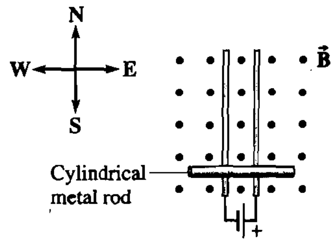
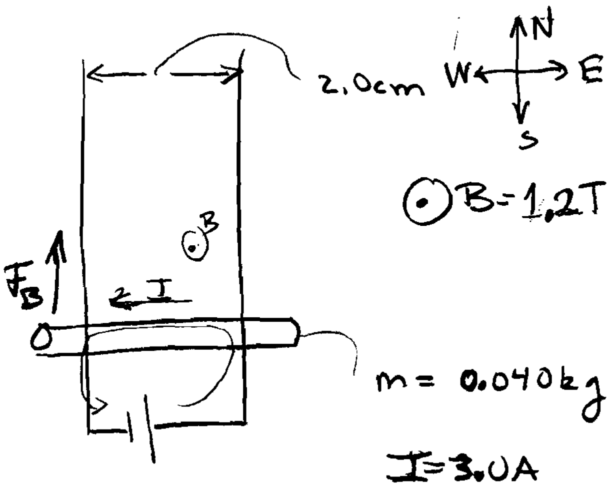
19.

46. Parallel conducting tracks, separated by 2.0 cm, run north and south. There is a uniform magnetic field of 1.2 T pointing upward (out of the page). A 0.040-kg cylindrical metal rod is placed across the tracks and a battery is connected between the tracks, with its positive terminal connected to the east track. If the current through the rod is 3.0 A, find the magnitude and direction of the magnetic force on the rod.





$\odot$ B = 1.2 T

m = 0.040 kg

I = 3.0 A

$\theta = 90^\circ$

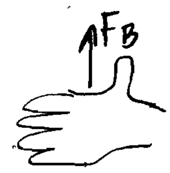
$F_B = I(L \times B)$

$= I L B \sin\theta$

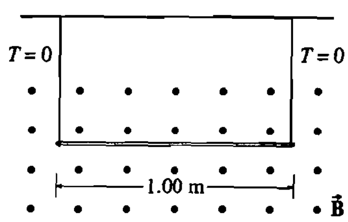
$= (3.0\,A)(0.02\,m)(1.2\,T)\sin 90^\circ$

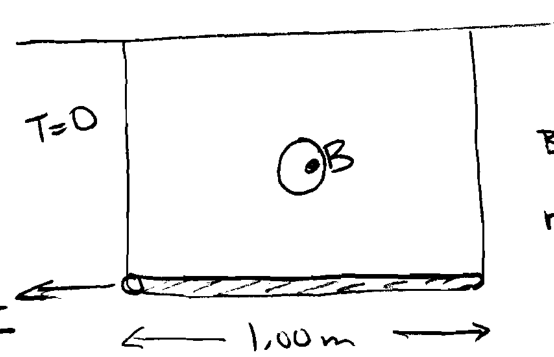
$F_B = 0.072\,N$ North

Force is N due to I ← $\odot$ B



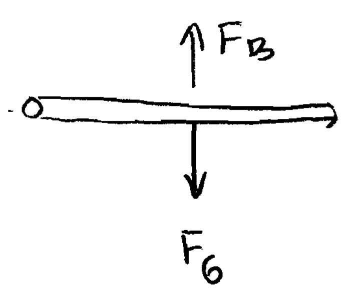
48. A straight, stiff wire of length 1.00 m and mass 25 g is suspended in a magnetic field $B = 0.75$ T. The wire is connected to an emf. How much current must flow in the wire and in what direction so that the wire is suspended and the tension in the supporting wires is zero?





B = 0.75 T

m = 25 g

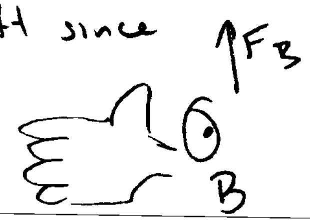


$F_B = F_g$

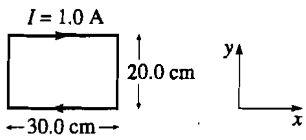
$I L B \sin\theta = mg$ (sin θ = 1)

$I = \frac{mg}{LB} = \frac{(0.025\,kg)\,9.8\,m/s^2}{(1.00\,m)(0.75\,T)} =$ **0.33 A = I Left**

