^{-19})\right]}{3.2\times10^{-14}}$$

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

(b)

$K = U_E$

Lyman series

a) $n_1 = 1$ $\quad$ $n_2 = 2$

$$\frac{1}{\lambda} = R_y\left(\frac{1}{1^2} - \frac{1}{2^2}\right)$$

$$\frac{1}{\lambda} = R_y(0.75)$$

b) $n_1 = 1$ $\quad$ $n_2 = \infty$

$$\frac{1}{\lambda} = R_y\left(\frac{1}{1^2} - \frac{1}{\infty^2}\right)$$

$$\frac{1}{\lambda} = R_y(1 - 0)$$

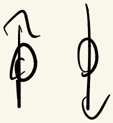
Bohr model

$$E_n = k\left(\frac{Z^2}{n^2}\right) \text{ where } k = -13.6$$

for He, $Z = 2$ $n = 1$

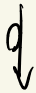
Energy of Magnetic Moment

a) μ = magnetic moment



$-\mu\vec{B}$

$\Delta E = 2\mu\vec{B}$

b)  $E = \frac{hc}{\lambda}$ = 

$E = \frac{hc}{\lambda}$ $\lambda = \frac{hc}{E}$

Half-Life of Radioactive Substance

$$N = N_0 \left(\frac{1}{2}\right)^{t/t_{1/2}}$$

$$\frac{N}{N_0} = \left(\frac{1}{2}\right)^{t/t_{1/2}}$$

$$\log\left(\frac{N}{N_0}\right) = \log\left(\frac{1}{2}\right)\left(\frac{t}{t_{1/2}}\right)$$

$$\frac{t}{t_{1/2}} = \frac{\log\left(\frac{N}{N_0}\right)}{\log\left(\frac{1}{2}\right)}$$

Radioactive Sample Activity

1 Bq = 1 decay/s $\qquad N = N_0 e^{-\lambda t} \qquad \lambda = \frac{\ln 2}{t_{1/2}}$

a) $N = N_0 e^{-\lambda t}$

$\frac{N}{N_0} = e^{-\lambda t} \qquad \ln\left(\frac{N}{N_0}\right) = -\lambda t \Rightarrow \frac{-\ln\left(\frac{N}{N_0}\right)}{t} = \lambda$

b) $\lambda = \frac{\ln 2}{t_{1/2}}$

c) $N = \frac{R(t_{1/2})}{\ln 2}$

$t_{1/2}$ hours $\times$ 3600 = seconds

R = initial decay rate

Rub) lium (?)

$$N = N_0 e^{-\lambda t}$$

$$N_0 = Rb$$

$$N = Rb - Sr$$

$$\frac{N}{N_0} = e^{-\lambda t}$$

So $\frac{N}{N_0} = \frac{Rb - Sr}{Rb}$

$$\frac{N}{N_0} = 1 - \frac{Sr}{Rb}$$

$$1 - \frac{Sr}{Rb} = e^{-\lambda t}$$

$$1 - 0.01 = e^{-\lambda t}$$

$$\lambda = \frac{\ln 2}{t_{1/2}}$$

$$\ln(0.99) = -\lambda t$$

$$\ln(0.99) = -\left(\frac{\ln 2}{t_{1/2}}\right) t$$

Reduce Activity of Sample

$$N = N_0 e^{-\lambda t} \qquad \lambda = \frac{\ln 2}{t_{1/2}}$$

$$\ln\left(\frac{N}{N_0}\right) = -\lambda t$$

$$\frac{\ln\left(\frac{N}{N_0}\right)}{-\lambda} = t$$

Carbon Dating Charcoal

Original $= N_0 = 15 \times 10^{00} = 15000 = N_0$

$N = N_0 e^{-\lambda t}$

$\lambda = \frac{\ln 2}{t_{1/2}}$

$$\frac{\ln\left(\frac{N}{N_0}\right)}{-\lambda} = t$$