# PHYS 232 Review problem set Solutions

**P23.57** $F = \frac{k_e q_1 q_2}{r^2}$: $\tan\theta = \frac{15.0}{60.0}$

$\theta = 14.0°$

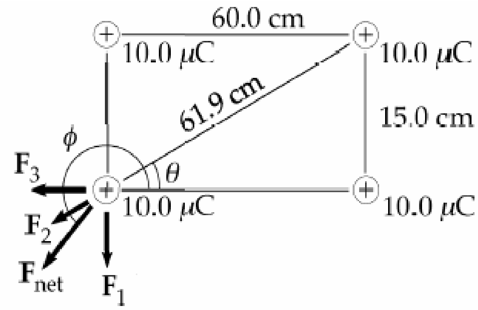


**FIG. P23.57**

$$F_1 = \frac{(8.99\times10^9)(10.0\times10^{-6})^2}{(0.150)^2} = 40.0\text{ N}$$

$$F_3 = \frac{(8.99\times10^9)(10.0\times10^{-6})^2}{(0.600)^2} = 2.50\text{ N}$$

$$F_2 = \frac{(8.99\times10^9)(10.0\times10^{-6})^2}{(0.619)^2} = 2.35\text{ N}$$

$$F_x = -F_3 - F_2\cos 14.0° = -2.50 - 2.35\cos 14.0° = -4.78\text{ N}$$

$$F_y = -F_1 - F_2\sin 14.0° = -40.0 - 2.35\sin 14.0° = -40.6\text{ N}$$

$$F_{\text{net}} = \sqrt{F_x^2 + F_y^2} = \sqrt{(4.78)^2 + (40.6)^2} = \boxed{40.9\text{ N}}$$

$$\tan\phi = \frac{F_y}{F_x} = \frac{-40.6}{-4.78}$$

$$\phi = \boxed{263°}$$

**24. 26: You need to be able to apply Gauss' Law to problems like these; review the examples 24.4, 24.5, 24.6 24.7 and 24.8 from the book. I am using the result from example 24.7 here.**

**P24.26** (a) $E = \frac{2k_e\lambda}{r}$ $3.60\times10^4 = \frac{2(8.99\times10^9)(Q/2.40)}{0.190}$

$Q = +9.13\times10^{-7}\text{ C} = \boxed{+913\text{ nC}}$

(b) $\mathbf{E} = \boxed{0}$

**P25.66** (a) From Gauss's law, $\boxed{E_A = 0}$ (no charge within)

$$E_B = k_e \frac{q_A}{r^2} = \left(8.99 \times 10^9\right) \frac{\left(1.00 \times 10^{-8}\right)}{r^2} = \boxed{\left(\frac{89.9}{r^2}\right) \text{ V/m}}$$

$$E_C = k_e \frac{\left(q_A + q_B\right)}{r} = \left(8.99 \times 10^9\right) \frac{\left(-5.00 \times 10^{-9}\right)}{r^2} = \boxed{\left(-\frac{45.0}{r^2}\right) \text{ V/m}}$$

(b) $$V_C = k_e \frac{\left(q_A + q_B\right)}{r} = \left(8.99 \times 10^9\right) \frac{\left(-5.00 \times 10^{-9}\right)}{r} = \boxed{\left(-\frac{45.0}{r}\right) \text{ V}}$$

$$\therefore \text{At } r_2,\ V = -\frac{45.0}{0.300} = -150 \text{ V}$$

$$\text{Inside } r_2,\ V_B = -150 \text{ V} + \int_{r_2}^{r} \frac{89.9}{r^2} dr = -150 + 89.9\left(\frac{1}{r} - \frac{1}{0.300}\right) = \boxed{\left(-450 + \frac{89.9}{r}\right) \text{ V}}$$

$$\therefore \text{At } r_1,\ V = -450 + \frac{89.9}{0.150} = +150 \text{ V so } \boxed{V_A = +150 \text{ V}}.$$

**P26.27**

$$C_s = \left(\frac{1}{5.00} + \frac{1}{10.0}\right)^{-1} = 3.33\ \mu\text{F}$$

$$C_{p1} = 2(3.33) + 2.00 = 8.66\ \mu\text{F}$$

$$C_{p2} = 2(10.0) = 20.0\ \mu\text{F}$$

$$C_{eq} = \left(\frac{1}{8.66} + \frac{1}{20.0}\right)^{-1} = \boxed{6.04\ \mu\text{F}}$$

