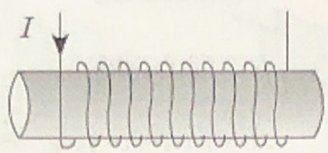
Key

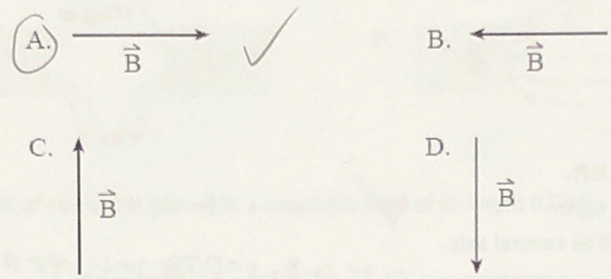
Magnetism Review

1. An electric current flows through a solenoid as shown below.

RHR
• Thumb = current
• Fingers curl inside left to right.

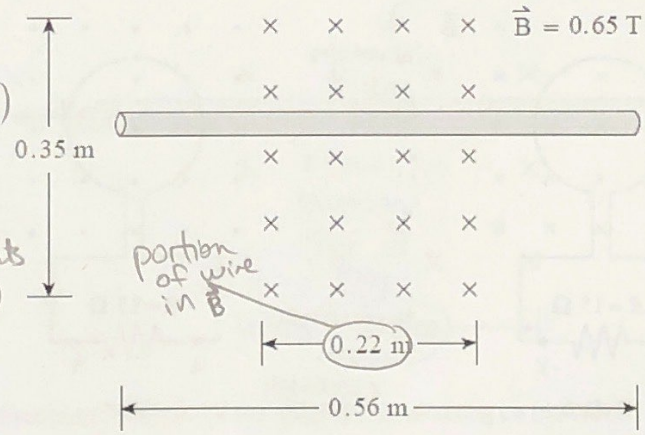


What is the direction of the magnetic field inside the solenoid?



2. A long conductor is placed in a 0.65T magnetic field as shown below.

• palm up ($\vec{F}$)
• fingers into page ($\vec{B}$)
• thumb points right (I)



$F = BIl$

$I = \frac{F}{Bl}$

$= \frac{1.6N}{(0.65T)(0.22m)}$

$= 11\ A$ [right] ✓

What are the magnitude and direction of the current that produces a 1.6N force on the wire directed up the page?

RHR

3. A proton has a speed of 5.0×10^6m/s while travelling perpendicular to a 0.14T magnetic field. What is the magnetic force on the proton?

4. The flux through a circular coil with a radius of 0.075m is 0.013Wb when placed perpendicular to a magnetic field. What is the strength of the magnetic field?

③ $F = qvB$

$= (1.6\times10^{-19}C)(5\times10^6 m/s)(0.14T)$

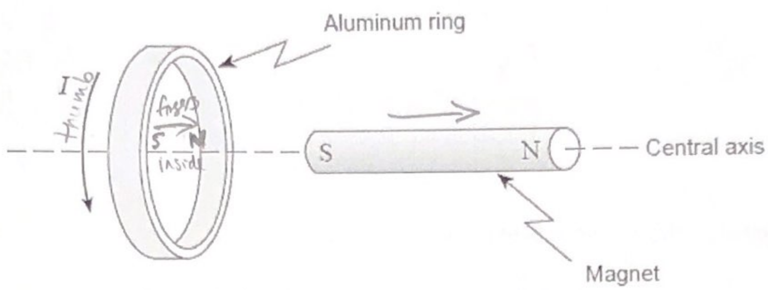
$= 1.1\times10^{-13}N$ ✓

④ $\Phi = BA$

$B = \frac{\Phi}{A} = \frac{0.013Wb}{\pi(0.075m)^2}$

$= 0.74T$ ✓

5. The diagram below shows an aluminum ring and the current induced in it by the nearby magnet that is free to move along its central axis.



The magnet must be

A. stationary.
B. moving to the left.
(C.) moving to the right. ✓
D. spinning about its central axis.

$-B_f = -0.75T$ since opp direction

6. A loop of wire of area $0.32m^2$ is placed in a 0.75T magnetic field as shown. The magnetic field is changed to 0.35T in the opposite direction in 0.45s.

$\mathcal{E} = -N\frac{\Delta\Phi}{\Delta t}$

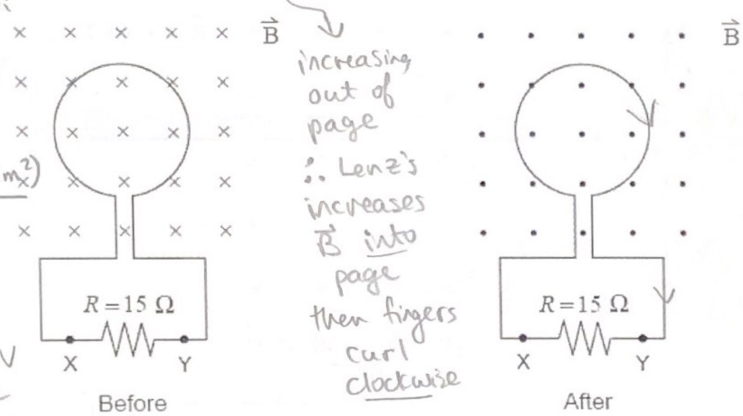
$= -1\frac{(\Delta BA)}{\Delta t}$

$= \frac{-(0.35 - -0.75)(0.32m^2)}{0.45s}$

$= 7.8\bar{2} \times 10^{-1} V$

$\mathcal{E} = IR \quad I = \frac{\mathcal{E}}{R} = \frac{0.78\bar{2}V}{15\Omega}$

$= 0.052 A$

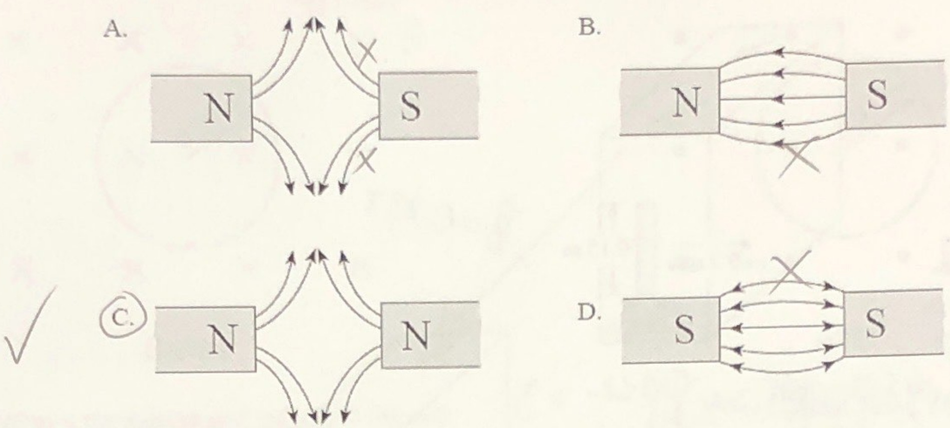


What are the magnitude and direction of the current ~~length~~ through the 15Ω resistor?

