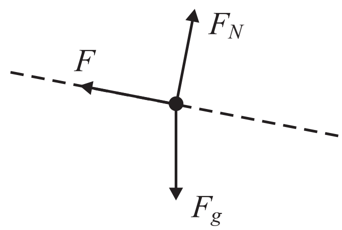
1. (a)



(b) $\sum F_x = F_{gx} - F = ma$

$$\boxed{Mg\sin\theta - bv = M\frac{dv}{dt}}$$

(c) $\sum F_x = F_{gx} - F = ma = 0$

$bv = Mg\sin\theta$

$$\boxed{v_T = \frac{Mg}{b}\sin\theta}$$

(d) $Mg\sin\theta - bv = M\dfrac{dv}{dt}$

$$\frac{dt}{M} = \frac{dv}{Mg\sin\theta - bv}$$

$$\frac{-bdv}{Mg\sin\theta - bv} = \frac{-b}{M}dt \qquad \text{let } u = -bv\text{, then} du = -b$$

$$\int \frac{-bdv}{Mg\sin\theta - bv} = \frac{-b}{M}\int dt$$

$$\ln\left(Mg\sin\theta - bv\right) = \frac{-b}{M}t + C$$

$$Mg\sin\theta - bv = e^{-\frac{b}{M}t+C} = e^{-\frac{b}{M}t}e^{C} = De^{-\frac{b}{M}t} \qquad \text{where } C \text{ is the constant of integration and } D = e^{C}$$

$$bv = Mg\sin\theta - De^{-\frac{b}{M}t}$$

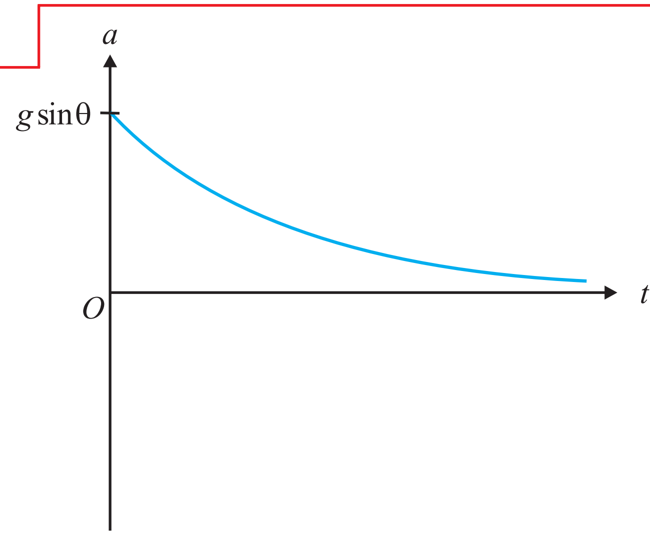
$$v = \frac{Mg}{b}\sin\theta - \frac{D}{b}e^{-\frac{b}{M}t} = \frac{Mg}{b}\sin\theta - Ke^{-\frac{b}{M}t} \qquad \text{where} K = \frac{D}{b}.\ \text{Assume at } t = 0, v = 0$$

$$0 = \frac{Mg}{b}\sin\theta - Ke^{-\frac{b}{M}(0)} = \frac{Mg}{b}\sin\theta - K(1)$$

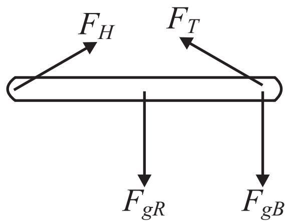
$$K = \frac{Mg}{b}\sin\theta$$

$$\boxed{v = \frac{Mg}{b}\sin\theta\left(1 - e^{-\frac{b}{M}t}\right)}$$

(e)



2. (a)



Note: F_{gR} is shown as acting at the center of mass of the rod.

(b) $\sum \tau = \tau_T - \tau_{gR} - \tau_{gB} = 0$ using the hinge as the axis of rotation.

