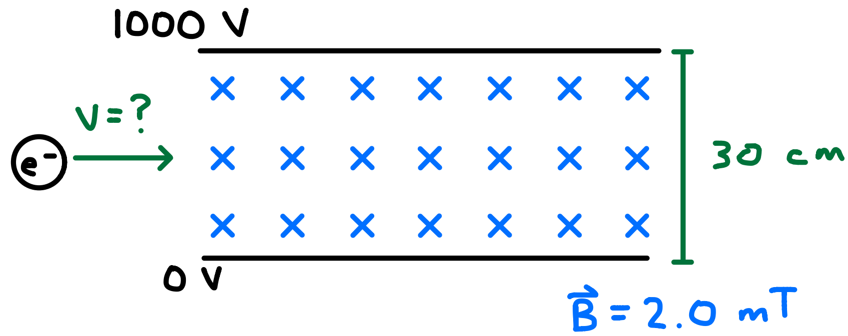
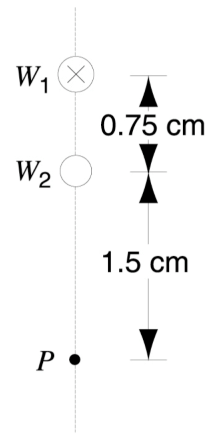
An electron enters a region with both an electric field and a magnetic field. What must be the speed of the electrons if they are to pass through undeflected?



$1.67 \times 10^6 \frac{m}{s}$

Two long straight parallel wires, separated by 0.75cm, are perpendicular to the plane of the page as shown. Wire *W_1* carries a current of 6.6 A into the page. What must be the current (magnitude and direction) in wire *W_2* for the resultant magnetic field at point *P* to be zero?

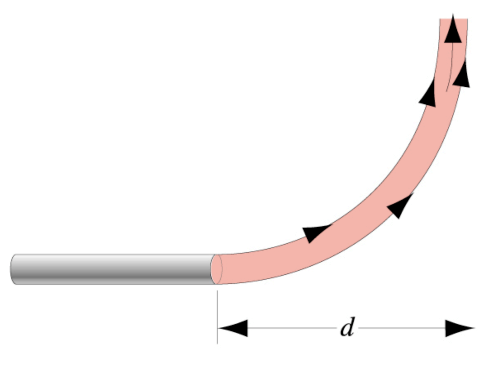


4.4 A OUT OF THE PAGE

Emerging from a thin-foil “window” at the end of an accelerator tube, you have a beam of electrons, each with mass *m*, charge *e* and kinetic energy *K*. There is a metal plate a distance *d* from this window and at right angles to the direction of the emerging beam, as shown.

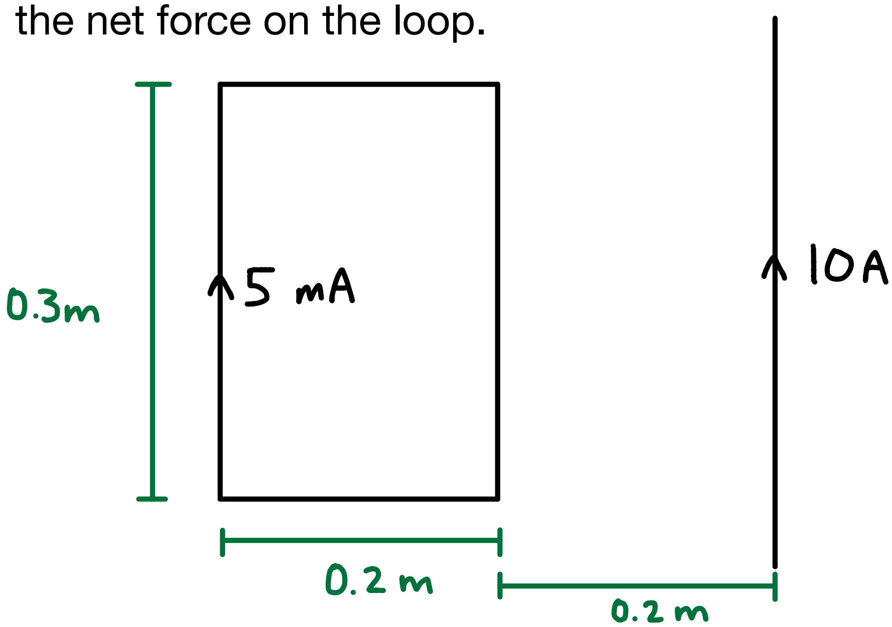
a) Show that, in order to prevent the beam of electrons from hitting the plate, we must apply a magnetic field of strength B such that $B \geq \sqrt{\dfrac{2mK}{e^2 d^2}}$

b) How is the magnetic field oriented?



b) OUT OF THE PAGE

A long wire is positioned in the same plane as a loop. Determine the net force on the loop.



