1. Two electrons are located in a region of space where the magnetic field is zero. Electron **A** is at rest; and electron **B** is moving westward with a constant velocity. A non-zero magnetic field directed eastward is then applied to the region. In what direction, if any, will each electron be moving after the field is applied?

          electron **A**   *electron* **B**

X A.   at rest   westward

__ B.   northward   eastward

__ C.   at rest   eastward

__ D.   southward   downward, toward the earth

__ E.   upward, away from earth   westward

An electron at rest is not affected by a magnetic field. A moving electron is not affected by a magnetic field parallel to its path

2. A loop of wire with a weight of 1.47N is oriented vertically and carries a current I = 1.75 A. A segment of the wire passes through a magnetic field directed into the plane of the page as shown. The net force on the wire is measured using a balance and found to be zero. What is the magnitude of the magnetic field?
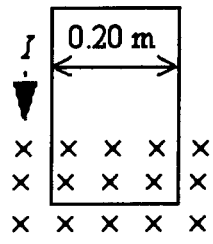
Force on sides is inward and cancels. Force on bottom is upward and must cancel gravity

$$mg = BI\ell$$

$$B = \frac{mg}{I\ell} = \frac{1.47\ N}{1.75A \times 0.20\ M}$$

$$B = 4.2\ T$$

__ A.   zero

__ B.   0.51 T

__ C.   0.84 T

__ D.   1.5 T

X E.   4.2 T

3. A solenoid of length 0.25 m and radius 0.02 m is comprised of 120 turns of wire. Determine the magnitude of the magnetic field at the center of the solenoid when it carries a current of 15 A.

__ A. 2.26×10^{-3} T

__ B. 4.52×10^{-3} T

X C. 9.05×10^{-3} T

__ D. 7.50×10^{-3} T

__ E.   zero

$$B = \mu_0 nI = \mu_0 \frac{N}{\ell} I$$

$$B = \frac{4\pi \times 10^{-7} \times 120 \times 15A}{0.25\ M} = 9.05 \times 10^{-3}\ T$$

4. A rectangular loop has sides of length 0.06 m and 0.08 m. The wire carries a current of 10 A in the direction shown. The loop is in a uniform magnetic field of magnitude 0.2 T and directed in the positive x direction. What is the magnitude of the torque on the loop?
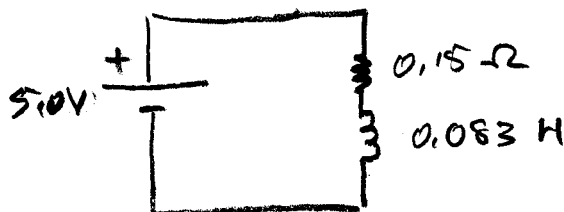

$$\tau = NIAB \sin 60°$$

$$\tau = 1 \cdot 10A \cdot (0.08 \times 0.06 \; M^2) \times$$
$$\times 0.2T \times \sin 60°$$
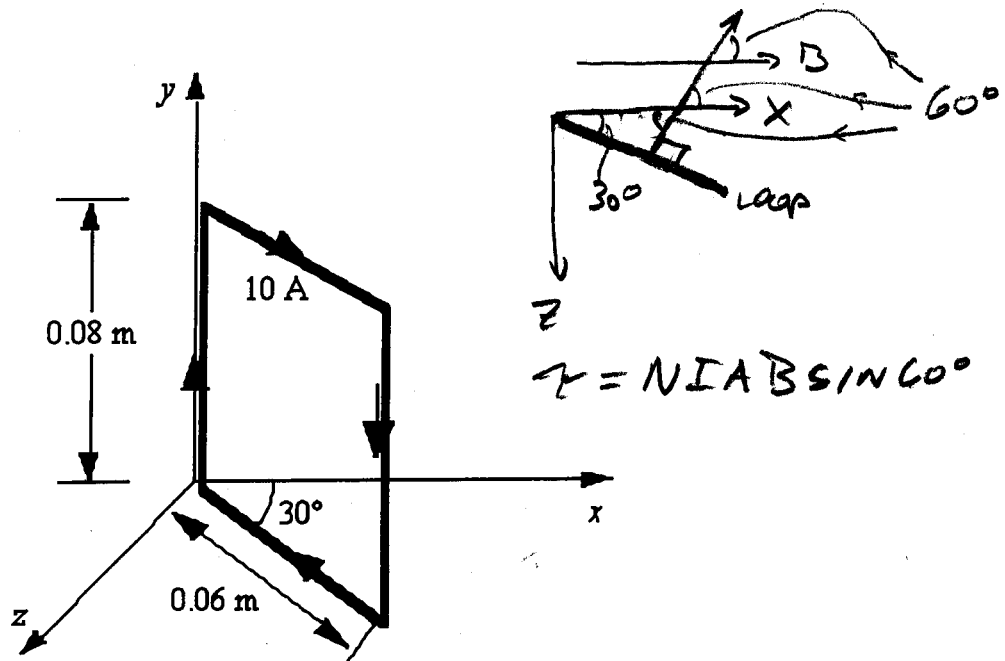
$$\tau = 8.3 \times 10^{-3} \; N\text{-}m$$

