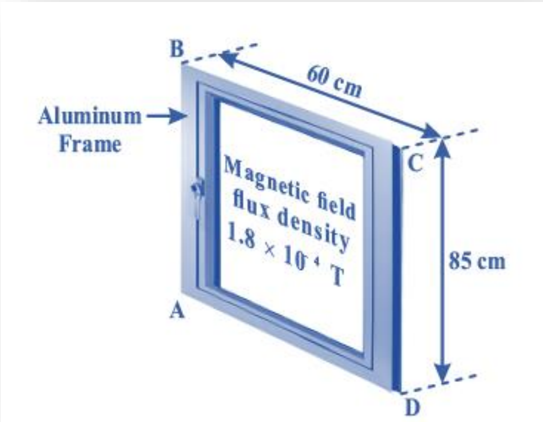
1. An aluminum window has a width of 60 cm and a length of 85 cm, as shown in the figure.



(a) When the window is closed, the magnetic flux density is 1.8×10^{-4} normal to the window.

(b) Calculate the magnetic flux through the window.

Data:	SOLUTION:
$W = 60\text{ cm} = 60 \times 10^{-2}\ m$ $L = 85\text{ cm} = 85 \times 10^{-2}\ m$ $A = 60 \times 10^{-2} \times 85 \times 10^{-2}$ $A = 0.51\ m^2$ $B = 1.8 \times 10^{-4}\ T$ To determine $\Phi_m = ?$	$\Phi = \vec{B} \cdot \vec{A}$ $\Phi = B\ A\ \cos\theta$ $\Phi_{max} = (1.8 \times 10^{-4})\ (0.51)\ \cos 0^0$ $\Phi_{max} = (1.8 \times 10^{-4})\ (0.51)\ (1)$ $\Phi_{max} = 9.18 \times 10^{-5}\ Wb$

2. The poles of a horseshoe magnet measure 8 cm x 3.2cm. The magnetic flux density between the magnet poles is 80 mT. Outside of the magnet, the magnetic flux density is zero. Calculate the magnetic flux density between the poles of a magnet.

Data:	SOLUTION:
$A = 8\text{ cm} \times 3.2\text{ cm}$ $A = 8 \times 10^{-2} \times 3.2 \times 10^{-2}$ $A = 2.56 \times 10^{-3}\ m^2$ $B = 80\ mT$ $B = 80 \times 10^{-3}\ T$ To determine $\Phi_m = ?$	$\Phi = \vec{B} \cdot \vec{A}$ $\Phi = B\ A\ \cos\theta$ $\Phi = B\ A\ \cos 90^0 = B\ A\ \cos(1)$ $\Phi = B\ A$ $\Phi_{max} = (80 \times 10^{-3})\ (2.56 \times 10^{-3})$ $\Phi_{max} = 2.048 \times 10^{-4}\ wb$

3. A wire 1.80 m long carries a current of 13.0 A and makes an angle of 35.0° with a uniform magnetic field of magnitude B = 1.50 T. Calculate the magnetic force on the wire.

Data:	SOLUTION:
$L = 1.8\ m$	$F = B\,I\,L\,\sin\theta$
$I = 13.0\ A$	$F = (1.50)(13.0)(1.8)\sin(35.0^0)$
$B = 1.50\ T$	$F = (1.50)(13.0)(1.8)(0.5735)$
To determine	$F = 20.13\ N$
$F = ?$	

4. A solenoid has length L = 1.23 m and inner diameter d = 3.55 cm, and it carries a current I = 5.57 A. It consists of five close-packed layers, each with 850 turns along length L. What is B at its center?

Data:	SOLUTION:
$L = 1.23\ m$	$B = \mu_0\, n\, I$
$d = 3.55\ cm = 3.55 \times 10^{-2}\ m$	$B = \mu_0 \left(\frac{N}{L}\right) I$
$I = 5.57\ A$	$B = (4\pi \times 10^{-7})\left(\frac{4250}{1.23}\right)(5.57)$
$layers = 5$	$B = \frac{0.029747}{1.23}$
$turns = 850$	$B = 0.0242\ T$
$N = (\text{layers})(turns)$	$B = 24.2 \times 10^{-3}\ T = 24.2\ mT$
$N = (5)(850) = 4250$	
$\mu_0 = 4\pi \times 10^{-7}\ \text{T m A}^{-1}$	
To determine	
$B = ?$	

5. A moving coil galvanometer has a resistance of 50 Ω and it gives full scale deflection at 4 mA current. A voltmeter is made using this galvanometer and a 5 K Ω resistance. Calculate the maximum voltage that can be measured using this voltmeter.