I must point to the left since

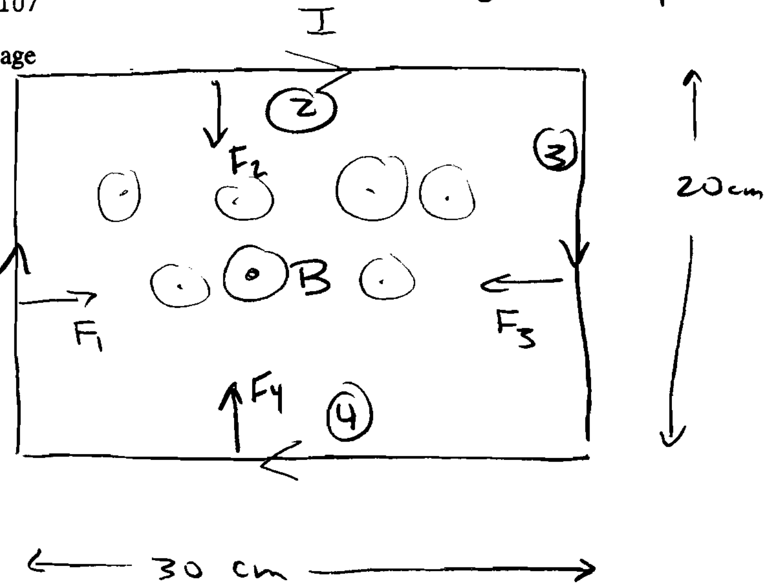


19. 49. A 20.0 cm × 30.0 cm rectangular loop of wire carries 1.0 A of current clockwise around the loop. (a) Find the magnetic force on each side of the loop if the magnetic field is 2.5 T out of the page (b) What is the net magnetic force on the loop?



Problems 49, 50, and 107

$\theta = 90°$ for each side of the loop



$B = 2.5\,T$

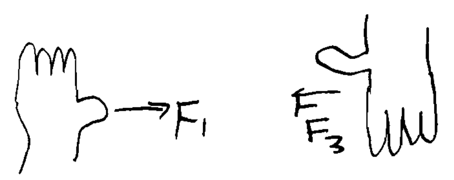
$I = 1.0\,A$

$F_1 = ILB\sin\theta$ ($\sin\theta = 1$)

$= (2.5\,T)(0.20\,m)(1.0\,A)$

$= 0.5\,N$

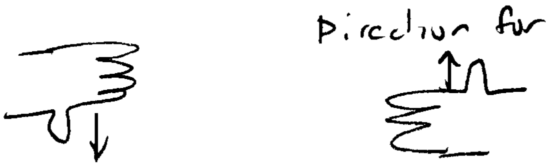
$|F_3| = |F_1| = 0.5\,N$



$|F_2| = |F_4| = ILB = (1.0\,A)(0.30\,m)(2.5\,T) = 0.75\,N$

Direction for F_2 =

Direction for F_4

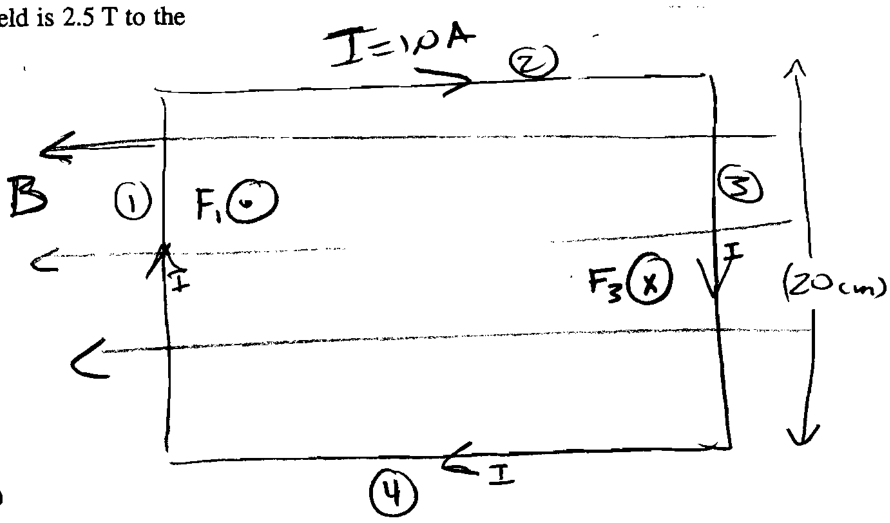


All four forces point towards the center of the loop.

b) The net force on the loop is zero
since F_1 is equal and opposite F_3 They cancel
and F_2 is equal and opposite F_4 They cancel

19.