7.5×10^{-9} N LEFT

You are considering a new design for an electric train. The engine is driven by the force due to the vertical component of the Earth's magnetic field on a conducting axle. Current is passed down one rail, onto a conducting wheel, through the axle, through the other conducting wheel, and then back to the source via the other rail.

a) What current is needed to provide a modest 10 kN force? (Take the vertical component of the Earth's magnetic field to be 10 μT and the length of the axle to be 3.0 m.)

b) How much power would be lost for each ohm of resistance in the rails?

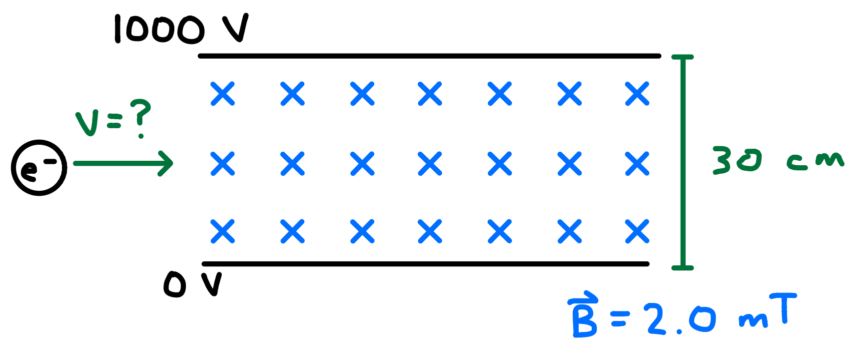
c) Is such a train feasible, totally unrealistic, or just marginally realistic?

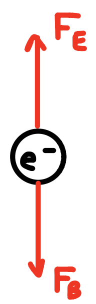
a) 3.33×10^{8} A

b) $1.11 \times 10^{17} \frac{W}{\Omega}$

c) TOTALLY UNREALISTIC

An electron enters a region with both an electric field and a magnetic field. What must be the speed of the electrons if they are to pass through undeflected?





$$F_B = F_E$$

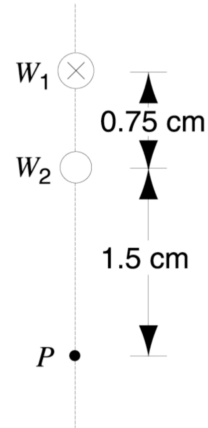
$$qvB = qE$$

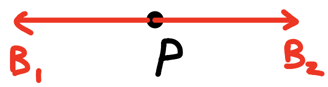
$$vB = \frac{\Delta V}{d}$$

$$v = \frac{\Delta V}{dB} = \frac{1000}{(0.3)(0.002)}$$

$$= \boxed{1.67 \times 10^{6} \ \frac{m}{s}}$$

Two long straight parallel wires, separated by 0.75cm, are perpendicular to the plane of the page as shown. Wire *W*_1 carries a current of 6.6 A into the page. What must be the current (magnitude and direction) in wire *W*_2 for the resultant magnetic field at point *P* to be zero?





$$B_1 = B_2$$

$$\frac{\mu_0 I_1}{2\pi d_1} = \frac{\mu_0 I_2}{2\pi d_2}$$

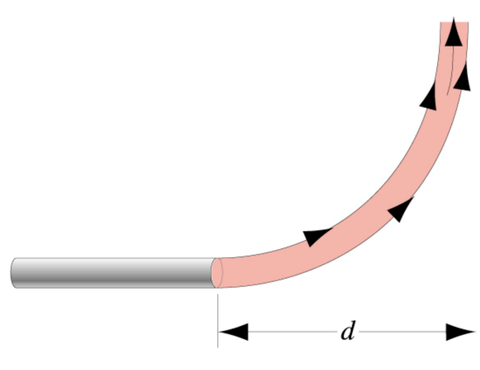
$$I_2 = \frac{d_2}{d_1} I_1 = \frac{0.0150}{0.0225}(6.6)$$

$$= \boxed{4.4\ \text{A OUT OF THE PAGE}}$$

Emerging from a thin-foil "window" at the end of an accelerator tube, you have a beam of electrons, each with mass *m*, charge *e* and kinetic energy *K*. There is a metal plate a distance *d* from this window and at right angles to the direction of the emerging beam, as shown.