___ A. 4.2 × 10⁻² N•m

___ B. 4.8 × 10⁻² N•m

___ C. 4.8 × 10⁻³ N•m

✗ D. 8.3 × 10⁻³ N•m

___ E. 9.6 × 10⁻³ N•m

5. A coil of wire with a resistance of 0.15 Ω has a self-inductance of 0.083 H. If a 5.0-V battery is connected across the ends of the coil and the current in the circuit reaches an equilibrium value, what is the stored energy in the inductor?

___ A. 92 J

✗ B. 46 J

___ C. 16 J

___ D. 4.1 J

___ E. 1.4 J

5.0V 0.15 Ω 0.083 H

THE COIL RESISTANCE ACTS LIKE IT IS IN SERIES, THEN OHM'S LAW SAYS

$$V = IR \quad SO \quad I = V/R = 5.0/0.15 = 33.3 \; A$$

$$STORED \; ENERGY \quad PE_L = \frac{1}{2} LI^2$$
$$= \frac{1}{2}(.083) \, 33.3^2$$
$$= 46 \; J$$

2

6. Four long, straight wires are parallel to each other; and their cross-section forms a square. Each side of the square is 0.02 m as shown in the figure. If each wire carries a current of 8.0 A in the direction shown in the figure, determine the magnitude of the total magnetic field at **P**, the center of the square.
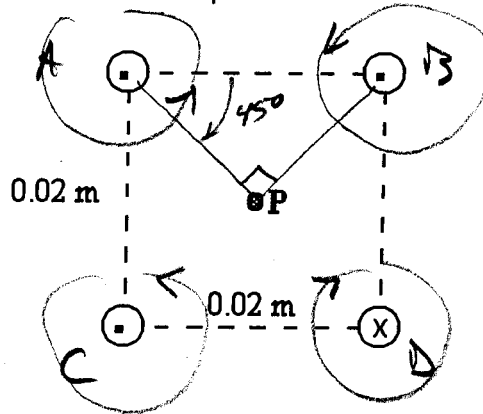

FIELDS FROM
B AND C
CANCEL

FIELDS FROM
A AND D
ADD.

___ A. 5.1×10^{-5} T
___ B. 1.1×10^{-4} T
___ C. 1.7×10^{-4} T
X D. 2.3×10^{-4} T
___ E. zero

DISTANCE FROM P TO A (or D)
IS $0.02 \cos 45°$

$$B = 2 \times \frac{\mu_0 I}{2\pi r} = 2 \times \frac{4\pi \times 10^{-7} \times 8}{2\pi \times .02 \cos 45°}$$

2 FIELDS ADD

$$B = 2.26 \times 10^{-4} \text{ T}$$

The figure shows a uniform, 3.0-T magnetic field that is normal to the plane of a conducting, circular loop with a resistance of 1.5 Ω and a radius of 0.024 m. The magnetic field is directed out of the paper as shown.
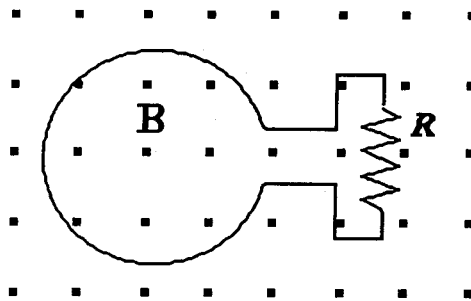
Note: The area of the non-circular portion of the wire is considered negligible compared to that of the circular loop.