$r_T F_T \sin\theta_T = r_{gR} F_{gR} \sin\theta_{gR} + r_{gB} F_{gB} \sin\theta_{gB}$

$(0.60\text{ m})F_T \sin 30 = (0.30\text{ m})(2.0\text{ kg})(9.8\text{ m/s}^2)\sin 90 + (0.60\text{ m})(0.50\text{ kg})(9.8\text{ m/s}^2)\sin 90$

$\boxed{F_T = 29\text{ N}}$

(c) When the rod is rotated about the hinge, half of its mass is an average of twice as far from the axis of rotation than when the rod is rotated about its center. Since, $dI = dmr^2$,the rotational inertia will be four times as great when the rod is rotated around the hinge as when it is rotated about its center. Therefore, the rotational inertia of the rod about the hinge is $\frac{1}{3}ML^2$.

$dI_{Rod} = dmr^2 = (\lambda dl)l^2 = \lambda l^2 dl \qquad dI_{Block} = dmr^2 = mL^2$

$I_{Rod} = \int_0^L \lambda l^2 dl = \lambda \left.\frac{l^3}{3}\right|_0^L = \left(\frac{M}{L}\right)\left(\frac{L^3}{3} - \frac{0^3}{3}\right) = \frac{1}{3}ML^2$

$I_{total} = I_{Rod} + I_{Block} = \frac{1}{3}M_R L^2 + M_B L^2 = \frac{1}{3}(2.0\text{ kg})(0.60\text{ m})^2 + (0.5\text{ kg})(0.60\text{ m})^2$

$\boxed{I_{total} = 0.42\text{ kg}\cdot\text{m}^2}$

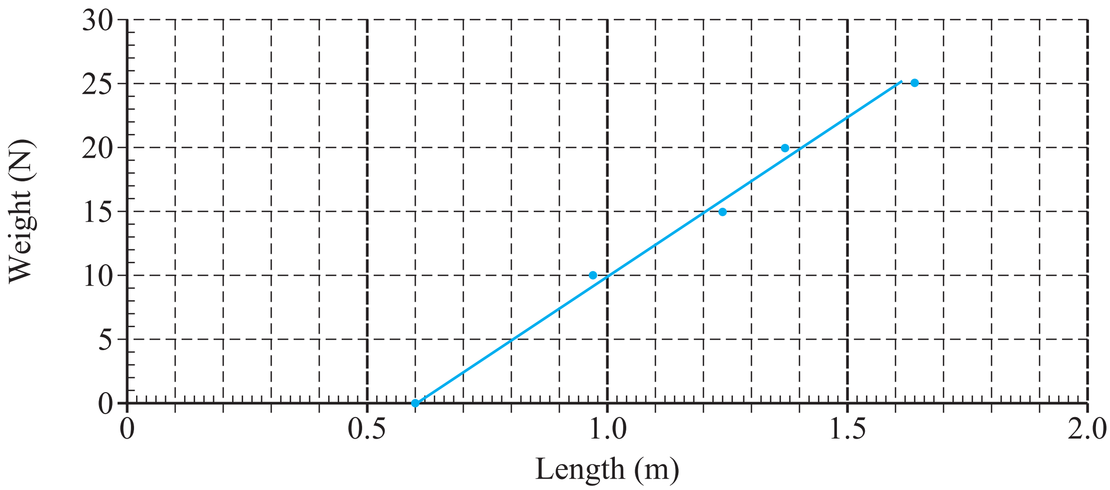
(d) $\sum \tau = -\tau_{gR} - \tau_{gB} = I\alpha$

$\left(\frac{4}{3}ML^2\right)\alpha = -r_{gR} F_{gR} \sin\theta_{gR} - r_{gB} F_{gB} \sin\theta_{gB}$

$(0.42\text{ kg}\cdot\text{m}^2)\alpha = -(0.30\text{ m})(2.0\text{ kg})(9.8\text{ m/s}^2)\sin 90 - (0.60\text{ m})(0.50\text{ kg})(9.8\text{ m/s}^2)\sin 90$

$\boxed{\alpha = 21\text{ rad/s}^2}$

3. (a)



