HOMEWORK#7 SOLUTION

[Chap 25]

19 •

Determine the Concept If we apply Kirchhoff's loop rule with the switch closed, we obtain $\varepsilon - IR - V_C = 0$. Immediately after the switch is closed, $I = 0$ and we have $\varepsilon = V_C$.

$\boxed{(b) \text{ is correct.}}$

26 ••

Determine the Concept All of the current provided by the battery passes through R_1, whereas only half this current passes through R_2 and R_3. Because $P = I^2R$, the power dissipated in R_1 will be four times that dissipated in R_2 and R_3. $\boxed{(c) \text{ is correct.}}$

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Picture the Problem We can use $P = fv$ to find the power the electric motor must develop to move the car at 80 km/h against a frictional force of 1200 N. We can find the total charge that can be delivered by the 10 batteries using $\Delta Q = NI\Delta t$. The total electrical energy delivered by the 10 batteries before recharging can be found using the definition of emf. We can find the distance the car can travel from the definition of work and the cost per kilometer of driving the car this distance by dividing the cost of the required energy by the distance the car has traveled.

(*a*) Express the power the electric motor must develop in terms of the speed of the car and the friction force:

$$P = fv = (1200\,\text{N})(80\,\text{km/h}) = \boxed{26.7\,\text{kW}}$$

(*b*) Use the definition of current to express the total charge that can be delivered before charging:

$$\Delta Q = NI\Delta t = 10(160\,\text{A}\cdot\text{h})\left(\frac{3600\,\text{s}}{\text{h}}\right) = \boxed{5.76\,\text{MC}}$$

where N is the number of batteries.

(*c*) Use the definition of emf to express the total electrical energy available in the batteries:

$$W = Q\mathcal{E} = (5.76\,\text{MC})(12\,\text{V}) = \boxed{69.1\,\text{MJ}}$$

(*d*) Relate the amount of work the batteries can do to the work required to overcome friction:

$$W = fd$$

Solve for and evaluate d:

$$d = \frac{W}{f} = \frac{69.1\,\text{MJ}}{1200\,\text{N}} = \boxed{57.6\,\text{km}}$$

(e) Express the cost per kilometer as the ratio of the ratio of the cost of the energy to the distance traveled before recharging:

$$\text{Cost/km} = \frac{(\$0.09/\text{kW}\cdot\text{h})\mathcal{E}It}{d} = \frac{(\$0.09/\text{kW}\cdot\text{h})(120\,\text{V})(160\,\text{A}\cdot\text{h})}{57.6\,\text{km}} = \boxed{\$0.03/\text{km}}$$

116 ••

Picture the Problem We can use Kirchhoff's loop rule (conservation of energy) to find both the initial and steady-state currents drawn from the battery and Ohm's law to find the maximum voltage across the capacitor.

(a) Apply Kirchhoff's loop rule to a loop around the outside of the circuit to obtain:

$$\mathcal{E} - (1.2\,\text{M}\Omega)I_0 - V_{\text{C}0} = 0$$

Because the capacitor initially is uncharged:

$$V_{\text{C}0} = 0$$

and

$$I_0 = \frac{\mathcal{E}}{1.2\,\text{M}\Omega} = \frac{120\,\text{V}}{1.2\,\text{M}\Omega} = \boxed{0.100\,\text{mA}}$$

(b) When a long time has passed:

$$I_{\text{C}\infty} = 0$$

Apply Kirchhoff's loop rule to a loop that includes the source and both resistors to obtain:

$$\mathcal{E} - (1.2\,\text{M}\Omega)I_\infty - (600\,\text{k}\Omega)I_\infty = 0$$

Solve for and evaluate I_∞:

$$I_\infty = \frac{\mathcal{E}}{1.2\,\text{M}\Omega + 600\,\text{k}\Omega} = \frac{120\,\text{V}}{1.2\,\text{M}\Omega + 600\,\text{k}\Omega} = \boxed{66.7\,\mu\text{A}}$$