	Magnitude of Current	Direction of Current
A.	0.019 A	X to Y
B.	0.019 A	Y to X
C.	0.052 A	X to Y
(D.)	0.052 A	Y to X

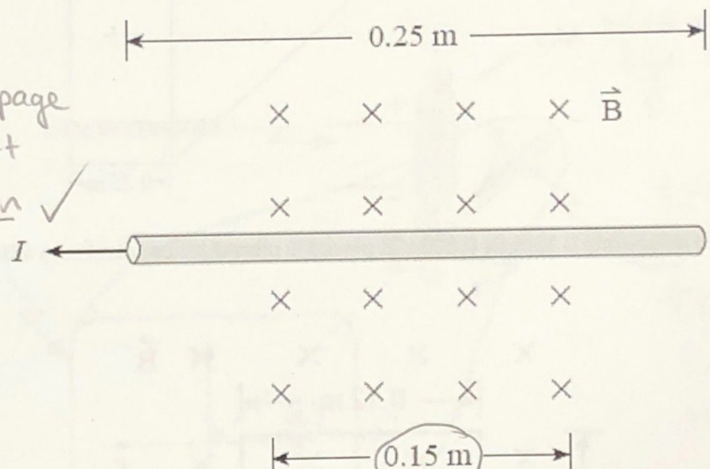
✓

7. Which of the following diagrams best shows the magnetic field lines between the poles of two permanent magnets? outside magnet: out of N, into S



8. A wire carrying 12A of current is placed in a magnetic field of strength 0.63T.

$\vec{B}$: Fingers into page
I: Thumb left
$\vec{F}$: palm down ✓



$F = BIl$

$= (0.63T)(12A)(0.15m)$

$= 1.1 N$ ✓ down

What are the magnitude and direction of the magnetic force acting on the wire?

9. A 460-turn solenoid having a diameter of 0.024m is 0.14m long. What is the magnetic field at the center of the solenoid when a 13A current flows through it?

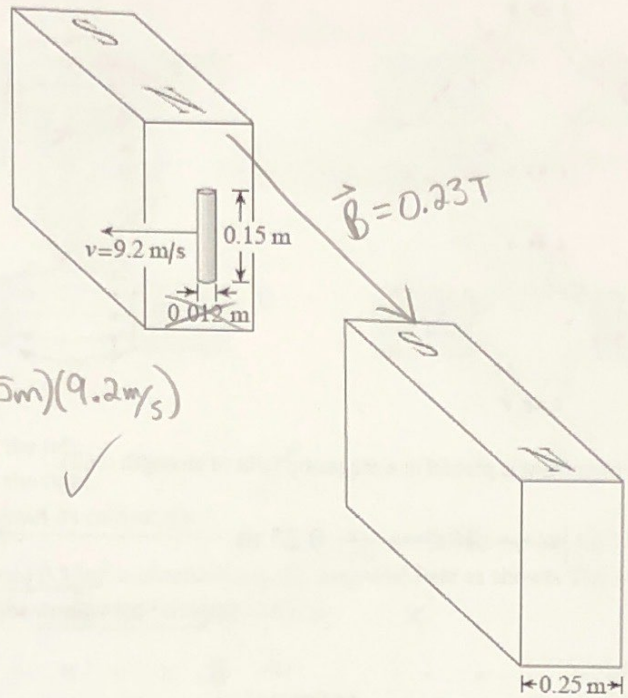
A. 0T
B. 5.4×10^{-2}T
C. 3.1×10^{-1}T
D. 6.3×10^{-1}T

$\vec{B} = \mu_0 \frac{N}{l} I$

$= \pi \times 4 \times 10^{-7} \frac{Tm}{A} \left(\frac{460}{0.14m}\right)(13A)$

$= 5.4 \times 10^{-2} T$ ✓

10. A conducting rod is moving perpendicular to a uniform magnetic field of 0.23T at a velocity of 9.2m/s. What emf is generated during this motion?



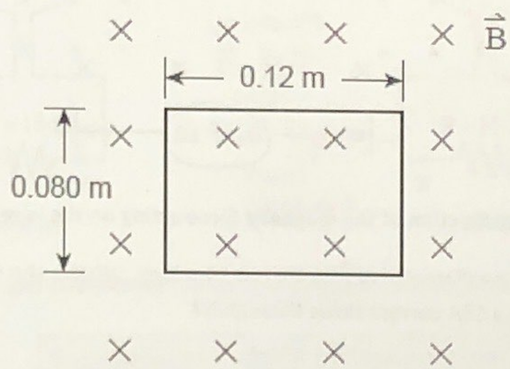
all ⊥

$\mathcal{E} = B l v$

$= (0.23T)(0.15m)(9.2m/s)$

$= 0.32V$ ✓

11. A rectangular coil measuring 0.12m by 0.080m is placed is placed perpendicular to a 0.85T magnetic field as shown.

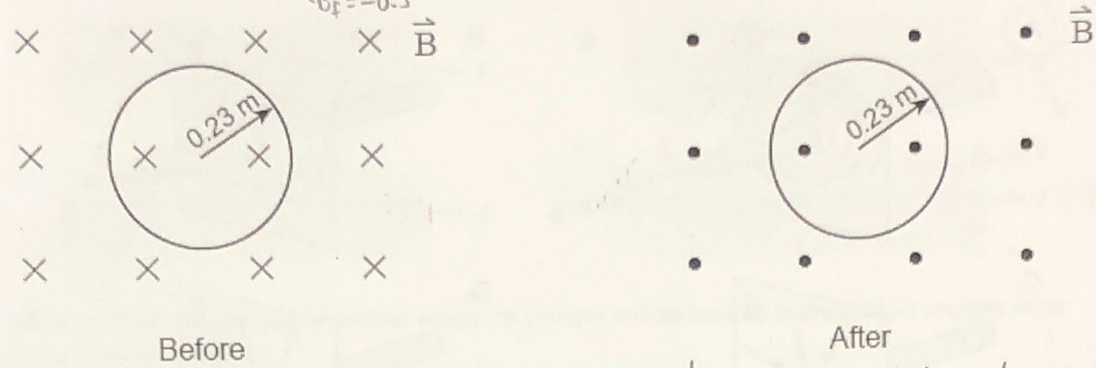


What is the magnetic flux through the coil?