(b) slope $= \dfrac{F}{\Delta x} = k$ (the spring constant)

$$k = \frac{(24.9\text{ N} - 0)}{(1.6\text{ m} - 0.60\text{ m})}$$

$$\boxed{k = 25\text{ N/m}}$$

(c) $GPE_1 = EPE_2$

$mgh = \frac{1}{2}kx^2$

$m(9.8\text{ m/s}^2)(1.5\text{ m}) = \frac{1}{2}(25\text{ N/m})(1.5\text{ m} - 0.60\text{ m})^2$

$$\boxed{m = 0.69\text{ kg}}$$

(d) i. $\sum F = F_S - F_g = 0$

$kx = mg$

$$x = \frac{mg}{k} = \frac{(0.69\text{ kg})(9.8\text{ m/s}^2)}{25\text{ N/m}} = 0.27\text{ m}$$

$$\boxed{0.87\text{ m}}$$

Note: 0.27 m is the distance beyond the normal length of the cord where the force of gravity exactly equals the force of the spring. At this point the net force is zero and the object no longer accelerates, thus, reaches its maximum speed. This distance must be added to the normal length of the cord (0.60 m) to determine the total distance the object falls to attain maximum speed.

ii. When the object is released, it will begin to accelerate downward due to the action of gravity. Once the object falls below the natural length of the cord, the magnitude of the upward restoring force will increase as the cord stretches more and more. The object will attain a maximum speed when it falls to a height where the upward force of the spring is exactly equal to the downward force of gravity resulting in a net force of zero and an acceleration of zero.

iii. $GPE_1 = KE_2$

$mgh' = \frac{1}{2}kx^2 + \frac{1}{2}mv^2$

$(0.69\text{ kg})(9.8\text{ m/s}^2)(0.87\text{ m}) = \frac{1}{2}(25\text{ N/m})(0.27\text{ m})^2 + \frac{1}{2}(0.69\text{ kg})v^2$

$$\boxed{v = 3.8\text{ m/s}}$$

1. (a) i. -Q, because the electric field inside a conductor, such as the metallic shell, is always 0. The temporary electric field within the metallic shell originating from the metal sphere will cause the free charges within the conductor to move until an electric field of zero is attained. To produce an electric field of zero in the shell, the electric field emanating from the positively charged sphere must be exactly canceled by the charges within the shell. This is achieved by an arrangement of negative charges at the inner surface of the shell with a total charge exactly equal to the total positive charge in the sphere.

ii. +Q, As stated above the free charges within a conductor will move until they experience an electric field of zero. Since there is a -Q at the inner surface, an arrangement of +Q charges at the outer surface would create an electric field of zero within the conducting metallic shell.

(b) i. $\boxed{E = 0}$

ii. $\int \vec{E} \cdot d\vec{A} = \frac{Q_{enc}}{\varepsilon_o}$ Choosing a Guassian sphere concentrically surrounding the metal sphere has a surface area of $4\pi r^2$.

$$E \cdot 4\pi r^2 = \frac{+Q}{\varepsilon_o}$$

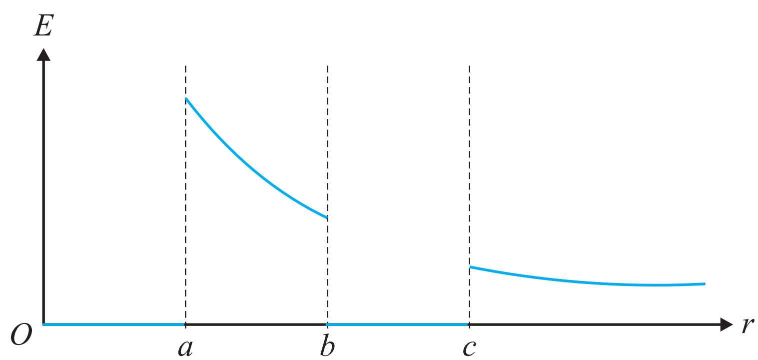
$$E = \frac{1}{4\pi r^2}\frac{Q}{\varepsilon_o}$$

$$\boxed{E = \frac{1}{4\pi\varepsilon_o}\frac{Q}{r^2} = k\frac{Q}{r^2}}$$

iii. $\boxed{E = 0}$

iv. $\boxed{E = k\frac{Q}{r^2}}$ The concentric Gaussian sphere will enclose a total charge of +Q just as in part (b) ii. above. Therefore, the expression for the electric field as a function of *r* will be the same.