Data:	SOLUTION:
$R_g = 50\ \Omega$	$R_X = \frac{V}{I_g} - R_g$
$I_g = 4\ mA = 4 \times 10^{-3}\ A$	$5000 = \frac{V}{4 \times 10^{-3}} - 50$
$R_X = 5\ k\Omega = 5000\ \Omega$	$(5000 + 50) \times 4 \times 10^{-3} = V$
To determine	$20.2\ Volts = V$
$V = ?$	

6. **Compute the magnitude of the magnetic field of a long, straight wire carrying a current of 1 A at a distance of 1m from it. Compare it with Earth's magnetic field.**

Data:	SOLUTION:
$I = 1\ A$ $r = 1\ m$ $\mu_0 = 4\pi \times 10^{-7}\ T\,m\,A^{-1}$ $B_E = 25\ \mu T = 25 \times 10^{-6}\ T$ To determine $B_W = ?$	$B_W = \frac{\mu_0 I}{2\pi r}$ $B_W = \frac{(4\pi \times 10^{-7})(1)}{2\pi(1)}$ $B_W = \frac{(4\pi \times 10^{-7})}{2\pi}$ $B_W = 2 \times 10^{-7}\ T$ *Compare B_E With Earth's magnetic field* B_E $\frac{B_E}{B_W} = \frac{25 \times 10^{-6}}{2 \times 10^{-7}}$ $\frac{B_E}{B_W} = 125$ $B_E = 125\ B_W$ *The magnetic field of Earth is 125 times that of a wire's magnetic field.*

7. **Find the current in a long straight wire that would produce a magnetic field twice the strength of the Earth's at a distance of 5.0cm from the wire. (Magnetic field of Earth =5.0x10^{-5} T).**

Data:	SOLUTION:
$I = 1\ A$ $r = 5\ cm = 5 \times 10^{-2}\ m$ $B_E = 5 \times 10^{-5}\ T$ $B = 2B_E$ $B = 2 \times 5 \times 10^{-5} = 10 \times 10^{-5}\ T$ $\mu_0 = 4\pi \times 10^{-7}\ T\,m\,A^{-1}$ To determine $I = ?$	$B = \frac{\mu_0 I}{2\pi r}$ $I = \frac{B \times 2\pi r}{\mu_0}$ $I = \frac{10 \times 10^{-5} \times 2(\pi)(5 \times 10^{-2})}{4\pi \times 10^{-7}}$ $I = \frac{5 \times 10^{-6}}{2 \times 10^{-7}}$ $I = 25\ A$

8. What is the flux density at a distance of 0.1 m in air from along straight conductor carrying a current of 6.5 A. Calculate the force per unit length on a similar parallel conductor at a distance of 0.1m from the first and carrying a current of 3 A.

Data:

$r_1 = 0.1\ \mathrm{m}$

$I_1 = 6.5\ \mathrm{A}$

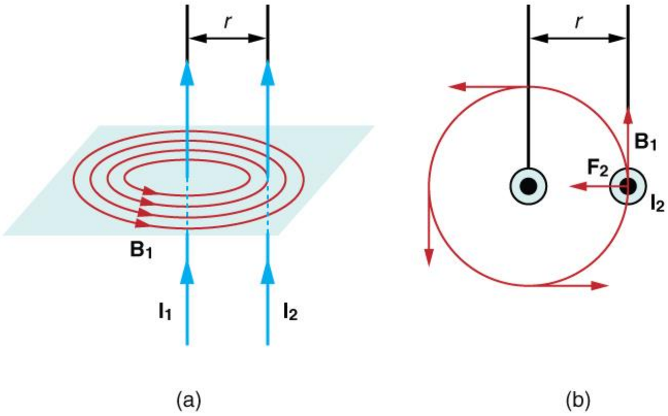
$r_2 = 0.1\ \mathrm{m}$

$I_2 = 3\ \mathrm{A}$

$\mu_0 = 4\pi \times 10^{-7}\ \ \mathrm{T\,m\,A^{-1}}$

To determine

$B = ?$



SOLUTION:

$$B_1 = \frac{\mu_0 I_1}{2\pi r_1}$$

$$B_1 = \frac{(4\pi \times 10^{-7})(6.5)}{2\pi(0.1)}$$

$$B_1 = \frac{1.3 \times 10^{-6}}{0.1}$$

$$B_1 = 1.3 \times 10^{-5}\ T$$

$$F_2 = B_1 I_2 L$$

$$\frac{F_2}{L} = \left(\frac{\mu_0 I_1}{2\pi r_1}\right) I_2$$

$$\frac{F_2}{L} = \frac{\mu_0 I_1 I_2}{2\pi r_1}$$

$$\frac{F_2}{L} = \frac{(4\pi \times 10^{-7})(6.5)(3)}{2\pi(0.1)}$$

$$\frac{F_2}{L} = 3.9 \times 10^{-5}\ T$$

WORKED EXAMPLES

1 A current-carrying conductor of a certain length placed at 90^0 to the magnetic field experiences a force F. What force will be if the current is increased four times, the length is halved, and the magnetic field is tripled?