(c) The maximum voltage across the capacitor equals the potential difference across the 600-kΩ under steady-state conditions. Apply Ohm's law to obtain:

$$V_{\text{C}\infty} = I_\infty R_{600\,\text{k}\Omega} = (66.7\,\mu\text{A})(600\,\text{k}\Omega) = \boxed{40.0\,\text{V}}$$

[Chap 26]

***1 •**

Determine the Concept Because the electrons are initially moving at 90° to the magnetic field, they will be deflected in the direction of the magnetic force acting on them. Use the right-hand rule based on the expression for the magnetic force acting on a moving charge $\vec{F} = q\vec{v} \times \vec{B}$, remembering that, for a negative charge, the force is in the direction opposite that indicated by the right-hand rule, to convince yourself that the particle will follow the path whose terminal point on the screen is 2. $\boxed{(b) \text{ is correct.}}$

3 •

Determine the Concept False. An object experiences acceleration if either its speed changes or the direction it is moving changes. The magnetic force, acting perpendicular to the direction a charged particle is moving, changes the particle's *velocity* by changing the direction it is moving and hence accelerates the particle.

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Picture the Problem We can use Newton's 2nd law for circular motion to express the radius of curvature *R* of each particle in terms of its charge, momentum, and the magnetic field. We can then divide the proton's radius of curvature by that of the ^{7}Li nucleus to decide which of these alternatives is correct.

Apply $\sum F_{\text{radial}} = ma_c$ to the lithium nucleus to obtain:

$$qvB = m\frac{v^2}{R}$$

Solve for *r*:

$$R = \frac{mv}{qB}$$

For the ^{7}Li nucleus this becomes:

$$R_{\text{Li}} = \frac{p_{\text{Li}}}{3eB}$$

For the proton we have:

$$R_{\text{p}} = \frac{p_{\text{p}}}{eB}$$

Divide equation (2) by equation (1) and simplify to obtain:

$$\frac{R_{\text{p}}}{R_{\text{Li}}} = \frac{\frac{p_{\text{p}}}{eB}}{\frac{p_{\text{Li}}}{3eB}} = 3\frac{p_{\text{p}}}{p_{\text{Li}}}$$

Because the momenta are equal:

$$\frac{R_{\text{p}}}{R_{\text{Li}}} = 3 \text{ and } \boxed{(a) \text{ is correct.}}$$

***12 •**

Determine the Concept Application of the right-hand rule indicates that a positively charged body would experience a downward force and, in the absence of other forces, be deflected downward. Because the direction of the magnetic force on an electron is opposite that of the force on a positively charged object, an electron will be deflected upward. $\boxed{(c)\text{ is correct.}}$

24 ••

Picture the Problem We can use $\vec{F} = I\vec{\ell}\times\vec{B}$ to find the force acting on the segments of the wire as well as the magnetic force acting on the wire if it were a straight segment from *a* to *b*.

Express the magnetic force acting on the wire:

$$\vec{F} = \vec{F}_{3\,\text{cm}} + \vec{F}_{4\,\text{cm}}$$

Evaluate $\vec{F}_{3\,\text{cm}}$:

$$\begin{aligned}\vec{F}_{3\,\text{cm}} &= (1.8\,\text{A})\left[(3\,\text{cm})\hat{\boldsymbol{i}}\times(1.2\,\text{T})\hat{\boldsymbol{k}}\right]\\ &= (0.0648\,\text{N})\left(-\hat{\boldsymbol{j}}\right)\\ &= -(0.0648\,\text{N})\hat{\boldsymbol{j}}\end{aligned}$$

Evaluate $\vec{F}_{4\,\text{cm}}$:

$$\begin{aligned}\vec{F}_{4\,\text{cm}} &= (1.8\,\text{A})\left[(4\,\text{cm})\hat{\boldsymbol{j}}\times(1.2\,\text{T})\hat{\boldsymbol{k}}\right]\\ &= (0.0864\,\text{N})\hat{\boldsymbol{i}}\end{aligned}$$