50. Repeat Problem 49 if the magnetic field is 2.5 T to the left (in the $-x$-direction).



$F_2 = F_4 = 0$
since $\theta = 0, 180$
$\sin 0 = 0$

$|F_3| = |F_1| = ILB = (10\,A)(0.2\,m)(2.5\,T) = 0.5\,N$

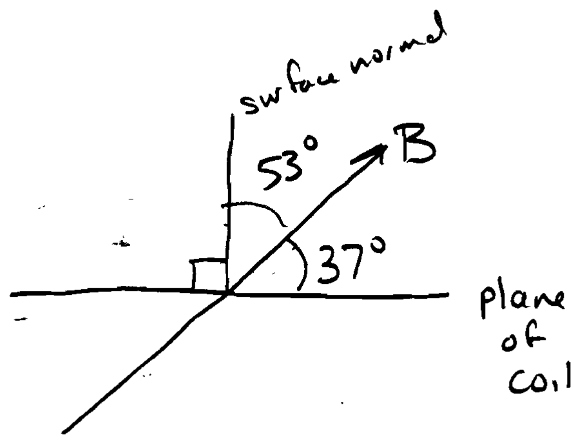
F_1 points out of the page

F_3 points into the page

$F_{net} = 0$ since $F_1 = -F_3$

55. A square loop of wire of side 3.0 cm carries 3.0 A of current. A uniform magnetic field of magnitude 0.67 T makes an angle of 37° with the plane of the loop.

(a) What is the magnitude of the torque on the loop?
(b) What is the net magnetic force on the loop?



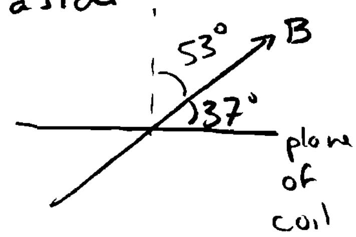
a) $\tau = NIAB\sin\theta$

Square coil 3 cm on a side

$N = 1$

$I = 3.0\,A$

$B = 0.67\,T$



$A = (0.03\,m)(0.03\,m) = 9\times10^{-4}\,m^2$

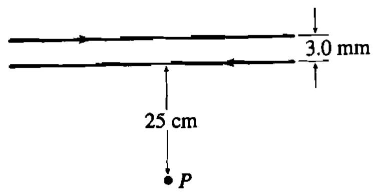
θ = angle between B and a perpendicular to the loop
$= 90 - 37° = 53°$

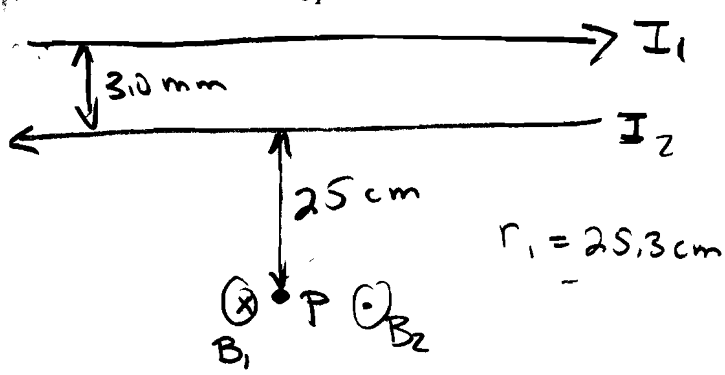
$\tau = (3.0\,A)(9\times10^{-4}\,m^2)(0.67\,T)\sin 53°$
$= 1.44\times10^{-3}\,N\cdot m$

b) $F_{net} = 0$

Force on one side is equal + opposite to the other.

19. 61. Two wires each carry 10.0 A of current (in *opposite directions*) and are 3.0 mm apart. Calculate the magnetic field 25 cm away at point *P*, in the plane of the wires.