7. What is the average current around the loop if the magnitude of the magnetic field is doubled in 0.4 s?

___ A. 2.8×10^{-3} A, clockwise
___ B. 4.5×10^{-3} A, clockwise
___ C. 4.5×10^{-3} A, counterclockwise
X D. 9.0×10^{-3} A, clockwise
___ E. 9.0×10^{-3} A, counterclockwise

$$\Phi = BA \cos\theta = BA$$

$$BA = B \cdot \pi r^2$$

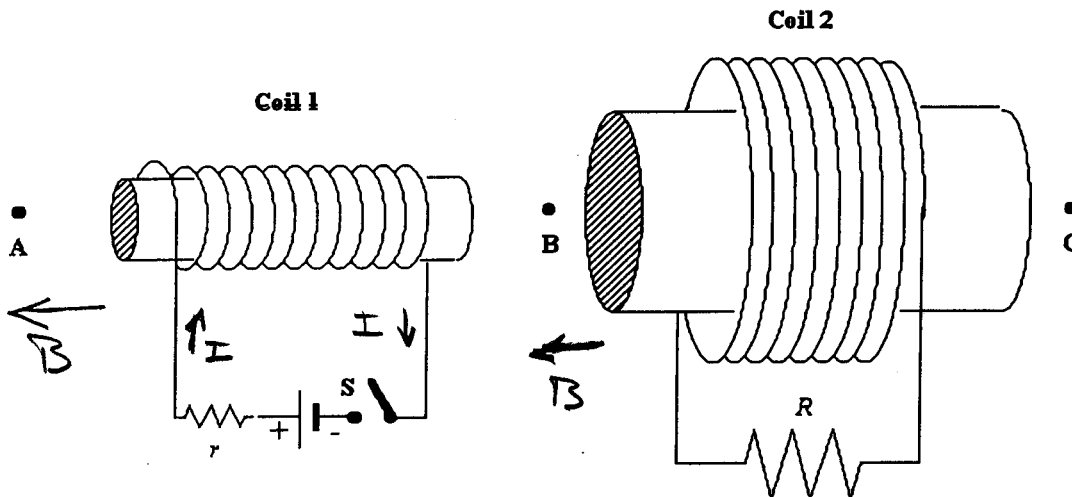$$\Phi = 3.0 \times \pi \times (.024)^2 = 5.43 \times 10^{-3}$$

B DOUBLES SO Φ DOUBLES

$$|\varepsilon| = \frac{\Delta\Phi}{\Delta t} = 1.36 \times 10^{-2} \text{ V} \quad \longleftarrow \quad \Delta\Phi = 5.43 \times 10^{-3} \quad \Delta t = 0.4 s$$

$$I = V/R = 1.36 \times 10^{-2}/1.5\Omega = 9.0 \times 10^{-3} \text{ A, CLOCKWISE TO}$$

OPPOSE THE INCREASE IN B AND Φ.

3

Two coils, **1** and **2**, with iron cores are positioned as shown in the figure. Coil **1** is part of a circuit with a battery and a switch.

Coil 2

Coil 1

8. Assume that **S** has been closed for a long time. Which one of the following changes will result in an induced magnetic field in coil **2** that points toward **C**?

  __ A. The switch **S** is opened.

  __ B. The iron core is removed from coil **1**.

  __ C. Coil **1** and its core are moved toward **A**.

  X D. Coil **1** and its core are moved toward **B**.

  __ E. Coil **2** and its core are moved toward **C**.

MAGNETIC FIELD B IS AS SHOWN IN BOTH CORES. TO INDUCE AN OPPOSITE MAGNETIC FIELD YOU WOULD INCREASE B SO THE OPPOSITE FIELD WOULD OPPOSE THE CHANGE.

9. The current in a solenoid is decreased to one-half of its original value. Which one of the following statements is true concerning the self-inductance of the solenoid?

  X A. The self-inductance does not change.

  __ B. The self-inductance increases by a factor of two.

  __ C. The self-inductance decreases by a factor of two.

  __ D. The self-inductance increases by a factor of four.

  __ E. The self-inductance decreases by a factor of four.

L DEPENDS ON THE SIZE AND SHAPE OF THE COIL, NOT THE CURRENT.

10. In an ac circuit, a 0.025-H inductor is connected to a generator which has an rms voltage of 25 V and operates at 50.0 Hz. What is the rms current through the inductor?