Substitute to obtain:

$$\begin{aligned}\vec{F} &= -(0.0648\,\text{N})\hat{\boldsymbol{j}} + (0.0864\,\text{N})\hat{\boldsymbol{i}}\\ &= \boxed{(0.0864\,\text{N})\hat{\boldsymbol{i}} - (0.0648\,\text{N})\hat{\boldsymbol{j}}}\end{aligned}$$

If the wire were straight from *a* to *b*:

$$\vec{\ell} = (3\,\text{cm})\hat{\boldsymbol{i}} + (4\,\text{cm})\hat{\boldsymbol{j}}$$

The magnetic force acting on the wire is:

$$\begin{aligned}\vec{F} &= (1.8\,\text{A})\left[(3\,\text{cm})\hat{\boldsymbol{i}} + (4\,\text{cm})\hat{\boldsymbol{j}}\right]\times(1.2\,\text{T})\hat{\boldsymbol{k}} = -(0.0648\,\text{N})\hat{\boldsymbol{j}} + (0.0864\,\text{N})\hat{\boldsymbol{i}}\\ &= \boxed{(0.0864\,\text{N})\hat{\boldsymbol{i}} - (0.0648\,\text{N})\hat{\boldsymbol{j}}}\end{aligned}$$

in agreement with the result obtained above when we treated the two straight segments of the wire separately.

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Picture the Problem We can apply Newton's 2$^{\text{nd}}$ law to an orbiting particle to obtain an expression for the radius of its orbit R as a function of its mass m, charge q, speed v, and the magnetic field B.

Apply $\sum F_{\text{radial}} = ma_{\text{c}}$ to an orbiting particle to obtain:

$$qvB = m\frac{v^2}{r}$$

Solve for r:

$$r = \frac{mv}{qB}$$

Express the kinetic energy of the particle:

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

Solve for v to obtain:

$$v = \sqrt{\frac{2K}{m}}$$

Substitute in equation (1) to obtain:

$$r = \frac{m}{qB}\sqrt{\frac{2K}{m}} = \frac{1}{qB}\sqrt{2Km} \qquad (1)$$

Using equation (1), express the ratio $R_{\text{d}}/R_{\text{p}}$:

$$\frac{R_{\text{d}}}{R_{\text{p}}} = \frac{\dfrac{1}{q_{\text{d}}B}\sqrt{2Km_{\text{d}}}}{\dfrac{1}{q_{\text{p}}B}\sqrt{2Km_{\text{p}}}} = \frac{q_{\text{p}}}{q_{\text{d}}}\sqrt{\frac{m_{\text{d}}}{m_{\text{p}}}}$$

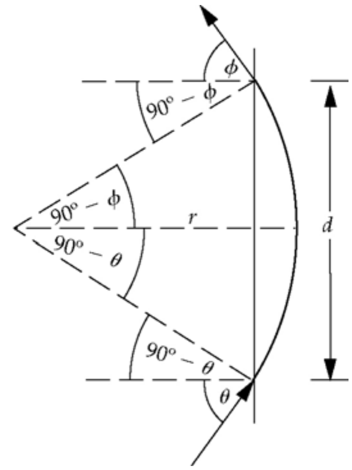
$$= \frac{e}{e}\sqrt{\frac{2m_{\text{p}}}{m_{\text{p}}}} = \boxed{\sqrt{2}}$$

Using equation (1), express the ratio R_{α}/R_{p}:

$$\frac{R_{\alpha}}{R_{\text{p}}} = \frac{\dfrac{1}{q_{\alpha}B}\sqrt{2Km_{\alpha}}}{\dfrac{1}{q_{\text{p}}B}\sqrt{2Km_{\text{p}}}} = \frac{q_{\text{p}}}{q_{\alpha}}\sqrt{\frac{m_{\alpha}}{m_{\text{p}}}}$$

$$= \frac{e}{2e}\sqrt{\frac{4m_{\text{p}}}{m_{\text{p}}}} = \boxed{1}$$

Picture the Problem The trajectory of the proton is shown to the right. We know that, because the proton enters the field perpendicularly to the field, its trajectory while in the field will be circular. We can use symmetry considerations to determine ϕ. The application of Newton's 2nd law to the proton while it is in the magnetic field and of trigonometry will allow us to conclude that $r = d$ and to determine their value.