$\Phi = BA = 0.85T(0.12m \times 0.08m)$

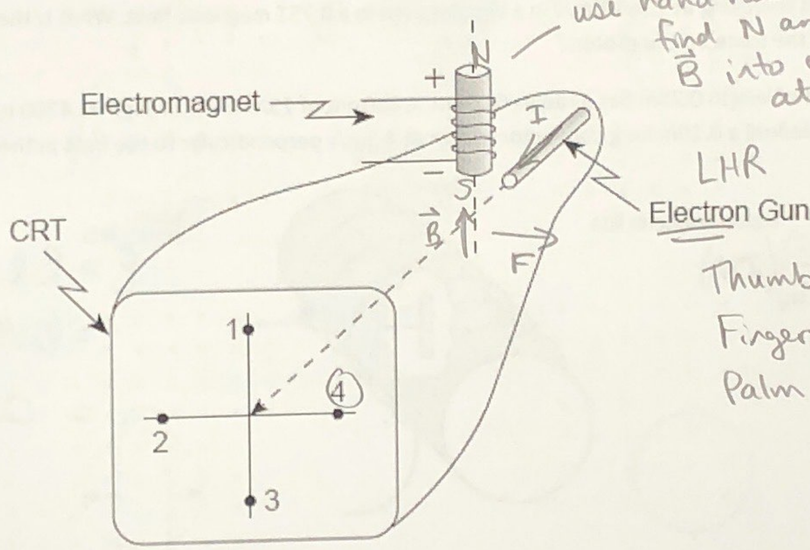
$= 8.2 \times 10^{-3}$ Wb ✓

12. A single loop of wire of radius 0.23m is placed in a 0.75T magnetic field as shown. The magnetic field is changed to a strength of 0.50T in the opposite direction in 0.61s.



What is the average emf induced in the coil? $\mathcal{E} = -N\frac{\Delta\Phi}{\Delta t} = \frac{-1(B_f - B_i)A}{\Delta t} = \frac{-(-0.5-0.75)(\pi 0.23^2)}{0.61s} = 0.34V$

13. With the electromagnet turned off, electrons in a cathode ray tube strike the center of the screen as shown.



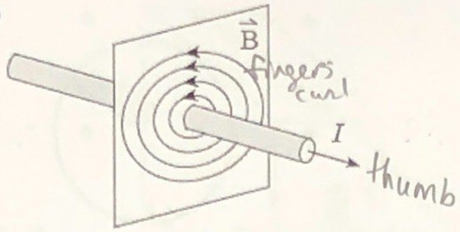
When the electromagnet is turned on, where will the electron beam now strike the screen?

A. 1
B. 2
C. 3
D. 4

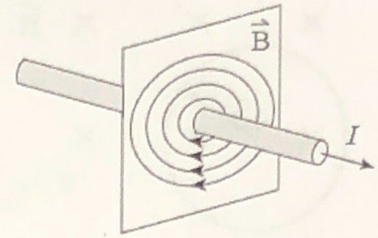
RHR

14. Which of the following diagrams best shows the magnetic field due to a long straight wire carrying a conventional current I as shown?

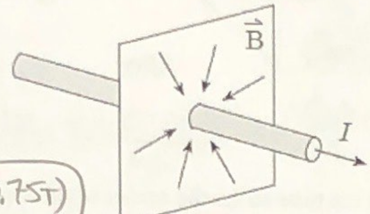
(A.) ✓



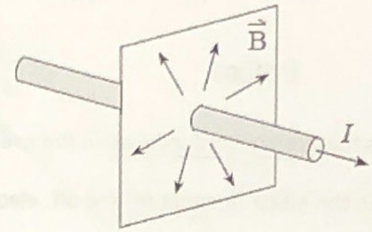
B.



C.



D.



$F_B = QvB$

$= (1.6\times10^{-19})(2.3\times10^{6}\,\tfrac{m}{s})(0.75T)$

$= 2.8\times10^{-13}N$ ✓

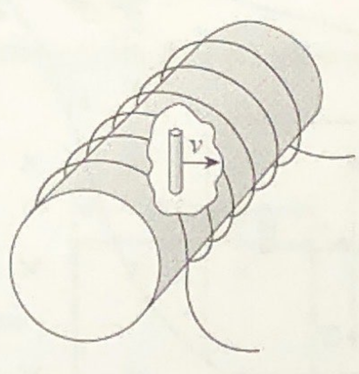
15. A proton is travelling at 2.3×10^{6}m/s in a circular path in a 0.75T magnetic field. What is the magnitude of the force on the proton?

16. A solenoid of length 0.75m has a radius 0.092m. A current of 25A flows through its 4700 turns. Within this solenoid a 0.10m long conductor moves at 4.3m/s perpendicular to the field in the solenoid.

$B = \mu \frac{N}{l} I$

$= \pi\times4\times10^{-7}\left(\frac{4700}{0.75m}\right)(25A)$

$= 0.19687T$



Then

$\mathcal{E} = Blv$

$= (0.19687T)(0.1m)(4.3\,m/s)$

$= 0.085V$ ✓

What emf is induced between the ends of the conductor? 0.1m

17. A rectangular coil of wire containing 250 loops is placed in a magnetic field. Each loop measures 0.075m by 0.28m. The magnetic field changes over a time interval of 0.36s producing an average emf of 1.3V. What is the change in the magnetic field strength?

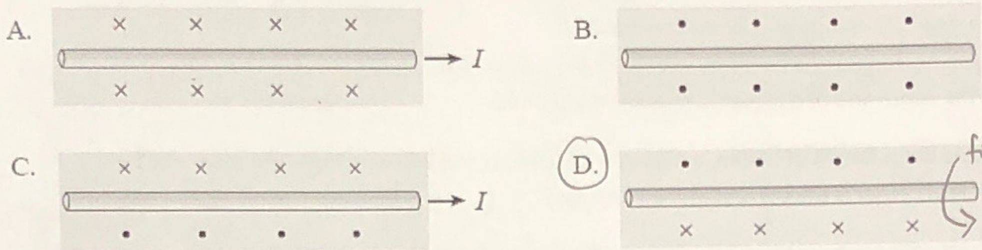
$\mathcal{E} = -N\frac{\Delta\Phi}{\Delta t}$