At point P, B_1 is into the page and B_2 is out of the page, since 25cm >> 3mm They will essentially cancel

$$B = \frac{\mu_0 I}{2\pi r}$$

$$B_1 = \frac{4\pi \times 10^{-7}\,\frac{mT}{A}\,(10.0A)}{2\pi(.253\,m)}$$

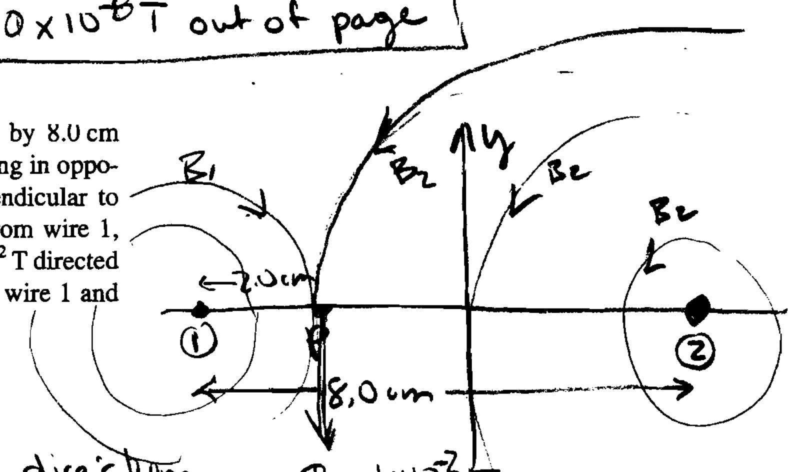
$$B_2 = \frac{4\pi \times 10^{-7}\,\frac{mT}{A}\,10.0A}{2\pi(0.25m)}$$

$B_1 = 7.91 \times 10^{-6}$ T into page

$B_2 = 8 \times 10^{-6}$ T out of page

$B = B_2 - B_1 = 9.0 \times 10^{-8}$ T out of page

71. Two long straight parallel wires separated by 8.0 cm carry currents of equal magnitude but heading in opposite directions. The wires are shown perpendicular to the plane of this page. Point *P* is 2.0 cm from wire 1, and the magnetic field at point *P* is 1.0×10^{-2} T directed in the $-y$-direction. Calculate the current in wire 1 and its direction.



$|I_1| = |I_2|$ but opposite directions

(If) I_1 points out of the page, B is in the wrong direction ccw

so I_1 points into the page so I_2 must be out of the page and it's B will also point down at P

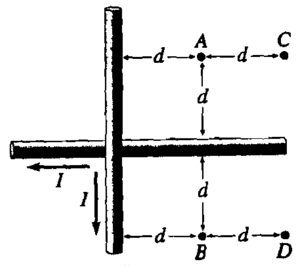
$B_1 = \frac{\mu_0 I_1}{2\pi r_1}$ and $B_2 = \frac{\mu_0 I_2}{2\pi r_2}$ but $I_1 = I_2$

$$B = B_1 + B_2 = \frac{\mu_0 I}{2\pi r_1} + \frac{\mu_0 I}{2\pi r_2} = \frac{\mu_0 I}{2\pi}\left(\frac{r_2 + r_1}{r_1 r_2}\right)$$

$$I_1 = \frac{2\pi B}{\mu_0}\left(\frac{r_1 r_2}{r_1 + r_2}\right) = \frac{2\pi(1\times 10^{-2}T)}{4\pi \times 10^{-7}\,\frac{Tm}{A}}\left(\frac{(0.06\,m)(0.02m)}{0.08m}\right) = 750A$$

Into page

19 67. Two long straight wires carry the same amount of current in the directions indicated. The wires cross each other in the plane of the paper. Rank points A, B, C, and D in order of decreasing field strength.