**P27.60** 2 wires $\rightarrow \ell = 100$ m

$$R = \frac{0.108\ \Omega}{300\ \text{m}}(100\ \text{m}) = 0.036\,0\ \Omega$$

(a) $$(\Delta V)_{\text{home}} = (\Delta V)_{\text{line}} - IR = 120 - (110)(0.036\,0) = \boxed{116\ \text{V}}$$

(b) $$\mathcal{P} = I(\Delta V) = (110\ \text{A})(116\ \text{V}) = \boxed{12.8\ \text{kW}}$$

(c) $$\mathcal{P}_{\text{wires}} = I^2R = (110\ \text{A})^2(0.036\,0\ \Omega) = \boxed{436\ \text{W}}$$

**P28.71** (a) After steady-state conditions have been reached, there is no DC current through the capacitor.

Thus, for $R_3$: $\boxed{I_{R_3} = 0\ \text{(steady-state)}}$.

For the other two resistors, the steady-state current is simply determined by the 9.00-V emf across the 12-kΩ and 15-kΩ resistors in series:

For $R_1$ and $R_2$: $$I_{(R_1+R_2)} = \frac{\varepsilon}{R_1+R_2} = \frac{9.00\ \text{V}}{(12.0\ \text{k}\Omega + 15.0\ \text{k}\Omega)} = \boxed{333\ \mu\text{A (steady-state)}}.$$

(b) After the transient currents have ceased, the potential difference across $C$ is the same as the potential difference across $R_2(= IR_2)$ because there is no voltage drop across $R_3$. Therefore, the charge $Q$ on $C$ is

$$Q = C(\Delta V)_{R_2} = C(IR_2) = (10.0\ \mu\text{F})(333\ \mu\text{A})(15.0\ \text{k}\Omega)$$
$$= \boxed{50.0\ \mu\text{C}}.$$

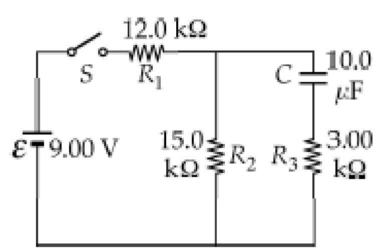


**FIG. P28.71(b)**

(c) When the switch is opened, the branch containing $R_1$ is no longer part of the circuit. The capacitor discharges through $(R_2 + R_3)$ with a time constant of $(R_2 + R_3)C = (15.0\ \text{k}\Omega + 3.00\ \text{k}\Omega)(10.0\ \mu\text{F}) = 0.180\ \text{s}$. The initial current $I_i$ in this discharge circuit is determined by the initial potential difference across the capacitor applied to $(R_2 + R_3)$ in series:

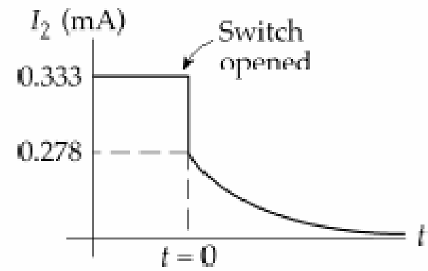

FIG. P28.71(c)

$$I_i = \frac{(\Delta V)_C}{(R_2 + R_3)} = \frac{IR_2}{(R_2 + R_3)} = \frac{(333\ \mu\text{A})(15.0\ \text{k}\Omega)}{(15.0\ \text{k}\Omega + 3.00\ \text{k}\Omega)} = 278\ \mu\text{A}.$$

Thus, when the switch is opened, the current through $R_2$ changes instantaneously from 333 $\mu$A (downward) to 278 $\mu$A (downward) as shown in the graph. Thereafter, it decays according to

$$I_{R_2} = I_i e^{-t/(R_2+R_3)C} = \boxed{(278\ \mu\text{A})e^{-t/(0.180\ \text{s})}\ (\text{for } t > 0)}.$$

