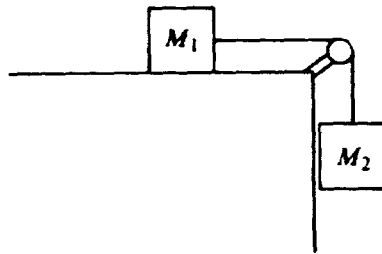


**1987**

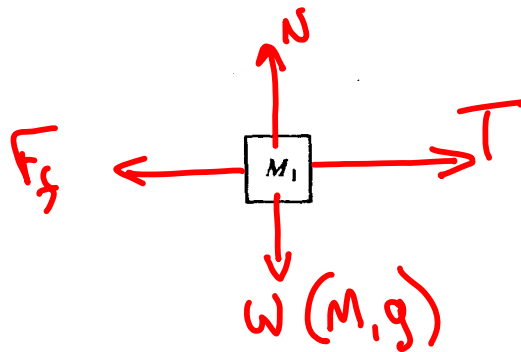
**AP Physics-B**

**Free-Response  
Questions**



1. In the system shown above, the block of mass  $M_1$  is on a rough horizontal table. The string that attaches it to the block of mass  $M_2$  passes over a frictionless pulley of negligible mass. The coefficient of kinetic friction  $\mu_k$  between  $M_1$  and the table is less than the coefficient of static friction  $\mu_s$ .

(a) On the diagram below, draw and identify all the forces acting on the block of mass  $M_1$ .



(b) In terms of  $M_1$  and  $M_2$  determine the minimum value of  $\mu_s$  that will prevent the blocks from moving.

The blocks are set in motion by giving  $M_2$  a momentary downward push. In terms of  $M_1$ ,  $M_2$ ,  $\mu_k$ , and  $g$ , determine each of the following:

- (c) The magnitude of the acceleration of  $M_1$   
 (d) The tension in the string

$$b) \sum F = 0$$

$$M_2 g = \mu M_1 g$$

$$\mu = \frac{M_2}{M_1}$$

$$c) \sum F = ma$$

$$M_2 g - \mu M_1 g = (M_1 + M_2) a$$

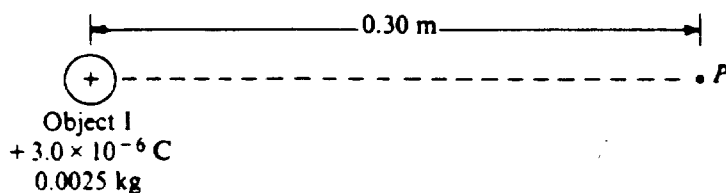
$$a = \frac{M_2 g - \mu M_1 g}{M_1 + M_2}$$

$$d) \sum F = ma$$

$$M_2 g - T = M_2 a$$

$$T = M_2 g - M_2 \left( \frac{M_2 g - \mu M_1 g}{M_1 + M_2} \right)$$

$$T = M_2 g \left( 1 - \frac{M_2 - \mu M_1}{M_1 + M_2} \right)$$



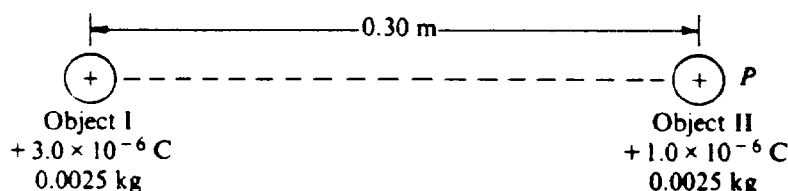
$$a) V = E\Delta = k \frac{Q}{r}$$

$$V = (9 \times 10^9) \left( \frac{3 \times 10^{-6}}{.3} \right)$$

$$V = 9 \times 10^4 \text{ V}$$

2. Object I, shown above, has a charge of  $+3 \times 10^{-6}$  coulomb and a mass of 0.0025 kilogram.

(a) What is the electric potential at point P, 0.30 meter from object I?



Object II, of the same mass as object I, but having a charge of  $+1 \times 10^{-6}$  coulomb, is brought from infinity to point P, as shown above.

(b) How much work must be done to bring the object II from infinity to point P?

(c) What is the magnitude of the electric force between the two objects when they are 0.30 meter apart?

(d) What are the magnitude and direction of the electric field at the point midway between the two objects?

The two objects are then released simultaneously and move apart due to the electric force between them. No other forces act on the objects.