a) Show that, in order to prevent the beam of electrons from hitting the plate, we must apply a magnetic field of strength B such that $B \geq \sqrt{\frac{2mK}{e^2 d^2}}$

b) How is the magnetic field oriented?



a)

$F_c = m a_c$

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

$K = \frac{1}{2} m v^2$

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

$q \cancel{v} B = m \frac{v^{\cancel{2}}}{R}$

$B = \frac{mv}{qR}$

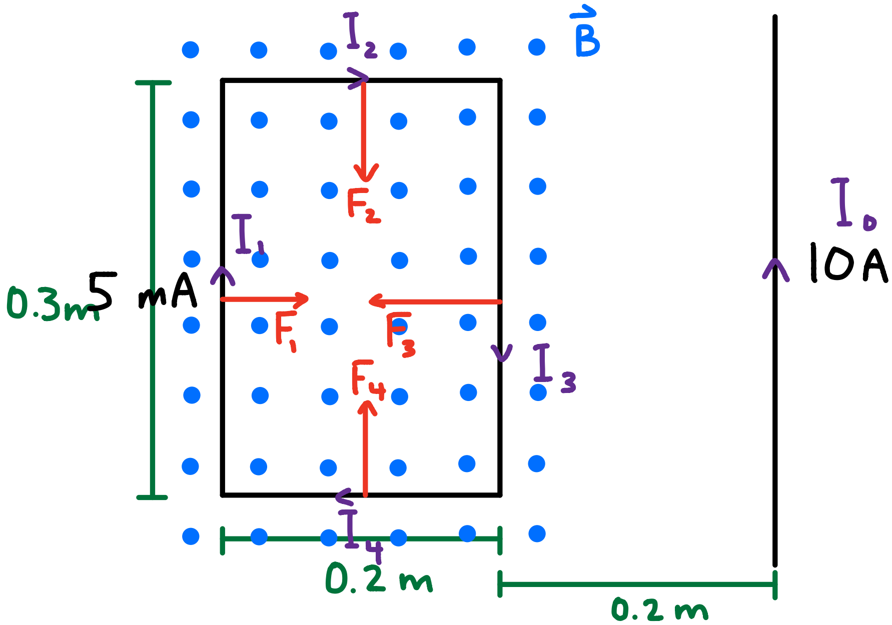
$= \frac{m}{qR} \sqrt{\frac{2K}{m}}$

$= \sqrt{\frac{2mK}{q^2 R^2}}$

IF $R \leq d$, $B \geq \sqrt{\frac{2mK}{e^2 d^2}}$ //

b) OUT OF THE PAGE

A long wire is positioned in the same plane as a loop. Determine the net force on the loop.



$$\vec{F}_{NET} = \vec{F}_1 + \vec{F}_2 + \vec{F}_3 + \vec{F}_4$$

$|F_2| = |F_4|$ BY SYMMETRY

$$= F_3 - F_1$$

$$= lIB_3 - lIB_1$$

$$= lI\frac{\mu_0 I_0}{2\pi d_3} - lI\frac{\mu_0 I_0}{2\pi d_1}$$

$$= \frac{lI\mu_0 I_0}{2\pi}\left(\frac{1}{d_3} - \frac{1}{d_1}\right)$$

$$= \frac{(0.3)(0.005)(4\pi \times 10^{-7})(10)}{2\pi}\left(\frac{1}{0.2} - \frac{1}{0.4}\right)$$

$$= \boxed{7.5 \times 10^{-9} \text{ N LEFT}}$$

You are considering a new design for an electric train. The engine is driven by the force due to the vertical component of the Earth's magnetic field on a conducting axle. Current is passed down one rail, onto a conducting wheel, through the axle, through the other conducting wheel, and then back to the source via the other rail.

a) What current is needed to provide a modest 10 kN force? (Take the vertical component of the Earth's magnetic field to be 10 μT and the length of the axle to be 3.0 m.)

b) How much power would be lost for each ohm of resistance in the rails?

c) Is such a train feasible, totally unrealistic, or just marginally realistic?

a)

$$F_B = \ell I B$$

$$I = \frac{F_B}{\ell B} = \frac{10 \times 10^3}{(3.0)(10 \times 10^{-6})} = \boxed{3.33 \times 10^8 \text{ A}}$$

b)

$$P = I^2 R$$

$$\frac{P}{R} = I^2 = (3.\overline{33} \times 10^8)^2 = \boxed{1.11 \times 10^{17} \ \frac{\text{W}}{\Omega}}$$

c) This is a humungous amount of power dissipated in the rails. For a typical conducting material, the rails would melt and be liquefied before the train could move much at all. So this is totally unrealistic!