(d) The charge $q$ on the capacitor decays from $Q_i$ to $\frac{Q_i}{5}$ according to

$$q = Q_i e^{-t/(R_2+R_3)C}$$

$$\frac{Q_i}{5} = Q_i e^{(-t/0.180\ \text{s})}$$

$$5 = e^{t/0.180\ \text{s}}$$

$$\ln 5 = \frac{t}{180\ \text{ms}}$$

$$t = (0.180\ \text{s})(\ln 5) = \boxed{290\ \text{ms}}$$

**P29.36** $\frac{1}{2}mv^2 = q(\Delta V)$ so $v = \sqrt{\frac{2q(\Delta V)}{m}}$

$r = \frac{mv}{qB}$ so $r = \frac{m\sqrt{2q(\Delta V)/m}}{qB}$

$r^2 = \frac{m}{q} \cdot \frac{2(\Delta V)}{B^2}$ and $(r')^2 = \frac{m'}{q'} \cdot \frac{2(\Delta V)}{B^2}$

$m = \frac{qB^2r^2}{2(\Delta V)}$ and $(m') = \frac{(q')B^2(r')^2}{2(\Delta V)}$ so $\frac{m'}{m} = \frac{q'}{q} \cdot \frac{(r')^2}{r^2} = \left(\frac{2e}{e}\right)\left(\frac{2R}{R}\right)^2 = \boxed{8}$

**P30.24** (a) In $B=\frac{\mu_0 I}{2\pi r}$, the field will be one-tenth as large at a ten-times larger distance: $\boxed{400\text{ cm}}$

(b) $\mathbf{B}=\frac{\mu_0 I}{2\pi r_1}\hat{\mathbf{k}}+\frac{\mu_0 I}{2\pi r_2}\left(-\hat{\mathbf{k}}\right)$ so $B=\frac{4\pi\times10^{-7}\text{ T}\cdot\text{m}(2.00\text{ A})}{2\pi\text{ A}}\left(\frac{1}{0.398\,5\text{ m}}-\frac{1}{0.401\,5\text{ m}}\right)=\boxed{7.50\text{ nT}}$

(c) Call $r$ the distance from cord center to field point and $2d=3.00\text{ mm}$ the distance between conductors.

$$B=\frac{\mu_0 I}{2\pi}\left(\frac{1}{r-d}-\frac{1}{r+d}\right)=\frac{\mu_0 I}{2\pi}\frac{2d}{r^2-d^2}$$

$$7.50\times10^{-10}\text{ T}=\left(2.00\times10^{-7}\text{ T}\cdot\text{m/A}\right)(2.00\text{ A})\frac{\left(3.00\times10^{-3}\text{ m}\right)}{r^2-2.25\times10^{-6}\text{ m}^2}\text{ so } r=\boxed{1.26\text{ m}}$$

The field of the two-conductor cord is weak to start with and falls off rapidly with distance.

(d) The cable creates $\boxed{\text{zero}}$ field at exterior points, since a loop in Ampère's law encloses zero total current. Shall we sell coaxial-cable power cords to people who worry about biological damage from weak magnetic fields?

**P31.59** (a) At time $t$, the flux through the loop is $\Phi_B=BA\cos\theta=(a+bt)\left(\pi r^2\right)\cos0°=\pi(a+bt)r^2$

At $t=0$, $\Phi_B=\boxed{\pi ar^2}$.

(b) $$\varepsilon=-\frac{d\Phi_B}{dt}=-\pi r^2\frac{d(a+bt)}{dt}=\boxed{-\pi br^2}$$

(c) $$I=\frac{\varepsilon}{R}=\boxed{-\frac{\pi br^2}{R}}$$

(d) $$\mathcal{P}=\varepsilon I=\left(-\frac{\pi br^2}{R}\right)\left(-\pi br^2\right)=\boxed{\frac{\pi^2b^2r^4}{R}}$$

**P32.17** (a) $\tau = \frac{L}{R} = 2.00 \times 10^{-3}\ \text{s} = \boxed{2.00\ \text{ms}}$

(b) $I = I_{\max}\left(1 - e^{-t/\tau}\right) = \left(\frac{6.00\ \text{V}}{4.00\ \Omega}\right)\left(1 - e^{-0.250/2.00}\right) = \boxed{0.176\ \text{A}}$

(c) $I_{\max} = \frac{\varepsilon}{R} = \frac{6.00\ \text{V}}{4.00\ \Omega} = \boxed{1.50\ \text{A}}$

(d) $0.800 = 1 - e^{-t/2.00\ \text{ms}} \rightarrow t = -(2.00\ \text{ms})\ln(0.200) = \boxed{3.22\ \text{ms}}$

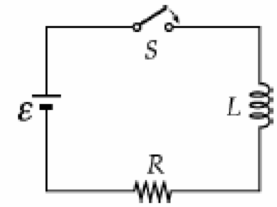

**FIG. P32.17**

**P34.5** (a) $f\lambda = c$

or $f(50.0\ \text{m}) = 3.00 \times 10^{8}\ \text{m/s}$

so $\boxed{f = 6.00 \times 10^{6}\ \text{Hz} = 6.00\ \text{MHz}}$.