$\mathcal{E} = -N\frac{\Delta B A}{\Delta t}$

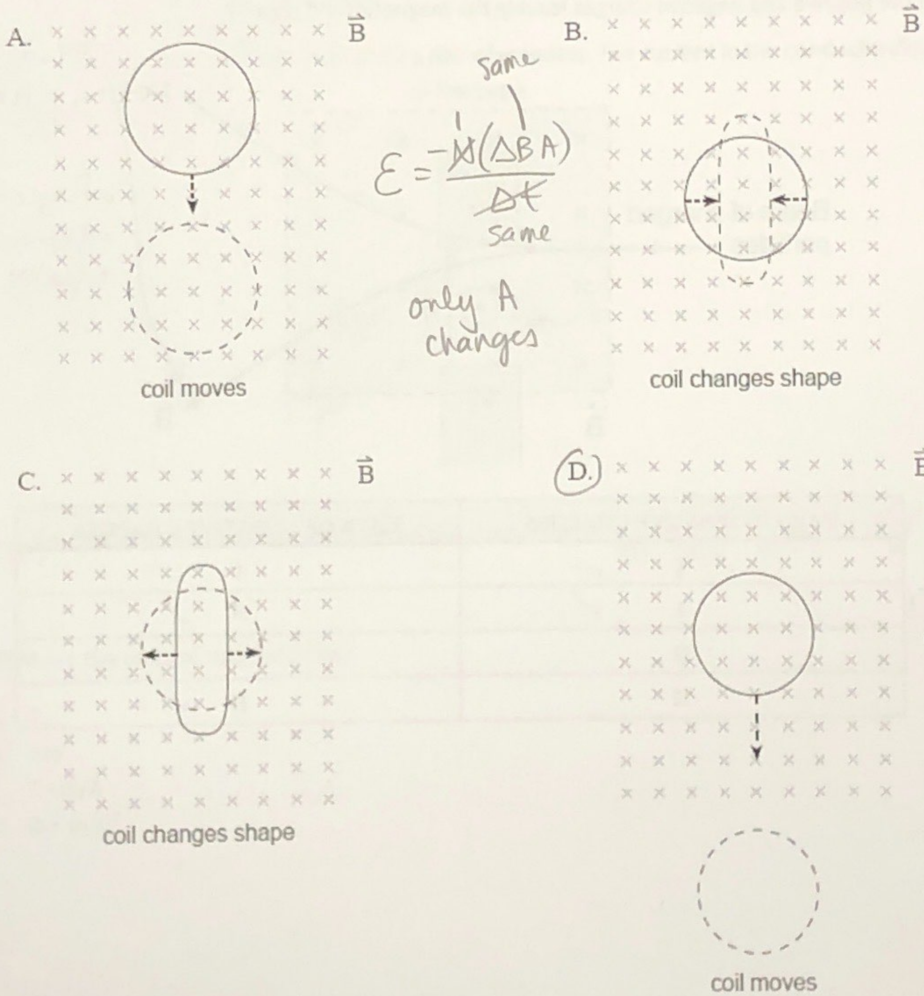
$\Delta B = \frac{\mathcal{E}\Delta t}{-NA} = \frac{(1.3V)(0.36s)}{-(250)(0.075\times0.28)} = -0.089T$ ✓

18. Which diagram shows the magnetic field created near a conductor carrying current towards the right?

RHR



19. In which of the following situations would the greatest emf be induced in the coil? All changes occur in the same time interval.



$\mathcal{E} = \frac{-N(\Delta B A)}{\Delta t}$ — same; same; only A changes

← biggest change of the Area that is in $\vec{B}$!

20. The direction of a magnetic field is determined to be the direction in which

A. a positive charge would tend to move.
B. a negative charge would tend to move.
C. the north end of a compass needle would point. — be attracted to S, so points in direction $\vec{B}$ goes (to S)
D. the south end of a compass needle would point.

goes from N to S outside a magnet

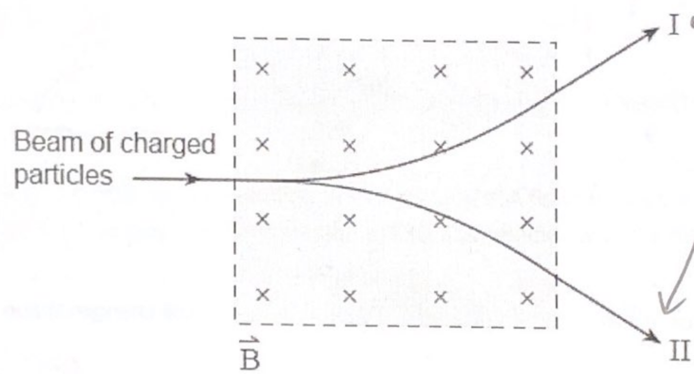
21. A solenoid has a length of 0.30m, a diameter of 0.040m and 500 windings. The magnetic field at its center is 0.045T. What is the current in the windings?

$B = \mu_0 \frac{N}{\ell} I$ $\quad I = \frac{\ell B}{\mu_0 N} = \frac{(0.3m)(0.045T)}{(\pi 4\times10^{-7})(500)} = 21A$

22. An aircraft with a wingspan of 24m flies at 85m/s perpendicular to a magnetic field. An emf of 0.19V is induced across the wings of the aircraft. What is the magnitude of the magnetic field?

#22: $\mathcal{E} = B\ell v$ $\quad B = \frac{\mathcal{E}}{\ell v} = \frac{0.19V}{(24m)(85m/s)} = 9.3\times10^{-5}T$

23. A beam of positively and negatively charged particles enters a magnetic field as shown. Which paths illustrate the positive and negative charges leaving the magnetic field region?



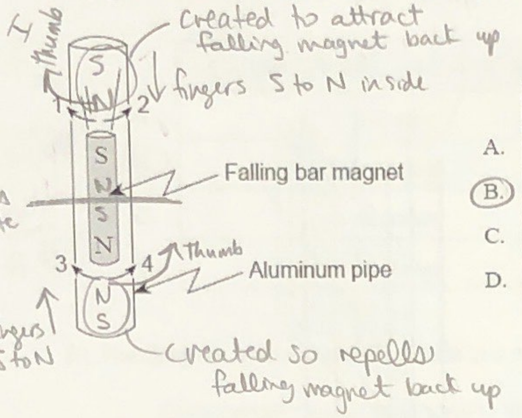
LHR for neg
RHR for pos

- fingers into pg ($\vec{B}$)
- thumb I
- palm $\vec{F}$

	PATH OF POSITIVE CHARGES	PATH OF NEGATIVE CHARGES
A.	I	I
B.	I	II
C.	II	I
D.	II	II

24. The diagram shows a bar magnet falling through an aluminum pipe. Electric currents are induced in the pipe immediately above and below the falling magnet. In which direction do these currents flow?