(c)



(d) $qV = \frac{1}{2}mv^2$

$$e\left(k\frac{Q}{10r}\right) = \frac{1}{2}m_e v^2$$

$$\boxed{v = \sqrt{\frac{kQe}{5m_e r}}}$$

2. (a) i. $R_{eq1} = R_3 + R_T = 100\ \Omega + 50\ \Omega = 150\ \Omega$

$$\frac{1}{R_{eq}} = \frac{1}{R_2} + \frac{1}{R_{eq1}} = \frac{1}{(300\ \Omega)} + \frac{1}{(150\ \Omega)}, \text{ thus, } R_{eq} = 100\ \Omega$$

$R_{Total} = R_1 + R_{eq} = 200\ \Omega + 100\ \Omega = 300\ \Omega$. Thus, $I = \frac{\varepsilon}{R_{Total}} = \frac{1500\text{ V}}{300\ \Omega} = 5.0\text{ A}$

$V_{R_2} = I_R R_{eq} = (5.0\text{ A})(100\ \Omega)$

$\boxed{V_{R_2} = 500\text{ V}}$

ii. Immediately before the switch is closed, the current through the inductor is zero. Since an inductor resists changes in current, the current through the inductor immediately after the switch is closed will be zero.

$R_{Total} = R_1 + R_2 = 200\ \Omega + 300\ \Omega = 500\ \Omega$. Thus, $I = \frac{\varepsilon}{R_{Total}} = \frac{1500\text{ V}}{500\ \Omega} = 3.0\text{ A}$

$V_{R_2} = I_R R_{eq} = (3.0\text{ A})(300\ \Omega)$

$\boxed{V_{R_2} = 900\text{ V}}$

iii. Use Kirchoff's Loop rule. Initially, the charge of the capacitor is zero, thus, the voltage accross the capacitor is zero. $I_{R_2} R_2 - I_C R_3 - \frac{Q}{C} = 0$. Therefore, the voltage across R_2 and R_3 are the same.

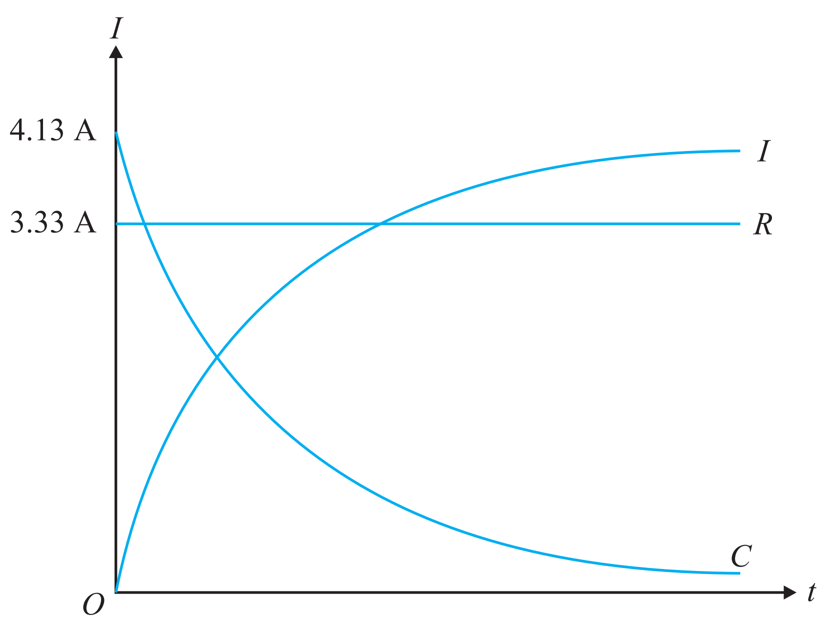
$$\frac{1}{R_{eq}} = \frac{1}{R_2} + \frac{1}{R_3} = \frac{1}{(300\ \Omega)} + \frac{1}{(100\ \Omega)}, \text{ thus, } R_{eq} = 75\ \Omega$$