(b) $\frac{E}{B} = c$

or $\frac{22.0}{B_{\max}} = 3.00 \times 10^{8}$

so $\mathbf{B}_{\max} = \boxed{-73.3\hat{\mathbf{k}}\ \text{nT}}$.

(c) $k = \frac{2\pi}{\lambda} = \frac{2\pi}{50.0} = 0.126\ \text{m}^{-1}$

and $\omega = 2\pi f = 2\pi\left(6.00 \times 10^{6}\ \text{s}^{-1}\right) = 3.77 \times 10^{7}\ \text{rad/s}$

$\mathbf{B} = \mathbf{B}_{\max}\cos(kx - \omega t) = \boxed{-73.3\cos\left(0.126x - 3.77 \times 10^{7} t\right)\hat{\mathbf{k}}\ \text{nT}}$.

**P37.6** $\lambda = \frac{340 \text{ m/s}}{2\,000 \text{ Hz}} = 0.170 \text{ m}$

Maxima are at $d \sin\theta = m\lambda$:

| | | | |
|---|---|---|---|
| $m = 0$ | gives | $\theta = 0°$ | |
| $m = 1$ | gives | $\sin\theta = \frac{\lambda}{d} = \frac{0.170 \text{ m}}{0.350 \text{ m}}$ | $\theta = 29.1°$ |
| $m = 2$ | gives | $\sin\theta = \frac{2\lambda}{d} = 0.971$ | $\theta = 76.3°$ |
| $m = 3$ | gives | $\sin\theta = 1.46$ | No solution. |

Minima are at $d \sin\theta = \left(m + \frac{1}{2}\right)\lambda$:

| | | | |
|---|---|---|---|
| $m = 0$ | gives | $\sin\theta = \frac{\lambda}{2d} = 0.243$ | $\theta = 14.1°$ |
| $m = 1$ | gives | $\sin\theta = \frac{3\lambda}{2d} = 0.729$ | $\theta = 46.8°$ |
| $m = 2$ | gives | $\sin\theta = 1.21$ | No solution. |

$\boxed{\text{So we have maxima at } 0°,\ 29.1°,\ \text{and } 76.3°;\ \text{minima at } 14.1°\ \text{and } 46.8°}$.

**P39.17** (a) $\Delta t = \gamma \Delta t_p = \frac{\Delta t_p}{\sqrt{1-(v/c)^2}} = \frac{15.0 \text{ yr}}{\sqrt{1-(0.700)^2}} = \boxed{21.0 \text{ yr}}$

(b) $d = v(\Delta t) = [0.700c](21.0 \text{ yr}) = [(0.700)(1.00 \text{ ly/yr})](21.0 \text{ yr}) = \boxed{14.7 \text{ ly}}$

(c) The astronauts see Earth flying out the back window at $0.700c$:

$d = v(\Delta t_p) = [0.700c](15.0 \text{ yr}) = [(0.700)(1.00 \text{ ly/yr})](15.0 \text{ yr}) = \boxed{10.5 \text{ ly}}$

(d) Mission control gets signals for 21.0 yr while the battery is operating, and then for 14.7 years after the battery stops powering the transmitter, 14.7 ly away:

$21.0 \text{ yr} + 14.7 \text{ yr} = \boxed{35.7 \text{ yr}}$

**P39.41** We must conserve both energy and relativistic momentum of the system of fragments. With subscript 1 referring to the $0.868c$ particle and subscript 2 to the $0.987c$ particle,

$$\gamma_1 = \frac{1}{\sqrt{1-(0.868)^2}} = 2.01 \text{ and } \gamma_2 = \frac{1}{\sqrt{1-(0.987)^2}} = 6.22.$$

Conservation of energy gives $E_1 + E_2 = E_{\textbf{total}}$

which is $\gamma_1 m_1 c^2 + \gamma_2 m_2 c^2 = m_{\text{total}} c^2$

or $2.01 m_1 + 6.22 m_2 = 3.34 \times 10^{-27}$ kg.