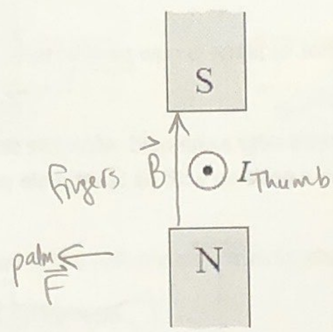
Lenz's Law – trys to stop magnet from falling



	ABOVE THE MAGNET	BELOW THE MAGNET
A.	1	3
(B.)	1	4
C.	2	3
D.	2	4

✓

25. The diagram shows a conductor between a pair of magnets. The current in the conductor flows out of the page.

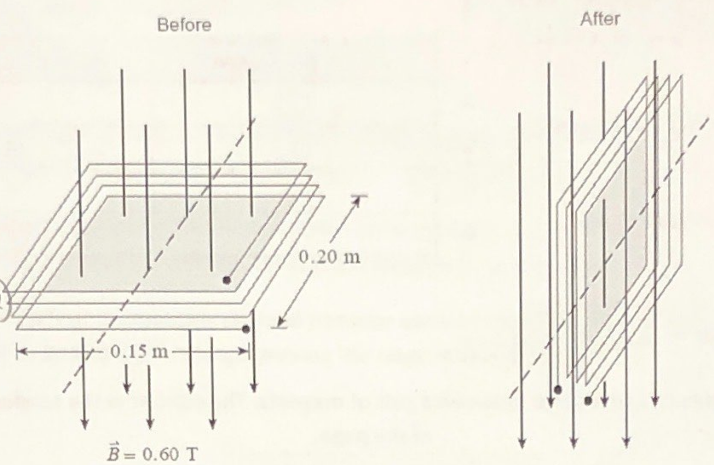


In what direction will the magnetic force act on the conductor? to the left ✓

26. What are the units of magnetic flux?

A. T
(B.) Wb ✓
C. T • m/A
D. D • m/C²

27. The diagram shows a coil with 25 windings and dimensions 0.15m by 0.20m. Its plane is perpendicular to a magnetic field of magnitude 0.60 T.



$\mathcal{E} = -N\frac{\Delta\Phi}{\Delta t}$

$= -25\frac{(\Phi_f - \Phi_i)}{\Delta t}$

$= -25\frac{(-BA)}{\Delta t}$

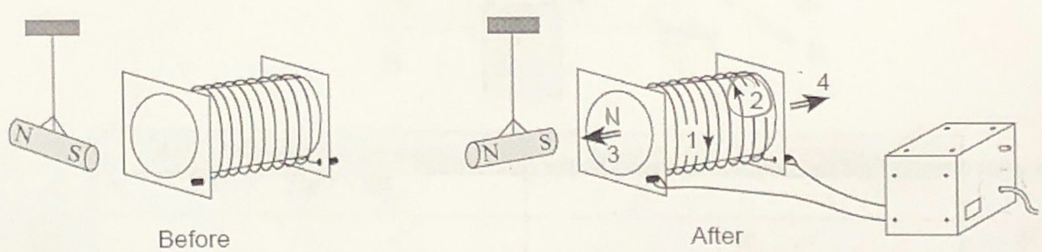
$= \frac{25(0.6T)(0.15\times0.2)}{4.17\times10^{-2}s}$

$= 11V$

If the coil rotates 90° in 4.17 x 10^{-2} s so that its plane is now parallel to the magnetic field, what average emf is induced during this time?

→ $\mathcal{E}=0$ → $\Phi_f = 0$

28. The diagram shows a magnet suspended near a solenoid. After the solenoid has been connected to a power supply, the magnet rotates to a new position with its South Pole pointing towards the solenoid.



What arrows show the direction of the current in the solenoid and the direction of the magnetic field caused by this current?

	DIRECTION OF CURRENT	DIRECTION OF MAGNETIC FIELD
A.	1	3
B.	1	4
C.	2	3
D.	2	4

29. A charged particle travels in a circular path in a magnetic field. What changes to the magnetic field and to the velocity of the particle would both cause the radius of its path to decrease?

$F_c = F_m$

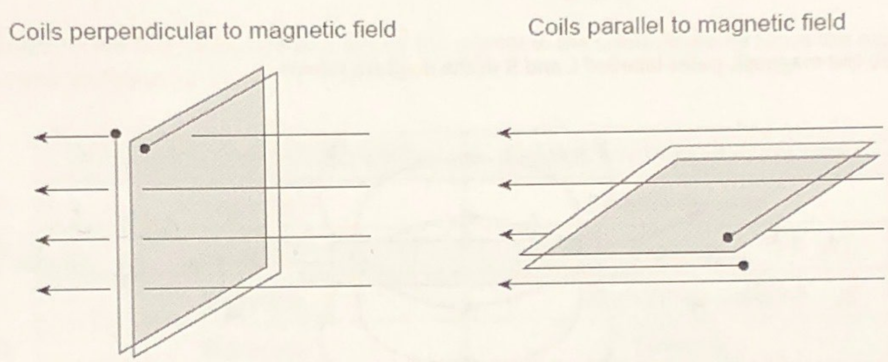
$\frac{mv^2}{r} = QvB$

$\downarrow r = \frac{mv\downarrow}{QB\uparrow}$

	CHANGE TO THE MAGNETIC FIELD	CHANGE TO THE VELOCITY
A.	increase	increase
(B.)	increase	decrease
C.	decrease	increase
D.	decrease	decrease

✓

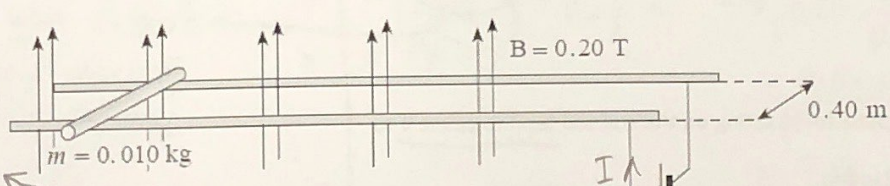
30. The diagram below shows two coils in a magnetic field.



An electric current can be induced in the coil oriented with its plane.

A. Parallel to a constant magnetic field
B. Parallel to a changing magnetic field
C. Perpendicular to a constant magnetic field
(D.) Perpendicular to a changing magnetic field ✓

31. The diagram shows a 0.010 kg metal rod resting on two long horizontal frictionless rails which remain 0.40m apart. The circuit has a resistance of 3.0Ω and is located in a uniform 0.20 T magnetic field.



① $\mathcal{E} = Blv$

$v = \frac{\mathcal{E}}{Bl} = \frac{15V}{(0.2T)(0.4m)} = 187.5 \, m/s = 1.9 \times 10^2 \, m/s = v_f$ ✓

Find the initial acceleration and maximum velocity for the rod.

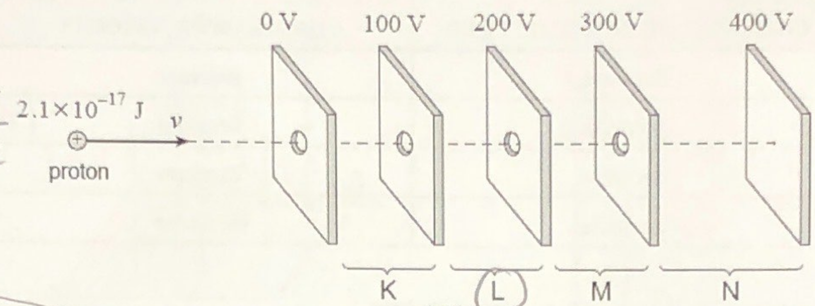
$F = BIl = ma$

$a = \frac{BIl}{m} = \frac{(0.2T)(5A)(0.4m)}{0.01 \, kg} = 40. \, m/s^2$ ✓

electrostatics question, oops!