(e) What is the speed of object I when the objects are very far apart?

$$b) W = qV$$

$$= (1 \times 10^{-6})(9 \times 10^4)$$

$$W = 9 \times 10^{-2} \text{ J}$$

$$c) F = qE \quad (\text{or } F = k \frac{q_1 q_2}{r^2})$$

$$F = (1 \times 10^{-6}) \left( \frac{9 \times 10^9}{.3^2} \right)$$

$$F = 30 \times 10^{-2} = .3 \text{ N}$$

$$d) E = k \frac{Q}{r^2}$$

$$E_r = E_1 - E_2 = (9 \times 10^9) \frac{3 \times 10^{-6}}{.15^2} - (9 \times 10^9) \frac{1 \times 10^{-6}}{.15^2}$$

$$E_r = 8 \times 10^5 \text{ N/C} \quad (+ \text{ means to RIGHT...})$$

$$e) \text{ Mom \& KE}$$

$$m_1 v_1 = m_2 v_2$$

$$W = 2 \text{ KE} = 2 \left( \frac{1}{2} m v^2 \right)$$

$$.09 \text{ J} = (.0025) v^2$$

$$v = 6 \text{ m/s}$$

3. A freezer contains 20 kilograms of food with a specific heat of  $2 \times 10^3 \frac{\text{J}}{\text{kg} \cdot ^\circ\text{C}}$ . The temperature inside the freezer is initially  $-5^\circ\text{C}$ . The freezer motor then operates for 10 minutes, reducing the temperature to  $-8^\circ\text{C}$ .

(a) How much heat is removed from the food during this time?

The freezer motor operates at 400 watts.

(b) How much energy is delivered to the freezer motor during the 10-minute period?

(c) During this time, how much total heat is ejected into the room in which the freezer is located?

(d) Determine the temperature change in the room if the specific heat of air is  $700 \frac{\text{J}}{\text{kg} \cdot ^\circ\text{C}}$ . Assume there are 80 kilograms of air in the room, the volume of the air is constant, and there is no heat loss from the room.

$$\begin{aligned} a) \quad Q &= mc\Delta T \\ &= (20 \text{ kg})(2 \times 10^3 \text{ J/kg} \cdot ^\circ\text{C})(3^\circ\text{C}) \end{aligned}$$

$$Q = 1.2 \times 10^5 \text{ J}$$

$$b) \quad \epsilon = Pt = (400 \text{ W})(600 \text{ s})$$

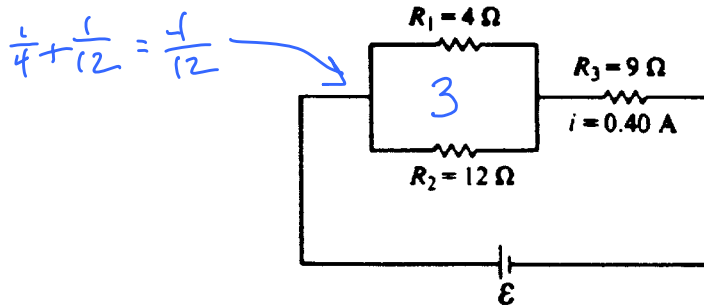
$$\epsilon = 2.4 \times 10^5 \text{ J}$$

$$\begin{aligned} c) \quad Q_{\text{room}} &= Q_{\text{food}} + \epsilon_{\text{motor}} \\ &= 1.2 \times 10^5 + 2.4 \times 10^5 \end{aligned}$$

$$Q_R = 3.6 \times 10^5 \text{ J}$$

$$\begin{aligned} d) \quad Q &= mc\Delta T \\ \Delta T &= \frac{Q}{mc} \\ &= \frac{3.6 \times 10^5}{(80)(700)} \end{aligned}$$

$$\Delta T = 6.4^\circ\text{C}$$



4. Three resistors are arranged in a circuit as shown above. The battery has an unknown but constant emf  $\mathcal{E}$  and a negligible internal resistance.

(a) Determine the equivalent resistance of the three resistors.

$$R_T = 3 + 9 = 12 \Omega$$

The current  $I$  in resistor  $R_3$  is 0.40 ampere.

(b) Determine the emf  $\mathcal{E}$  of the battery.

(c) Determine the potential difference across resistor  $R_1$ .

(d) Determine the power dissipated in resistor  $R_1$ .

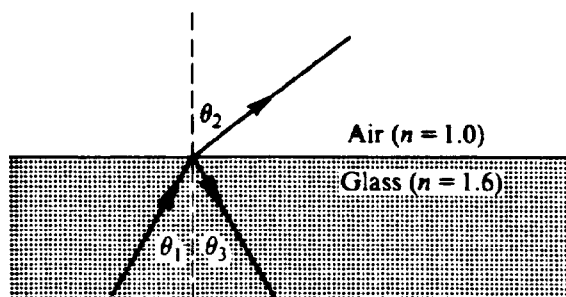
(e) Determine the amount of charge that passes through resistor  $R_3$  in one minute.

$$b) V_T = I_T R_T = (.4A)(12\Omega) = 4.8V$$

$$c) V_4 = V_{12} = V_{||} = V_3 = \frac{1}{4} V_T = 1.2V \quad \text{--- or } V = IR_1 = (.4)(3)$$

$$d) P = VI = (1.2V)\left(\frac{.4}{1}\right) = 0.36W$$

$$e) Q = It = (.4A)(60\text{ sec}) = 24C$$



5. Light of frequency  $6.0 \times 10^{14}$  hertz strikes a glass/air boundary at an angle of incidence  $\theta_1$ . The ray is partially reflected and partially refracted at the boundary, as shown above. The index of refraction of this glass is 1.6 for light of this frequency.