This reduces to: $m_1 + 3.09 m_2 = 1.66 \times 10^{-27}$ kg. (1)

Since the final momentum of the system must equal zero, $p_1 = p_2$

gives $\gamma_1 m_1 u_1 = \gamma_2 m_2 u_2$

or $(2.01)(0.868c) m_1 = (6.22)(0.987c) m_2$

which becomes $m_1 = 3.52 m_2$. (2)

Solving (1) and (2) simultaneously, $m_1 = \boxed{8.84 \times 10^{-28} \text{ kg}}$ and $m_2 = \boxed{2.51 \times 10^{-28} \text{ kg}}$.

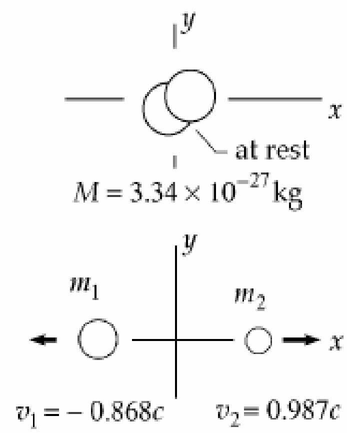


FIG. P39.41

***P40.27** The electron's kinetic energy is

$$K = \frac{1}{2}mv^2 = \frac{1}{2}9.11\times10^{-31}\text{ kg}\left(2.18\times10^{6}\text{ m/s}\right)^2 = 2.16\times10^{-18}\text{ J}.$$

This is the energy lost by the photon, $hf_0 - hf'$

$\frac{hc}{\lambda_0} - \frac{hc}{\lambda'} = 2.16\times10^{-18}$ J. We also have

$$\lambda' - \lambda_0 = \frac{h}{m_e c}(1-\cos\theta) = \frac{6.63\times10^{-34}\text{ Js s}}{9.11\times10^{-31}\text{ kg}\left(3\times10^{8}\text{ m}\right)}(1-\cos 17.4°)$$

$$\lambda' = \lambda_0 + 1.11\times10^{-13}\text{ m}$$

(a) Combining the equations by substitution,

$$\frac{1}{\lambda_0} - \frac{1}{\lambda_0 + 0.111\text{ pm}} = \frac{2.16\times10^{-18}\text{ J s}}{6.63\times10^{-34}\text{ Js}\left(3\times10^{8}\text{ m}\right)} = 1.09\times10^{7}/\text{m}$$

$$\frac{\lambda_0 + 0.111\text{ pm} - \lambda_0}{\lambda_0^2 + \lambda_0(0.111\text{ pm})} = 1.09\times10^{7}/\text{m}$$

$$0.111\text{ pm} = \left(1.09\times10^{7}/\text{m}\right)\lambda_0^2 + 1.21\times10^{-6}\lambda_0$$

$$1.09\times10^{7}\lambda_0^2 + 1.21\times10^{-6}\text{ m}\lambda_0 - 1.11\times10^{-13}\text{ m}^2 = 0$$

$$\lambda_0 = \frac{-1.21\times10^{-6}\text{ m} \pm \sqrt{\left(1.21\times10^{-6}\text{ m}\right)^2 - 4\left(1.09\times10^{7}\right)\left(-1.11\times10^{-13}\text{ m}^2\right)}}{2\left(1.09\times10^{7}\right)}$$

only the positive answer is physical: $\lambda_0 = \boxed{1.01\times10^{-10}\text{ m}}$.

(b) Then $\lambda' = 1.01\times10^{-10}\text{ m} + 1.11\times10^{-13}\text{ m} = 1.01\times10^{-10}\text{ m}$.
Conservation of momentum in the transverse direction:

$$0 = \frac{h}{\lambda'}\sin\theta - \gamma m_e v\sin\phi$$

$$\frac{6.63\times10^{-34}\text{ J}\cdot\text{s}}{1.01\times10^{-10}\text{ m}}\sin 17.4° = \frac{9.11\times10^{-31}\text{ kg}\left(2.18\times10^{6}\text{ m/s}\right)\sin\phi}{\sqrt{1-\left(2.18\times10^{6}/3\times10^{8}\right)^2}}$$

$$1.96\times10^{-24} = 1.99\times10^{-24}\sin\phi \qquad \phi = \boxed{81.1°}$$