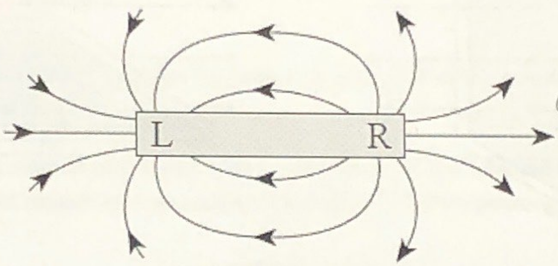
32. A proton with kinetic energy of 2.1×10^{-17} J is moving into a region of charged parallel plates. The proton will be stopped momentarily in what region?

$V = \frac{\Delta E_p}{Q} = \frac{2.1\times10^{-17}\ J}{1.6\times10^{-19}\ C} = 131\ V$



✓

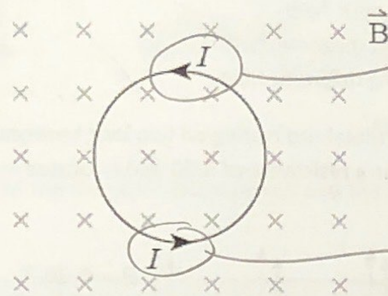
33. Identify the magnetic poles labelled L and R in the diagram shown.



in at S end

out at N end ✓

34. The diagram shows current *I* flowing in a circular coil located in a magnetic field.



fingers into page $\vec{B}$
thumb left (I)
palm down ($\vec{F}$)

fingers into pg
thumb right
palm up

The magnetic force acting on the coil will tend to cause it to

A. Expand
B. Contract
C. Move up the page
D. Move down the page

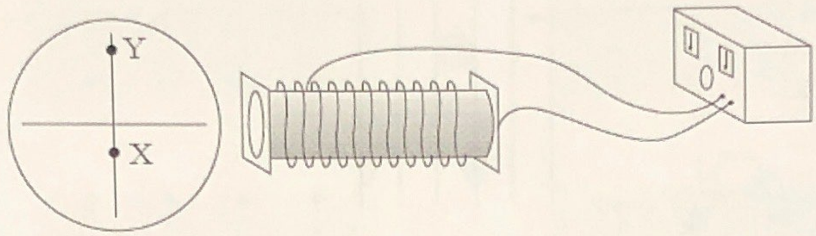
always being forced toward middle of circle ✓

$F = QvB = (0.6C)(240\frac{m}{s})(1.4\times10^{-4}T)$

$= 0.020N$ ✓

35. An aircraft whose wingspan is 15m carries a static charge of 0.60 C. It travels at 240 m/s perpendicular to a 1.4 x 10^{-4} T magnetic field. What magnetic force does the aircraft experience?

36. An undeflected electron beam strikes the centre of a cathode ray tube. A solenoid placed besides a cathode ray tube causes the electron beam to strike the screen at position X.



What changes to the magnitude and direction of the current in the solenoid would cause the electron beam to strike the screen at Y?

	CHANGE TO CURRENT MAGNITUDE	CHANGE TO CURRENT DIRECTION
A.	Increases	Remains the same
B.	Increases	Reverses
C.	Decreases	Remains the same
D.	Decreases	Reverses

✓

37. A coil having 150 turns and a cross-sectional area of 0.042 m² is oriented with its plane perpendicular to a 0.12 T magnetic field. If the field increases to 0.66 T in 0.25s, what emf is induced in the coil?

38. The magnetic field at the centre of a solenoid of length 0.25m is 1.2 x 10^{-2} T. The current in the windings is 7.5 A.

A. How many windings does the solenoid have?

B. If the cross-sectional area of the solenoid is 8.5 x 10^{-4} m², what is the flux through it?

(37)

$\mathcal{E} = -N\frac{\Delta\Phi}{\Delta t}$

$= \frac{-150(B_f - B_i)(A)}{0.25s}$

$= \frac{-150(0.66-0.12)(0.042m^2)}{0.25s}$

$= 14V$

(38) A. $B = \mu_0 \frac{N}{l} I \rightarrow N = \frac{Bl}{\mu_0 I}$

$= \frac{(1.2\times10^{-2}T)(0.25m)}{(\pi\times4\times10^{-7})(7.5A)}$

$= 318$ windings ✓

B. $\Phi = BA$

$= (1.2\times10^{-2}T)(8.5\times10^{4}m^2)$

$= 1.0\times10^{-5}$ Wb ✓

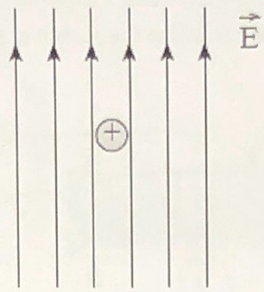
39. In an experiment, a positively charged oil droplet weighing 6.5×10^{-15} N is held stationary by a vertical electric field as show in the diagram.

$F_g = F_e$

$F_g = Q\vec{E}$

$Q = \frac{F_g}{\vec{E}}$

$= \frac{6.5 \times 10^{-15} N}{5.3 \times 10^{3} N/C}$

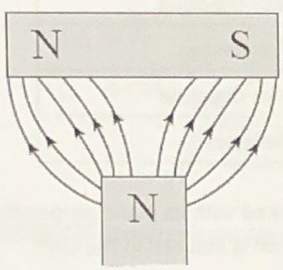


If the electric field strength is 5.3×10^3 N/C, what is the charge on the oil droplet?

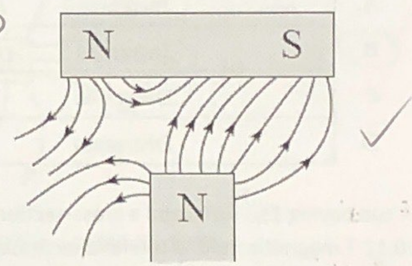
$= 1.2 \times 10^{-18} C$ ✓

40. Which of the following diagrams best represents the magnetic field in the region between the two permanent magnets? out of N, into S