From symmetry, it is evident that the angle θ in Figure 26-35 equals the angle ϕ:

$$\phi = \boxed{60.0°}$$

Use trigonometry to obtain:

$$\sin(90° - \theta) = \sin 30° = \frac{1}{2} = \frac{d/2}{r}$$

or $r = d$.

Apply $\sum F_{\text{radial}} = ma_c$ to the proton while it is in the magnetic field to obtain:

$$qvB = m\frac{v^2}{r}$$

Solve for r:

$$r = \frac{mv}{qB}$$

Substitute numerical values and evaluate $r = d$:

$$d = r = \frac{(1.67\times10^{-27}\ \text{kg})(10^7\ \text{m/s})}{(1.60\times10^{-19}\ \text{C})(0.8\,\text{T})} = \boxed{0.130\,\text{m}}$$

***80 ••**

Picture the Problem We can use a constant-acceleration equation to relate the velocity of the crossbar to its acceleration and Newton's 2nd law to express the acceleration of the crossbar in terms of the magnetic force acting on it. We can determine the direction of motion of the crossbar using a right-hand rule or, equivalently, by applying $\vec{F} = I\vec{\ell} \times \vec{B}$. We can find the minimum field B necessary to start the bar moving by applying a condition for static equilibrium to it.

(*a*) Using a constant-acceleration equation, express the velocity of the bar as a function of its acceleration and the time it has been in motion:

$$v = v_0 + at$$

or, because $v_0 = 0$,

$$v = at$$

Use Newton's 2nd law to express the acceleration of the rail:

$$a = \frac{F}{m}$$

where F is the magnitude of the magnetic force acting in the direction of the crossbar's motion.

Substitute to obtain:

$$v = \frac{F}{m}t$$

Express the magnetic force acting on the current-carrying crossbar:

$$F = ILB$$

Substitute to obtain:

$$v = \boxed{\frac{ILB}{m}t}$$

(*b*) Apply to conclude that the magnetic force is to the right and so the motion of the crossbar will also be to the right.

(*c*) Apply $\sum F_x = 0$ to the crossbar:

$$ILB_{\text{min}} - f_{\text{s,max}} = 0$$

or

$$ILB_{\text{min}} - \mu_s mg = 0$$

Solve for B_{min} to obtain:

$$B_{\text{min}} = \boxed{\frac{\mu_s mg}{IL}}$$

[Honors section: chap25]

***121** •••

Picture the Problem Let R_1 = 200 Ω, R_2 = 600 Ω, I_1 and I_2 their currents, and I_3 the current into the capacitor. We can apply Kirchhoff's loop rule to find the initial battery current I_0 and the battery current I_∞ a long time after the switch is closed. In part (*c*) we can apply both the loop and junction rules to obtain equations that we can use to obtain a linear differential equation with constant coefficients describing the current in the 600-Ω resistor as a function of time. We can solve this differential equation by assuming a solution of a given form, differentiating this assumed solution and substituting it and its derivative in the differential equation. Equating coefficients, requiring the solution to hold for all values of the assumed constants, and invoking an initial condition will allow us to find the constants in the assumed solution.

(*a*) Apply Kirchhoff's loop rule to the circuit at the instant the switch is closed:

$$\mathcal{E} - (200\,\Omega)I_0 - V_{C0} = 0$$

Because the capacitor is initially uncharged:

$$V_{C0} = 0$$

Solve for and evaluate I_0:

$$I_0 = \frac{\mathcal{E}}{200\,\Omega} = \frac{50\,\text{V}}{200\,\Omega} = \boxed{0.250\,\text{A}}$$

(*b*) Apply Kirchhoff's loop rule to the circuit after a long time has passed:

$$50\,\text{V} - (200\,\Omega)I_\infty - (600\,\Omega)I_\infty = 0$$

Solve for I_∞ to obtain:

$$I_\infty = \frac{50\,\text{V}}{800\,\Omega} = \boxed{62.5\,\text{mA}}$$