$R_{Total} = R_1 + R_{eq} = 200\ \Omega + 75\ \Omega = 275\ \Omega$. Thus, $I = \frac{\varepsilon}{R_{Total}} = \frac{1500\text{ V}}{275\ \Omega} = 5.5\text{ A}$

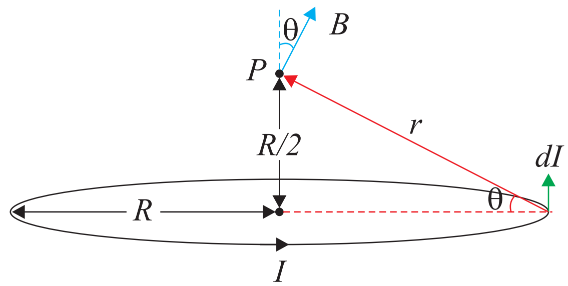
$V_{R_2} = I_R R_{eq} = (5.5\text{ A})(75\ \Omega)$

$\boxed{V_{R_2} = 410\text{ V}}$

(b)



3. (a)



The current segment is tangent to and in the plane of the loop.

i. Up, toward the top of the page.

ii. $dB_y = \frac{\mu_o}{4\pi}\frac{Id\vec{l} \times \hat{r}}{r^2}\cos\theta = \frac{\mu_o}{4\pi}\frac{Idl\sin 90}{r^2}$

$$B_1 = \int dB_y = \int \frac{\mu_o}{4\pi}\frac{Idl}{r^2}\cos\theta = \int \frac{\mu_o}{4\pi}\frac{Idl}{r^2}\frac{R}{r} = \int \frac{\mu_o}{4\pi}\frac{IdlR}{r^3} = \int_0^{2\pi} \frac{\mu_o}{4\pi}\frac{IRd\phi}{\left[\sqrt{R^2 + (R/2)^2}\right]^3}$$

$$B_1 = \frac{\mu_o}{4\pi}\frac{IR}{\left[\sqrt{R^2 + (R^2/4)}\right]^3}\int_0^{2\pi} d\phi = \frac{\mu_o}{4\pi}\frac{IR}{\left[\sqrt{\frac{5}{4}R^2}\right]^3}\phi\Big|_0^{2\pi} = \frac{\mu_o}{4\pi}\frac{IR}{\left[\frac{\sqrt{5}}{2}R\right]^3}(2\pi - 0) = \frac{\mu_o}{4\pi}\frac{IR}{\frac{\sqrt{5^3}}{8}R^3}(2\pi)$$

$$\boxed{B_1 = \frac{4}{5\sqrt{5}}\frac{\mu_o I}{R^2}}$$

(b) $B_{net} = B_1 + B_2 = \frac{4}{5\sqrt{5}}\frac{\mu_o I}{R^2} + \frac{4}{5\sqrt{5}}\frac{\mu_o I}{R^2}$

$$\boxed{B_{net} = \frac{8}{5\sqrt{5}}\frac{\mu_o I}{R^2}}$$

(c) $\phi_B = \int \vec{B}\cdot\vec{A} = \int B_{net} A\cos\theta = \int B_{net} A\cos 0$

$$\boxed{\phi_B = B_{net} s^2}$$

(d) $\text{emf} = -\frac{d}{dt}\phi = -\frac{d}{dt}\left(B_{net} s^2 \cos\theta\right) = -B_{net} s^2 \frac{d}{dt}(\cos\omega t)$

$$\boxed{\text{emf} = B_{net} s^2 \omega \sin\omega t}$$