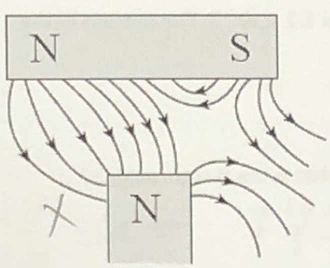
A. ✗



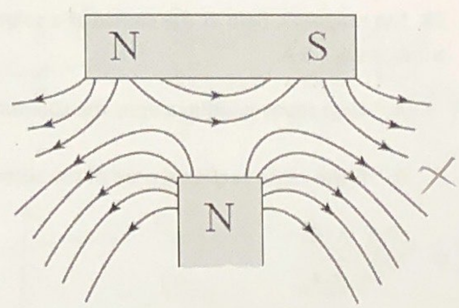
(B.) ✓



C. ✗

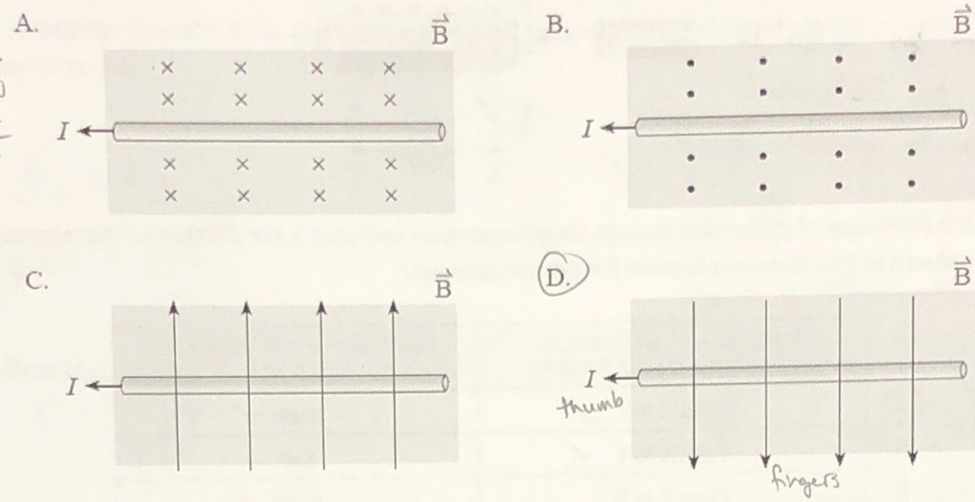


D. ✗



41. In which diagram would the current-carrying conductor experience a magnetic force out of the page?

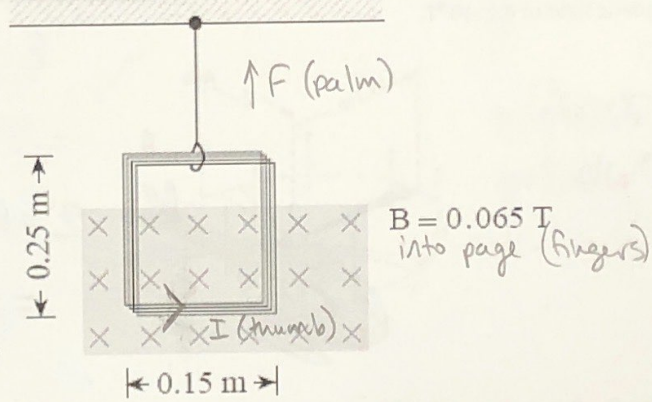
Fingers $= \vec{B}$
Thumb $= I$
palm $= \vec{F}$



✓ palm up

42. A coil of 25 turns of wire is suspended by a thread. When a current flows through the coil, the tension in the thread is reduced by 4.0 x 10^{-2} N.

the length is 25×0.15m (part of loop that will create force)



What are the magnitude and direction of the current? RHR → CCW

$F = BIl$

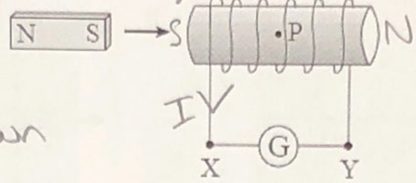
$I = \frac{F}{Bl}$

$= \frac{4.0 \times 10^{-2}\,N}{(0.065T)(25 \times 0.15m)} = 0.16A$ ✓

43. A bar magnet is moving toward a solenoid.

Lenz's created to repulse incoming S- pole

- fingers go S to N inside solenoid
- thumb points down



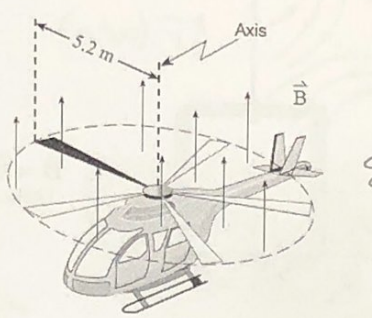
What is the direction of the current through the galvanometer and what is the direction of the magnetic field produced by this current at location P inside the solenoid?

	DIRECTION OF THE CURRENT THROUGH THE GALVANOMETER	DIRECTION OF THE MAGNETIC FIELD AT P (inside solenoid S to N)
✓ (A.)	From X to Y ✓	Right ✓
B.	From X to Y ✓	Left
C.	From Y to X	Right ✓
D.	From Y to X	Left

44. The 5.2m long metal rotor blades of a helicopter spin at 6.0 revolutions per second perpendicular to the earth's magnetic field of $4.7x10^{-5}$T.

$T = \frac{1}{6}$ s

$\Phi = BA$
$= (4.7\times10^{-5}\,T)(\pi\times5.2^2\,m^2)$
$= 4.0\times10^{-3}\,Wb$



$\mathcal{E} = B\ell v$ — velocity half way along blade for v_{avg}

$\frac{\text{Circum}}{t} =$

$\mathcal{E} = (4.7\times10^{-5}\,T)(5.2\,m)\left(\frac{2\pi\times\frac{5.2\,m}{2}}{\frac{1}{6}\,s}\right)$

$= 2.4\times10^{-2}\,V$

What is the magnetic flux swept out by the rotor blades in one revolution and what is the emf induced between the axis and tip of a rotor blade?

	MAGNETIC FLUX	EMF INDUCED
(A)	4.0×10^{-3} Wb ✓	2.4×10^{-2} V ✓
B.	4.0×10^{-3} Wb ✓	4.0×10^{-3} V
C.	2.4×10^{-2} Wb	2.4×10^{-2} V ✓
D.	2.4×10^{-2} Wb	4.0×10^{-3} V

✓

$F_m = F_c$

$qvB = \frac{mv^2}{r}$

$r = \frac{mv}{qB} = \frac{(1.67\times10^{-27}\,kg)(3.6\times10^5\,m/s)}{(1.6\times10^{-19}\,C)(5.0\times10^{-5}\,T)} = 75\,m$

45. a) A proton moves with a speed of 3.6×10^5 m/s at right angles to a uniform 5.0×10^{-5}T magnetic field. What is the radius of curvature for the motion of the proton?

RHR

b) Describe the path of the proton in the magnetic field and use principles of physics to explain the proton's motion. if $\vec{B}$ is north (fingers) and proton moves east (thumb), then $\vec{F}$ is up (palm) so proton's direction changes.
As p's direction changes so does direction of $\vec{F}$... proton curves in circ. path.