Data:

$I_1 = 4I$ A

$L_1 = \frac{L}{2}$

$B_1 = 3$ B

To determine

$F_1 = ?$

SOLUTION:

The force on a current-carrying wire is

$F = B\,I\,L$

Now,

$F_1 = B_1\ I_1\ L_1$

$F_1 = (3\text{ B})\ (4\ I)\ \left(\frac{L}{2}\right)$

$F_1 = 6\ F$

The forced increase six times

2 A conductor of length 50cm carrying a current of 5 A is placed perpendicular to a magnetic field of induction 2×10^{-3} T. Find the force on the conductor

Data:

$L = 50\text{ cm} = 50 \times 10^{-2}\ m$

$I = 5\ A$

$B = 2 \times 10^{-3}\ T$

To determine

$F = ?$

SOLUTION:

The force on a current-carrying wire is

$F = B\,I\,L$

$F = (2 \times 10^{-3})\ (5)\ (50 \times 10^{-2})$

$F = 5 \times 10^{-3}\ N$

3 Calculate the magnetic flux through a rectangular loop with dimensions 5 cm x 10 cm placed in a magnetic field of strength 0.2 T. The loop is oriented such that the magnetic field lines are perpendicular to the plane of the loop.

Data:

$A = 5\text{ cm} \times 10\text{ cm}$

$A = 5 \times 10^{-2}\text{m} \times 10 \times 10^{-2}\text{m}$

$A = 50 \times 10^{-4}\text{ m}$

$B = 0.2\text{ T}$

To determine

$\Phi = ?$

SOLUTION:

$\Phi = B\,A\,\cos\theta$

$\Phi = (0.2)\ (50 \times 10^{-4})\ \cos 0^0$

$\Phi = (0.2)\ (50 \times 10^{-4})\ (1)$

$\Phi = 1 \times 10^{-3}\ Wb$

4 **Suppose we have a solenoid with 500 turns per meter and a current of 2.5 amperes flowing through it. Calculate the magnetic flux density inside the solenoid.**

Data:	**SOLUTION:**
$number\ of\ turns\ (N) = 500$ $L = 1\ \text{m}$ $I = 2.5\ \text{A}$ $\mu_0 = 4\pi \times 10^{-7}$ To determine $B = ?$	$B = \mu_0\, n\, I$ $B = \mu_0 \left(\frac{N}{L}\right) I$ $B = (4\pi \times 10^{-7}) \left(\frac{500}{1}\right) (2.5)$ $B = 1.57 \times 10^{-3}\ T$

5 **Suppose we have a toroid with 1000 turns and a current of 3 amperes flowing through it. The toroid has a circular cross-section with a radius of 0.1 meters. Calculate the magnetic flux density inside the toroid.**

Data:	**SOLUTION:**
$number\ of\ turns\ (N) = 1000$ $I = 3\ \text{A}$ $r = 0.1\ \text{m}$ $\mu_0 = 4\pi \times 10^{-7}$ To determine $B = ?$	$B = \frac{\mu_0\, N\, I}{2\pi r}$ $B = \frac{(4\pi \times 10^{-7})(1000)(3)}{2\pi (0.1)}$ $B = 1.57 \times 10^{-3}\ T$

6 **A moving coil galvanometer of resistance 100 Ω is used as an ammeter using a Shunt of 0.1 Ω.The maximum deflection current in the galvanometer is 100 μA. Find the current in the circuit so that the ammeter gives maximum deflection.**

Data:	
$R_g = 100\ \Omega$ $R_S = 0.1\ \Omega$ $I_g = 100\ \mu\text{A} = 100 \times 10^{-6}\ A$ To determine $I = ?$ **SOLUTION:** $R_S = \frac{R_g\, I_g}{I - I_g}$	$(I - I_g)\, R_S = R_g\, I_g$ $I - I_g = \frac{R_g\, I_g}{R_S}$ $I = \frac{R_g\, I_g}{R_S} + I_g$ $I = \frac{(100)\,(100 \times 10^{-6})}{0.1} + 100 \times 10^{-6}$ $I = 0.1 + 100 \times 10^{-6}$ $I = 0.1001\ A\ \ or\ 100.1\ mA$

7 A galvanometer coil of 40 Ω resistance shows full-range deflection for a current of 4 mA. How can this galvanometer be converted into a voltmeter of range 0- 12V?

Data:	SOLUTION:
$R_g = 40\ \Omega$ $I_g = 4\ mA = 4 \times 10^{-3}\ A$ $V = 12\ V$ To determine $R_X = ?$	$R_X = \frac{V}{I_g} - R_g$ $R_X = \frac{12}{4 \times 10^{-3}} - 40$ $R_X = \frac{12}{4 \times 10^{-3}} - 40$ $R_X = 3000 - 40$ $R_X = 2960\ \Omega$

8 A 300-volt voltmeter has a total resistance of 20,000 ohms. What additional series resistance must be connected to it to increase its range to 500 volts?

Data:	SOLUTION:
$V_g = 300\ V$ $R_g = 20\,000\ \Omega$ $V = 500\ V$ To determine $R_X = ?$ SOLUTION: $I_g = \frac{V_g}{R_g}$ $I_g = \frac{300}{20000} = 0.015\ A$	$R_X = \frac{V}{I_g} - R_g$ $R_X = \frac{500}{0.015} - 20\,000$ $R_X = 33333.33 - 20\,000$ $R_X = 13333.33\ \Omega$