- Determine the value of  $\theta_3$  if  $\theta_1 = 30^\circ$ .
- Determine the value of  $\theta_2$  if  $\theta_1 = 30^\circ$ .
- Determine the speed of this light in the glass.
- Determine the wavelength of this light in the glass.
- What is the largest value of  $\theta_1$  that will result in a refracted ray?

a)  $i = r$   
 $\theta_1 = \theta_3 = 30^\circ$

b)  $n_i \sin i = n_r \sin r$   
 $r = \sin^{-1} \left( \frac{n_i \sin i}{n_r} \right)$   
 $r = \sin^{-1} \left( \frac{1.6 \sin 30^\circ}{1} \right)$

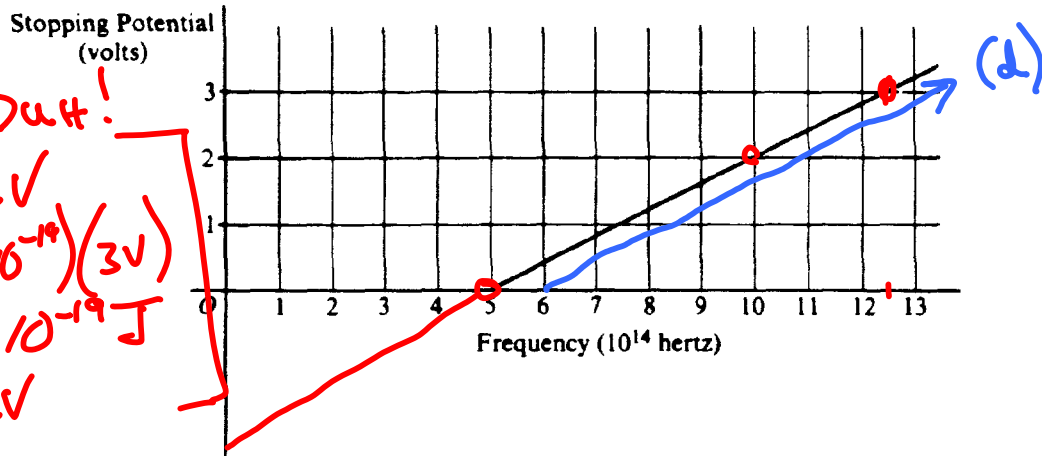
$\theta_2 = 53.1^\circ$

d)  $\lambda = \frac{v}{f} = \frac{1.875 \times 10^8}{6 \times 10^{14}}$   
 $\lambda = 3.125 \times 10^{-7} \text{ m}$

c)  $n = \frac{c}{v}$   
 $v = \frac{c}{n} = \frac{c}{1.6}$   
 $v = 1.875 \times 10^8 \text{ m/s}$

e)  $\theta_c = \sin^{-1} \frac{1}{n}$   
 $= \sin^{-1} \frac{1}{1.6}$   
 $\theta_c = 38.7^\circ$

6. In a photoelectric experiment, light is incident on a metal surface. Electrons are ejected from the surface, producing a current in a circuit. A reverse potential is applied in the circuit and adjusted until the current drops to zero. That potential at which the current drops to zero is called the stopping potential. The data obtained for a range of frequencies are graphed below.



- (a) For a frequency of light that has a stopping potential of 3 volts, what is the maximum kinetic energy of the ejected photoelectrons?
- (b) From the graph and the value of the electron charge, determine an experimental value for Planck's constant.
- (c) From the graph, determine the work function for the metal.
- (d) On the axes above, draw the expected graph for a different metal surface with a threshold frequency of  $6.0 \times 10^{14}$  hertz.

b)  $h$  is slope of Graph:  $K_{max} = hf - \phi$

$h = \frac{\Delta V}{\Delta f} = \frac{3eV}{7.5 \times 10^{14}} = 4 \times 10^{-15} eV \cdot s$

c)  $\phi$  is y-inter ( $\sim 2eV$ )

$\phi = hf - K_{max} = (4 \times 10^{-15})(10 \times 10^{14}) - 2eV$

$\phi = 2.07 eV$