7. $\boxed{\text{SSM}}$ ***REASONING*** The minimum length *d* of the rails is the speed *v* of the rod times the time *t*, or $d = vt$. We can obtain the speed from the expression for the motional emf given in Equation 22.1. Solving this equation for the speed gives $v = \frac{\xi}{BL}$, where ξ is the motional emf, *B* is the magnitude of the magnetic field, and *L* is the length of the rod. Thus, the length of the rails is $d = vt = \left(\frac{\xi}{BL}\right)t$. While we have no value for the motional emf, we do know that the bulb dissipates a power of $P = 60.0$ W, and has a resistance of $R = 240\ \Omega$. Power is related to the emf and the resistance according to $P = \frac{\xi^2}{R}$ (Equation 20.6c), which can be solved to show that $\xi = \sqrt{PR}$. Substituting this expression into the equation for *d* gives

$$d = \left(\frac{\xi}{BL}\right)t = \left(\frac{\sqrt{PR}}{BL}\right)t$$

SOLUTION Using the above expression for the minimum necessary length of the rails, we find that

$$d = \left(\frac{\sqrt{PR}}{BL}\right)t = \left[\frac{\sqrt{(60.0\ \text{W})(240\ \Omega)}}{(0.40\ \text{T})(0.60\ \text{m})}\right](0.50\ \text{s}) = \boxed{250\ \text{m}}$$

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46. ***REASONING AND SOLUTION*** The magnetic field at the center of a current loop of radius R is given by $B = \mu_0 I/(2R)$, so that

$$R = \frac{\mu_0 I}{2B} = \frac{\left(4\pi \times 10^{-7}\,\text{T}\cdot\text{m/A}\right)(12\text{ A})}{2\left(1.8\times 10^{-4}\text{ T}\right)} = \boxed{4.2\times 10^{-2}\text{ m}}$$

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47. ***REASONING AND SOLUTION*** The magnitude B of the magnetic field at a distance r from a long straight wire carrying a current I is $B = \mu_0 I/(2\pi r)$. Thus, the distance is

$$r = \frac{\mu_0 I}{2\pi B} = \frac{\left(4\pi\times10^{-7}\ \mathrm{T\cdot m/A}\right)\left(48\ \mathrm{A}\right)}{2\pi\left(8.0\times10^{-5}\ \mathrm{T}\right)} = \boxed{0.12\ \mathrm{m}} \qquad (21.5)$$

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48. ***REASONING*** The magnitude B of the magnetic field in the interior of a solenoid that has a length much greater than its diameter is given by $B = \mu_0 n I$ (Equation 21.7), where $\mu_0 = 4\pi \times 10^{-7}\ \text{T}\cdot\text{m/A}$ is the permeability of free space, n is the number of turns per meter of the solenoid's length, and I is the current in the wire of the solenoid. Since B and I are given, we can solve Equation 21.7 for n.

SOLUTION Solving Equation 21.7 for n, we find that the number of turns per meter of length is

$$n = \frac{B}{\mu_0 I} = \frac{7.0\ \text{T}}{\left(4\pi \times 10^{-7}\ \text{T}\cdot\text{m/A}\right)\left(2.0 \times 10^{2}\ \text{A}\right)} = \boxed{2.8 \times 10^{4}\ \text{turns/m}}$$

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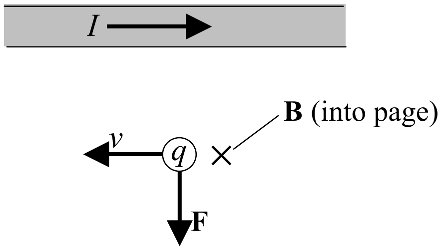
50. ***REASONING*** The magnitude of the magnetic force acting on the particle is $F = |q_0| vB \sin\theta$ (Equation 21.1), where $|q_0|$ and v are the charge magnitude and speed of the particle, respectively, B is the magnitude of the magnetic field, and θ is the angle between the particle's velocity and the magnetic field. The magnetic field is produced by a very long, straight wire, so its value is given by Equation 21.5 as $B = \mu_0 I/(2\pi r)$. By combining these two relations, we can determine the magnitude of the magnetic force.