46. A computer adapter contains a transformer that converts 120 V ac across its primary windings to 24 V ac across its secondary windings. The primary current is 1.2 A. What is the secondary current and what is the type of transformer?

a. 0.24 A, Step-up
b. 0.24 A, Step-down
c. 6.0 A, Step-up
d. 6.0 A, Step-down

$\frac{V_s}{V_p} = \frac{I_p}{I_s}$

$I_s = \frac{I_p V_p}{V_s} = \frac{(1.2A)(120)}{24} = 6\,A$

47. An automobile starter motor, connected to a 12.0 V battery, produces a back emf of 9.7 V when operating at normal speed. A malfunction prevents the starter motor from turning and the current increases to 180 A. What current does the starter motor draw when operating normally?

no V_{back} produced when not rotating

$V_{back} = 0 = \mathcal{E} - Ir$

$0 = 12 - (180A)r$

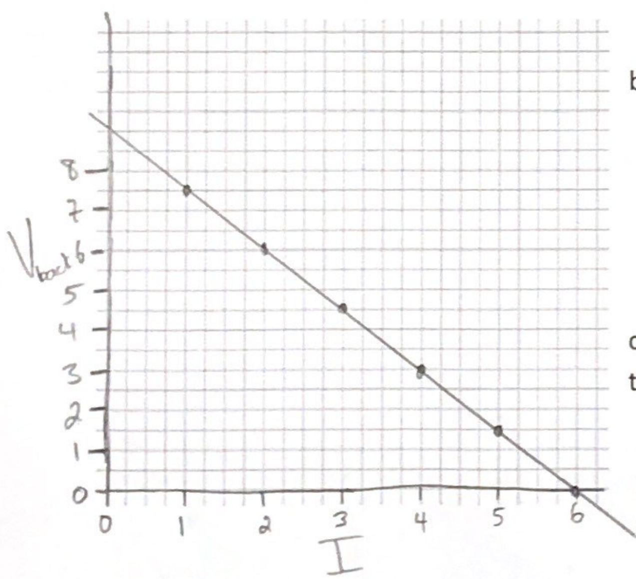
$r = 0.0666\,\Omega$

then $I_{running} = \frac{V_{back} - \mathcal{E}}{r} = \frac{9.7-12}{0.0666} = 35\,A$

48. An electric motor is connected to a 9.0 V power supply. The data table below shows how the back emf of the motor, *V_{back}*, varies with the current through the armature, *I*, as the mechanical load changes.

Back emf (V)	7.5	6.0	4.5	3.0	1.5	0.0
Current (A)	1.0	2.0	3.0	4.0	5.0	6.0

a. Plot this data on the graph below.



b. Determine the slope of the graph.

$m = \frac{rise}{run} = \frac{0-7.5}{6-1} = -1.5\,\frac{V}{A}$

$= -1.5\,\Omega$

c. What property of the motor does the slope of this graph represent?

internal resistance

49. An electric device operates on 9.0 V ac and has a total resistance of 21 Ω. An ideal transformer is used to change the incoming line voltage of 120 V ac to the operating voltage of 9.0 V ac.

V_p V_s

a. Is the transformer a step-up or step-down transformer?
b. What is the current in the primary side?

$I_s = \frac{V_s}{R} = \frac{9V}{21\Omega} = 0.42857A$

$\frac{I_p}{I_s} = \frac{V_s}{V_p}$

$I_p = I_s \frac{V_s}{V_p} = (0.42857A)\left(\frac{9V}{120V}\right) = 0.032A$

✓

50. A motor is connected to a 12 V dc supply and draws 5.0 A when it first starts up. What will be the back emf when the motor is operating at full speed and drawing 1.2 A?

$r = \frac{V}{I} = \frac{12V}{5A} = 2.4\Omega$

$V_{back} = \mathcal{E} - Ir = 12V - (1.2A)(2.4\Omega) = 9.1V$

✓

51. An ideal transformer has a potential difference of 180 V ac across the primary windings and a potential difference of ~~780~~ 1080 V ac across the secondary windings. There are 390 turns in the secondary. The secondary current is:

V_p V_s N_s

a. twice the primary current.
b. one half the primary current.
c. six times the primary current.
d. one-sixth the primary current. ✓

$\frac{I_s}{I_p} = \frac{V_p}{V_s} = \frac{N_p}{N_s}$

$I_s = \frac{180V}{1080V} I_p = \frac{1}{6} I_p$

✓

52. An electric motor is connected to a 12.0 V power supply. When the armature is prevented from rotating, the current is 8.0 A. When the motor is running at normal speed, the current is 2.0 A. What is the back emf in each case?

$V_{back} = 0$ so $\mathcal{E} = Ir$ so $r = \frac{\mathcal{E}}{I} = 1.5\Omega$

	Back emf when stationary	Back emf when running
a. ✓	0.0 V ✓	9.0 V
b.	0.0 V ✓	3.0 V
~~c.~~	12 V	9.0 V
~~d.~~	12 V	3.0 V

$V_{back} = \mathcal{E} - Ir = 12 - (2A)(1.5\Omega) = 9.0V$

53. A transformer has 840 primary (N_p) and 56 secondary (N_s) windings. The primary coil is connected to a 110 V (V_p) ac power supply which delivers a 0.30 A (I_p) current to the transformer.

a. Find the secondary voltage.

$$\frac{V_s}{V_p} = \frac{N_s}{N_p}$$

$$V_s = \frac{56}{840}(110V) = 7.3V \checkmark$$

b. Find the secondary current.

$$\frac{I_s}{I_p} = \frac{N_p}{N_s}$$

$$I_s = \frac{840}{56}(0.3A) = 4.5A \checkmark$$

54. As a carpenter drills into a beam, friction on the drill bit causes the armature of the drill to slow down. How will the back emf and the current through the armature change as the drill slows down?

	Back emf	Current
a.	Increase	Increase ✓
b.	Increase	Decrease
✓ (c.)	Decrease ✓	Increase ✓
d.	Decrease ✓	Decrease

V_{back} – decrease (would be zero if armature stopped)

I – increases as V_{back} decreases

55. An electric motor rotates at various speeds and the current through the armature changes accordingly. Which pair of conditions occurs when the motor generates the greatest back emf?

a. Fastest, largest current
✓ (b.) Fastest, smallest current
c. Slowest, largest current
d. Slowest, smallest current

$$V_{back} = \mathcal{E} - Ir$$

56. A transformer connected to a 120 V (V_p) ac supply has 7000 primary (N_p) and 350 secondary (N_s) windings. It delivers a secondary current of 2.4 A (I_s). Find the primary current and secondary voltage.

$$\frac{I_p}{I_s} = \frac{N_s}{N_p}$$

$$I_p = \frac{350}{7000}(2.4A) = 0.12A \checkmark$$

$$\frac{V_s}{V_p} = \frac{N_s}{N_p}$$

$$V_s = \frac{350}{7000}(120V) = 6.0V \checkmark$$

57. A dc motor has a resistance of 2.0 Ω. When connected to a 12 V source, with the motor rotating at its operational speed, a back emf of 5.5 V is generated. What is the current in the motor at operational speed?

$$V_{back} = \mathcal{E} - Ir$$

$$I = \frac{V_{back} - \mathcal{E}}{r} = \frac{5.5V - 12V}{2\Omega} = 3.3A \checkmark$$