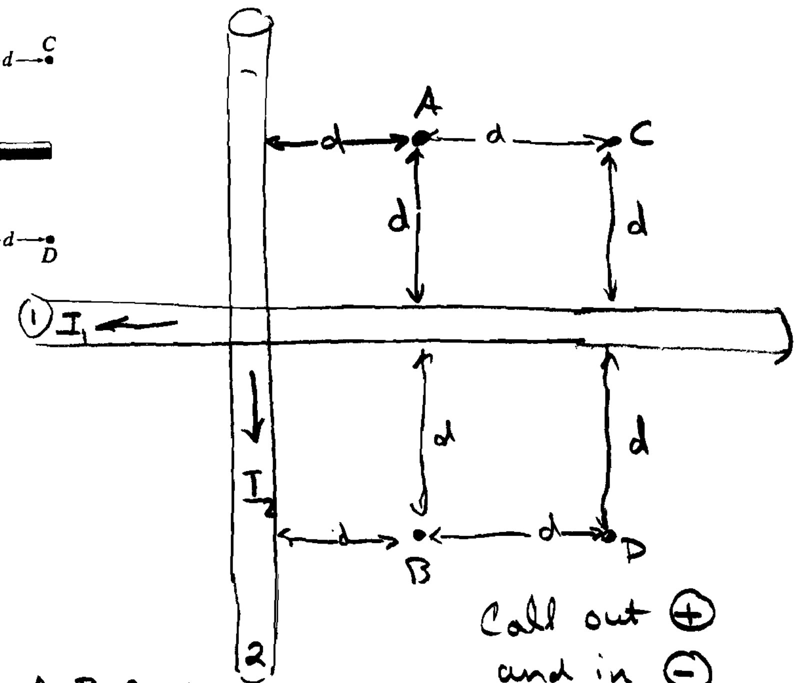


Call horizontal wire 1

Call vertical wire 2

B_1 is into the page at A and C

B_1 is out of the page at B and D



Call out ⊕ and in ⊖

B_2 is out of the page at A, B, C and D

Point A $\quad B = B_1 + B_2 = -\frac{\mu_0 I}{2\pi d} + \frac{\mu_0 I}{2\pi d} = 0$

Point C $\quad B = B_1 + B_2 = -\frac{\mu_0 I}{2\pi d} + \frac{\mu_0 I}{2\pi 2d} = -\frac{\mu_0 I}{4\pi d} = -\frac{1}{2}\left(\frac{\mu_0 I}{2\pi d}\right)$

point B $\quad B = B_1 + B_2$ same direction

$$= \frac{\mu_0 I}{2\pi d} + \frac{\mu_0 I}{2\pi d} = \frac{2\mu_0 I}{2\pi d} = 2\left(\frac{\mu_0 I}{2\pi d}\right)$$

point D $\quad B = \frac{\mu_0 I}{2\pi d} + \frac{\mu_0 I}{2\pi 2d} = \frac{3\mu_0 I}{4\pi d} = \frac{3}{2}\left(\frac{\mu_0 I}{2\pi d}\right)$

point B is strongest
D
C
A is weakest

Qualitatively we expect points B and D to have larger B than A and C since the fields due to both wires are in the same direction

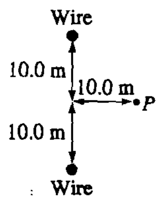
B should be strongest since it is closer to both wires

D should be next

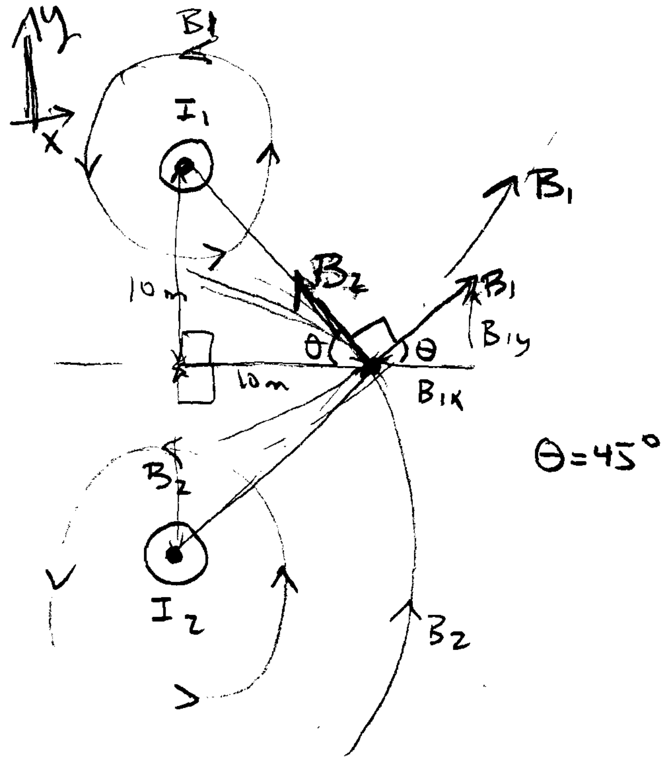
A is obviously zero since fields cancel so C is bigger than A.

19.

99. Two conducting wires perpendicular to the page are shown in cross section as gray dots in the figure. They each carry 10.0 A out of the page. What is the magnetic field at point P?