SOLUTION The direction of the magnetic field **B** produced by the current-carrying wire can be found by using Right-Hand Rule No. 2. At the location of the charge, this field points perpendicularly into the page, as shown in the drawing. Since the direction of the particle's velocity is perpendicular to the magnetic field, $\theta = 90.0°$. Substituting $B = \mu_0 I/(2\pi r)$ into $F = |q_0| vB \sin\theta$ gives



$$F = |q_0| vB\sin\theta = |q_0| v\left(\frac{\mu_0 I}{2\pi r}\right)\sin\theta$$

$$= \frac{(6.00 \times 10^{-6}\ \text{C})(7.50 \times 10^{4}\ \text{m/s})(4\pi\times10^{-7}\ \text{T}\cdot\text{m/A})(67.0\ \text{A})\sin 90.0°}{2\pi(5.00 \times 10^{-2}\ \text{m})} = \boxed{1.21 \times 10^{-4}\ \text{N}}$$

The direction of the magnetic force **F** exerted on the particle can be determined by using Right-Hand Rule No. 1. This direction, which is shown in the drawing, is

$\boxed{\text{perpendicular to the wire and is directed away from it}}$.

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51. **SSM** ***REASONING*** The magnitude of the magnetic field at the center of a circular loop of current is given by Equation 21.6 as $B = N\mu_0 I/(2R)$, where N is the number of turns, μ_0 is the permeability of free space, I is the current, and R is the radius of the loop. The field is perpendicular to the plane of the loop. Magnetic fields are vectors, and here we have two fields, each perpendicular to the plane of the loop producing it. Therefore, the two field vectors are perpendicular, and we must add them as vectors to get the net field. Since they are perpendicular, we can use the Pythagorean theorem to calculate the magnitude of the net field.

SOLUTION Using Equation 21.6 and the Pythagorean theorem, we find that the magnitude of the net magnetic field at the common center of the two loops is

$$B_{\text{net}} = \sqrt{\left(\frac{N\mu_0 I}{2R}\right)^2 + \left(\frac{N\mu_0 I}{2R}\right)^2} = \sqrt{2}\left(\frac{N\mu_0 I}{2R}\right)$$

$$= \frac{\sqrt{2}(1)\left(4\pi\times10^{-7}\ \text{T}\cdot\text{m/A}\right)(1.7\ \text{A})}{2(0.040\ \text{m})} = \boxed{3.8\times10^{-5}\ \text{T}}$$

53. ***REASONING*** The two rods attract each other because they each carry a current I in the same direction. The bottom rod floats because it is in equilibrium. The two forces that act on the bottom rod are the downward force of gravity $m\mathbf{g}$ and the upward magnetic force of attraction to the upper rod. If the two rods are a distance s apart, the magnetic field generated by the top rod at the location of the bottom rod is (see Equation 21.5) $B = \mu_0 I/(2\pi s)$. According to Equation 21.3, the magnetic force exerted on the bottom rod is $F = ILB\sin\theta = \mu_0 I^2 L \sin\theta/(2\pi s)$, where θ is the angle between the magnetic field at the location of the bottom rod and the direction of the current in the bottom rod. Since the rods are parallel, the magnetic field is perpendicular to the direction of the current (RHR-2), and $\theta = 90.0°$, so that $\sin\theta = 1.0$.