  __ A. 0.62 A

  __ B. 2.0 A

  X C. 3.2 A

  __ D. 7.1 A

  __ E. 14 A

$$V_{rms} = I_{rms} X_L \qquad X_L = 2\pi f L$$

$$I_{rms} = \frac{V_{rms}}{X_L} = \frac{25}{2\pi(50)(.025)}$$

$$I_{rms} = 3.18 \, A$$

11. A 2.0-kg rod has a length of 1.0 m and a resistance of 4.0 Ω. It slides with *constant speed* down a pair of frictionless vertical conducting rails that are joined at the bottom. A uniform magnetic field of magnitude 3.0 T is perpendicular to the plane formed by the rod and the rails as shown.
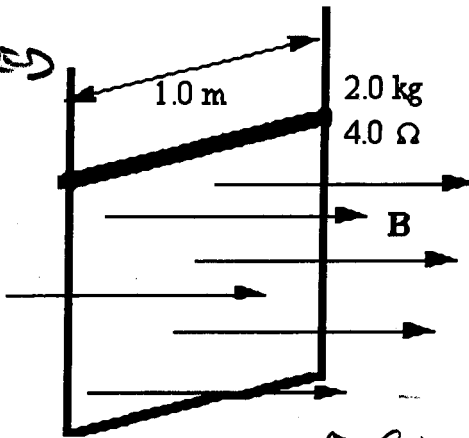
THE POWER CONSUMED
IN THE RESISTANCE
OF THE ROD IS
SUPPLIED BY THE
WORK DONE BY
GRAVITY.

$$I^2 R = \frac{mg\Delta h}{\Delta t}$$

$$I^2 R = mgv$$

1.0 m   2.0 kg
4.0 Ω

B

MEANWHILE, THE
MOTIONAL EMF IS

$$\varepsilon = B\ell v$$

AND $\varepsilon = V = IR$

SO $I = \varepsilon/R$

OR $I = B\ell v / R$

THUS $\left(\frac{B\ell v}{R}\right)^2 R = mgv$

$$\frac{B^2 \ell^2 v^2}{R^2} R = mgv$$

$$v = \frac{mgR}{B^2 \ell^2} = \frac{2.0 \times 9.8 \times 4.0}{3.0^2 \times 1.0^2}$$

$$v = 8.71 \ m/s$$

Determine the speed of the rod.

___ A.   0.38 m/s
___ B.   0.90 m/s   (see last
___ C.   2.6 m/s   PAGE FOR
___ D.   5.6 m/s   ANOTHER
X E.   8.7 m/s   SOLUTION)

12. A variable capacitor is connected to an ac source. What effect does *decreasing* the capacitance have on the reactance and current in this circuit?

	Reactance	Current
___ A.	no change	no change
___ B.	decreases	no change
___ C.	increases	increases
___ D.	decreases	increases
X E.	increases	decreases

$$V = I X_c = I \cdot \frac{1}{2\pi f C}$$

V IS FIXED SO IF C
DECREASES I MUST DECREASE
AND $X_c = \frac{1}{2\pi f C}$ INCREASES

An ac generator supplies a peak (not *rms*) voltage of 120 V at 60.0 Hz. It is connected in series with a 50.0-Ω resistor and a 0.5-H inductor.

13. What is the *rms* current through the resistor?

___ A.   2.4 A
___ B.   1.7 A
___ C.   1.3 A
___ D.   0.62 A
X E.   0.44 A

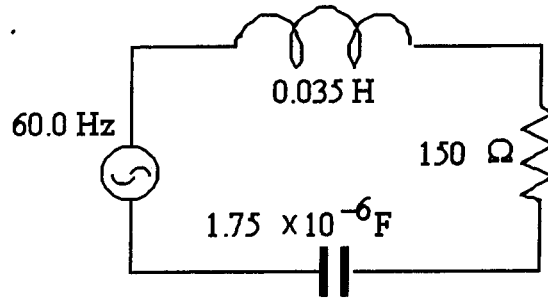$$V_m = 120 \quad V_{rms} = \frac{V_m}{\sqrt{2}} = \frac{120}{\sqrt{2}} = 84.8 \ V.$$

$$Z = \sqrt{R^2 + X_L^2} = \sqrt{R^2 + (2\pi f L)^2}$$

$$Z = \sqrt{50^2 + (2\pi \cdot 60 \cdot 0.5)^2} = 195 \ \Omega$$

$$V_{rms} = I_{rms} Z \quad SO \quad I_{rms} = \frac{84.8}{195}$$

$$I_{rms} = 0.435 \ A$$

5

14. Use the information given in the figure for the series RCL circuit to determine the phase angle between the current and the voltage.