B is tangent to field line so B ⊥ to radius



$$|B_1| = |B_2| = \frac{\mu_0 I}{2\pi r}$$

$$r = \sqrt{(10\text{m})^2 + (10\text{m})^2}$$

$$= 14.1\text{m}$$

$$|B_1| = \frac{\left(4\pi\times10^{-7}\frac{\text{Tm}}{\text{A}}\right)(10\text{ A})}{2\pi\,(14.1\text{m})}$$

$$= 1.42\times10^{-7}\text{ T} = |B_2|$$

$B_{1x} = B_1 \cos\theta = 1.42\times10^{-7}\text{T} \cos 45 = +1\times10^{-7}\text{ T}$

$B_{1y} = B_1 \sin\theta = +1\times10^{-7}\text{T}$

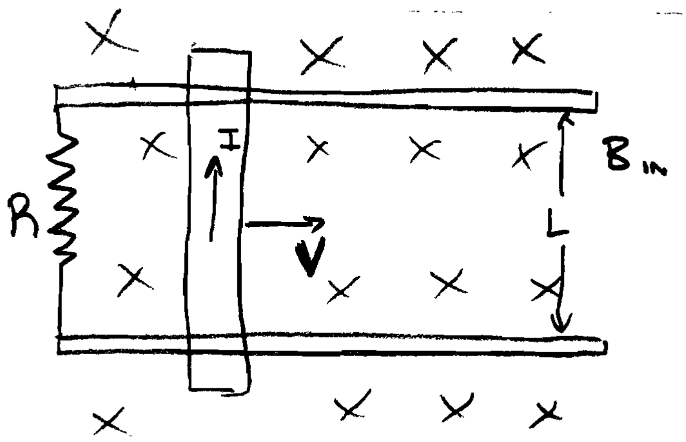
$B_{2x} = -1\times10^{-7}\text{T}$

$B_{2y} = +1\times10^{-7}\text{ T}$

x components cancel
y components add

$B = B_{1y} + B_{2y} = 2\times10^{-7}\text{T}$ +y-direction

20.1 A metal rod of length L moves to the right at a speed v
a) What is the current in the rod in terms of v, B, L, and R? (b) In what direction does the current flow? (c) What is the direction of the magnetic force on the rod? (d) What is the magnitude of the magnetic force in terms of v, B, L and R?



a) because the rod is moving, we have an induced EMF

$\mathcal{E} = vBL$

$I = \frac{\mathcal{E}}{R} = \frac{vBL}{R}$

b) $v \times B$ ↑ F_B

F_B on ⊕ ↑

F_B on ⊖ ↓

current is opposite ⊖ or ↑ I (ccw)

c) $F = I(L \times B)$

⊗ ↑I ⊗ ← F

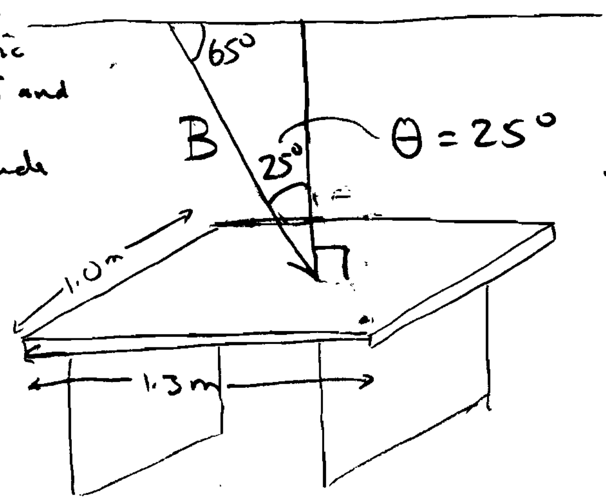
Force is opposite v or Left

d) $F_B = ILB\sin\theta$ (sin θ = 1), θ = 90

$= ILB$

$= \frac{vBL}{R}(LB) = \boxed{\frac{vB^2L^2}{R} = F_B}$

20.13 A horizontal desk measures 1.3 m × 1.0 m. If the earth's magnetic field has a magnitude of 0.44 mT and is directed 65° below the horizontal, what is the magnitude of the flux through the desk surface?



B = 0.44 mT

θ = angle between B and a line ⊥ to surface

$\Phi = BA\sin\theta$

$A = lw = (1.0\,m)(1.3\,m) = 1.3\,m^2$

$\theta = 90° - 65° = 25$

$\Phi = (0.44\times10^{-3}\,T)(1.3\,m^2)\sin 25$

$= 5.18\times10^{-4}\,Tm^2$

or $= 5.18\times10^{-4}\,Wb$