SOLUTION Taking upward as the positive direction, the net force on the bottom rod is

$$\frac{\mu_0 I^2 L \sin\theta}{2\pi s} - mg = 0$$

Solving for I, we find

$$I = \sqrt{\frac{2\pi mgs}{\mu_0 L}} = \sqrt{\frac{2\pi(0.073\ \text{kg})(9.80\ \text{m/s}^2)(8.2\times10^{-3}\ \text{m})}{(4\pi\times10^{-7}\ \text{T}\cdot\text{m/A})(0.85\ \text{m})}} = \boxed{190\ \text{A}}$$

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54. ***REASONING AND SOLUTION*** The net force on the wire loop is a sum of the forces on each segment of the loop. The forces on the two segments perpendicular to the long straight wire cancel each other out. The net force on the loop is therefore the sum of the forces on the parallel segments (near and far). These are

$$F_{\text{near}} = \mu_o I_1 I_2 L/(2\pi d_{\text{near}}) = \mu_0(12\text{ A})(25\text{ A})(0.50\text{ m})/[2\pi\,(0.11\text{ m})] = 2.7 \times 10^{-4}\text{ N}$$

$$F_{\text{far}} = \mu_o I_1 I_2 L/(2\pi d_{\text{far}}) = \mu_0(12\text{ A})(25\text{ A})(0.50\text{ m})/[2\pi\,(0.26\text{ m})] = 1.2 \times 10^{-4}\text{ N}$$

Note: F_{near} is a force of attraction, while F_{far} is a repulsive one. The magnitude of the net force is, therefore,

$$F = F_{\text{near}} - F_{\text{far}} = 2.7 \times 10^{-4}\text{ N} - 1.2 \times 10^{-4}\text{ N} = \boxed{1.5\times10^{-4}\text{ N}}$$

1. ***REASONING AND SOLUTION*** Using Equation 22.1, we find

$$\xi = vBL = (220\text{ m/s})(5.0 \times 10^{-6}\text{ T})(59\text{ m}) = \boxed{0.065\text{ V}}$$

6. ***REASONING*** The average power $\overline{P}$ delivered by the hand is given by $\overline{P} = W/t$, where W is the work done by the hand and t is the time interval during which the work is done. The work done by the hand is equal to the product of the magnitude F_{hand} of the force exerted by the hand, the magnitude x of the rod's displacement, and the cosine of the angle between the force and the displacement.

Since the rod moves to the right at a constant speed, it has no acceleration and is, therefore, in equilibrium. Thus, the force exerted by the hand must be equal to the magnitude F of the magnetic force that the current exerts on the rod. The magnitude of the magnetic force is given by $F = ILB\sin\theta$ (Equation 21.3), where I is the current, L is the length of the moving rod, B is the magnitude of the magnetic field, and θ is the angle between the direction of the current and that of the magnetic field.

SOLUTION The average power $\overline{P}$ delivered by the hand is

$$\overline{P} = \frac{W}{t} \tag{6.10a}$$

The work W done by the hand in Figure 22.5 is given by $W = F_{\text{hand}} x \cos\theta'$ (Equation 6.1). In this equation F_{hand} is the magnitude of the force that the hand exerts on the rod, x is the magnitude of the rod's displacement, and θ' is the angle between the force and the displacement. The force and displacement point in the same direction, so $\theta' = 0°$. Since the magnitude of the force exerted by the hand equals the magnitude F of the magnetic force, $F_{\text{hand}} = F$. Substituting $W = F_{\text{hand}} x \cos 0°$ into Equation 6.10a and using the fact that
$F_{\text{hand}} = F$, we have that

$$\overline{P} = \frac{W}{t} = \frac{F_{\text{hand}} x \cos 0°}{t} = \frac{F x \cos 0°}{t} \tag{1}$$

The magnitude F of the magnetic force is given by $F = ILB\sin\theta$ (Equation 21.3). In this case, the current and magnetic field are perpendicular to each other, so $\theta = 90°$ (see Figure 22.5). Substituting this expression for F into Equation 1 gives

$$\overline{P} = \frac{F x \cos 0°}{t} = \frac{(ILB\sin 90°) x \cos 0°}{t} \tag{2}$$

The term x/t in Equation 2 is the speed v of the rod. Thus, the average power delivered by the hand is

$$\overline{P} = \frac{(ILB\sin 90°) x \cos 0°}{t} = (ILB\sin 90°) v \cos 0°$$

$$= (0.040\text{ A})(0.90\text{ m})(1.2\text{ T})\sin 90°(3.5\text{ m/s})\cos 0° = \boxed{0.15\text{ W}}$$