0.035 H

60.0 Hz

150 Ω

1.75 ×10⁻⁶ F

___ A.   zero

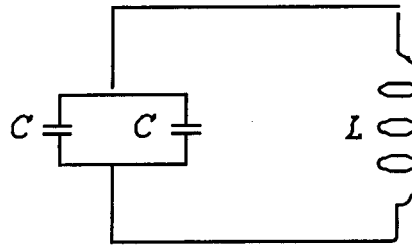___ B.   +5.3°

___ C.   −9.6°

X D.   −84°

___ E.   +90°

$$\phi = \text{PHASE ANGLE} = \text{TAN}^{-1} \frac{X_L - X_C}{R}$$

$$X_L = 2\pi f L = 2\pi \times 60 \times (.035) = 13.19 \ \Omega$$

$$X_C = \frac{1}{2\pi f C} = \frac{1}{2\pi \times 60 \times 1.75 \times 10^{-6}} = 1515 \ \Omega$$

$$\text{TAN}^{-1} \frac{1515 - 13.2}{150} = \text{TAN}^{-1}(-10.0) = -84.3°$$

15. Two 250-μF capacitors, with equal capacitances, and a 1.5-mH inductor are connected as shown in the figure. It is desired to "drive" the circuit by placing an ac generator in series with the inductor. Which output voltage for the generator will produce the largest current in the above circuit? Assume that V is in volts when t is in seconds.

C   C   L

___ A.   V = 0.6 sin[(1.1 × 10⁶ rad/s)t]

X B.   V = 0.6 sin[(1.2 × 10³ rad/s)t]

___ C.   V = 1.2 sin[(5.3 × 10⁶ rad/s)t]

___ D.   V = 1.2 sin[(2.3 × 10⁶ rad/s)t]

___ E.   V = 2.8 sin[(4.6 × 10⁶ rad/s)t]

EQUIVALENT TO 1 500 μF
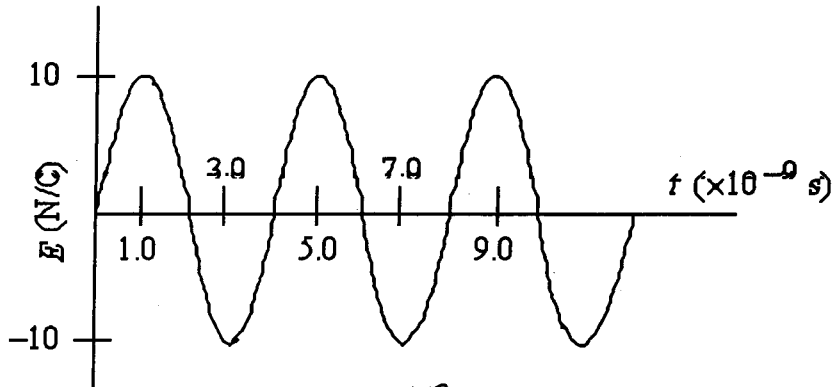CAPACITOR. MAXIMUM
CURRENT AT RESONANT
FREQUENCY (X_L AND X_C CANCEL)

$$f = \frac{1}{2\pi \sqrt{LC}}$$

So $\omega = 2\pi f = \frac{1}{\sqrt{LC}}$

$$\omega = \frac{1}{\sqrt{500 \times 10^{-6} \times 1.5 \times 10^{-3}}}$$

$$\omega = 1.15 \times 10^{3}$$

The figure shows the time variation of the magnitude of the electric field of an electromagnetic wave produced by a wire antenna.

$E_{MAX} = 10.0$

$E_{rms} = \dfrac{10.0}{\sqrt{2}} = 7.07$

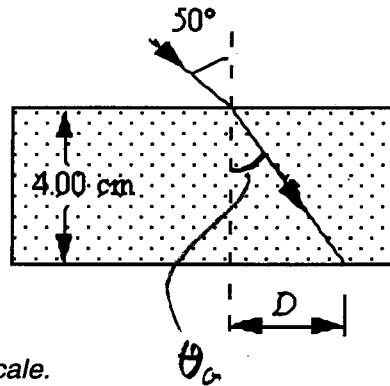16. What is the *rms* value of the magnitude of the magnetic field?

___ A. 1.4×10^{-8} T

X B. 2.4×10^{-8} T

___ C. 3.3×10^{-8} T

___ D. 4.6×10^{-8} T

___ E. 5.4×10^{-8} T

$B_{rms} = \dfrac{E_{rms}}{C} = \dfrac{7.07}{3 \times 10^8}$

$B = 2.36 \times 10^{-8}$

17. A ray of light passes from air into a block of glass with a refractive index of 1.50 as shown in the figure.

Note: *The drawing is not to scale.*
What is the value of the distance *D*?

___ A. 1.42 cm

___ B. 1.66 cm

___ C. 1.90 cm

___ D. 2.14 cm

X E. 2.38 cm

$n_{AIR} \cong 1.00$

$n_{AIR} \sin \theta_{AIR} = n_G \sin \theta_G$

$1.00 \sin 50° = 1.50 \sin \theta_G$

$\sin \theta_G = 0.511 \quad \theta_G \approx 30.7°$

$D = 4.00 \text{ cm} \times \tan \theta_G = 2.38 \text{ cm}$

7

18. Blue light with a wavelength of 425 nm passes from a vacuum into a glass lens; and the index of refraction is found to be 1.65. The glass lens is replaced with a plastic lens. The index of refraction for the plastic lens is 1.54. In which one of the two lenses does the light have the greatest speed and what is that speed?

__ A.   glass, 2.28 × 10⁸ m/s

__ B.   plastic, 2.13 × 10⁸ m/s

__ C.   glass, 1.82 × 10⁸ m/s

✗ D.   plastic, 1.95 × 10⁸ m/s

__ E.   The speed of the blue light is the same in the vacuum and both lenses; and it is 3.00 × 10⁸ m/s.

$$n = c/v \text{ so } v\uparrow \Rightarrow n\downarrow$$
$$v_{PLASTIC} = c/n_{PLASTIC} = 3\times10^8/1.54$$
$$v_{PLASTIC} = 1.95\times10^8 \text{ m/s}$$

19. A fiber optic line is composed of a core with an index of refraction of 1.47 and cladding with an index of 1.31. Which one of the following relations best describes angles of incidence θ that will result in total internal reflection within the fiber optic line?

__ A.   θ < 63°

✗ B.   θ > 63°

__ C.   θ < 27°

__ D.   θ > 27°

__ E.   0 ≤ θ ≤ 90°

TOTAL REFLECTION IS WHEN
$$n_{CLADDING} \sin 90° \le n_{FIBER} \sin \theta$$
$$1.31 \le 1.47 \sin \theta$$
$$\sin\theta \ge \frac{1.31}{1.47} = 0.891; \theta > 63°$$

20. Light with a wavelength of 589 nm in a vacuum strikes the surface of an unknown liquid at an angle of 31.2° with respect to the normal to the surface. If the light travels at a speed of 1.97 × 10⁸ m/s through the liquid, what is the angle of refraction?

✗ A.   19.9°

__ B.   26.1°

__ C.   34.2°

__ D.   39.3°

__ E.   51.9°

ASSUME LIGHT IS TRAVELING IN AIR, $n_{AIR} \cong 1.00$, BEFORE STRIKING THE LIQUID.

$$n_{AIR} \sin \theta_{AIR} = n_{LIQ} \sin \theta_{LIQ}$$
$$n_{LIQ} = c/v_{LIQ} = \frac{3\times10^8}{1.97\times10^8} = 1.52$$
$$1.00 \sin 31.2° = 1.52 \sin \theta_{LIQ}$$
$$\sin \theta_{LIQ} = \frac{\sin 31.2°}{1.52} = 0.341$$
$$\theta_{LIQ} = \sin^{-1}(0.341) = 19.9°$$

ALTERNATE SOLUTION FOR # 11:

MOTIONAL EMF IS $\varepsilon = B\ell v$

$\varepsilon = V = IR$ SO $I = \varepsilon/R = B\ell v/R$

MAGNETIC FORCE ON CURRENT = GRAVITY
BECAUSE VELOCITY IS CONSTANT, NO ACCELERATION
MEANS NO NET FORCE. SO

$F = BI\ell = mg$ SUBSTITUTE FOR I

$$B\left[\frac{B\ell v}{R}\right]\ell = mg$$

$$\frac{B^2\ell^2 v}{R} = mg \qquad \text{AND } v = mg R/B^2\ell^2$$

AS BEFORE