Physics 126 Spring 2009 **Name:**

Exam 3

Time Allowed: 2 hours

Circle the correct answer for 21 questions, worth 5 points each.

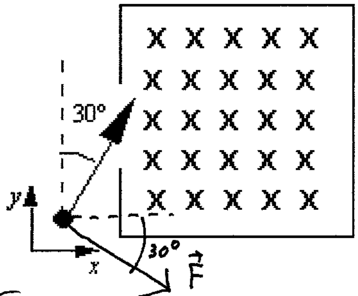
Physical Constants needed: Charge of electron $e=1.6\times10^{-19}$C;

Mass of proton = 1.67×10^{-27} kg

Permeability of free space $\mu_0=4\pi\times10^{-7}$ T-m/A

1 G = 10^{-4} T

1. An electron enters a region that contains a magnetic field directed into the page as shown. The velocity vector of the electron makes an angle of 30° with the +*y* axis. What is the direction of the magnetic force on the electron when it enters the field?



(a) at an angle of 30° below the positive *x* axis
(b) at an angle of 30° above the positive *x* axis
(c) at an angle of 60° below the positive *x* axis
(d) at an angle of 60° above the positive *x* axis

2. If the magnetic field in the previous problem is 0.6T, and the force on the electron is 4.8×10^{-13}N, what is the velocity of the electron?

(a) 5.0×10^6 m/s
(b) 5.0×10^7 m/s
(c) 4.0×10^6 m/s
(d) 4.0×10^7 m/s

$F = qvB$

$v = \frac{F}{qB} = \frac{4.8\times10^{-13}}{1.6\times10^{-19}\times0.6} = 5.0\times10^6$ m/s

3. An alpha particle with kinetic energy of 3.0 MeV entering a region where the magnetic field is 1.5T and pointing out of the paper will travel in a circle. What is the radius of the circle?

(a) 0.35m,
(b) 0.24m
(c) 0.17m
(d) 0.09m

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

$r = \frac{mv}{qB}$

$v = \sqrt{\frac{2K}{m}} = \sqrt{\frac{2\times3\times10^6\times1.6\times10^{-19}}{(4\times1.67\times10^{-27})}} = 1.2\times10^7$ m/s

$= \frac{(4\times1.67\times10^{-27})\times1.2\times10^7}{(2\times1.6\times10^{-19})\times1.5} = 0.17$ m

4. How many complete revolutions will the alpha particle in the previous problem make in 12 ms?

(a) 7,000
(b) 15,000
(c) 88,000
(d) 140,000

Period $T = \frac{2\pi r}{v} = \frac{2\pi \frac{mv}{qB}}{v} = \frac{2\pi m}{qB} = \frac{2\pi \times 4 \times 1.67\times10^{-27}}{2\times1.6\times10^{-19}\times1.5} = 8.7\times10^{-8}$ s

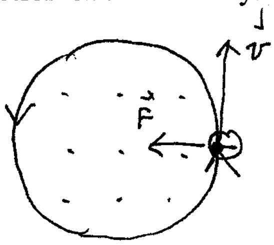
no. of revolutions $= \frac{12\times10^{-3}}{8.7\times10^{-8}} = 140,000$

5. Complete the following sentence:

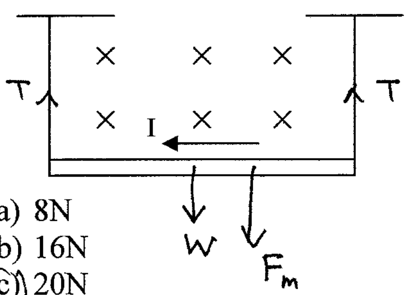
A magnetic field does not change the speed of a moving charged particle because

the magnetic force is perpendicular to the velocity of the particle and hence does no work.

6. An electron travels in a circular orbit in a magnetic field pointing out of the paper. Sketch the orbit and indicate the direction of the velocity.



7. The diagram below shows a metal rod suspended on its ends by two wires. The length of the rod is 50cm. Its weight is 28N. The rod is immersed in a magnetic field of 2.0T directed into the paper. Find the tension on each wire when a current of 12 A flows in the rod from right to left.



Magnetic force $= ILB$

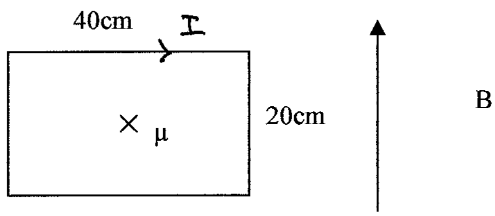
$= 12\times0.5\times2 = 12$ N downward

$2T = W + F_m = 28 + 12 = 40$ N

$T = 20$ N

(a) 8N
(b) 16N
(c) 20N
(d) 40N

8. The diagram below shows a current-carrying rectangular frame of metallic wires with dimensions indicated. The magnetic moment is 0.24A-m^2, and is directed into the paper. Find the magnitude and direction of the current.



$|\tilde{\mu}| = IA$

$I = \frac{|\tilde{\mu}|}{A} = \frac{0.24}{0.4 \times 0.2} = 3\text{ A}$

(a) 4A, clockwise
(b) 4A, counter clockwise
(c) 3A, clockwise
(d) 3A, counter clockwise

9. Referring to the previous problem, if the wire frame is now placed in a region where the magnetic field is uniform and is equal to 0.6 T pointing up, what is the magnitude of the torque on the frame, and in which direction will the top wire move as a result of the torque?

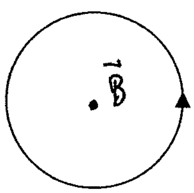
(a) 0.144 N-m, into the paper
(b) 0.144 N-m, out of the paper
(c) 0.288 N-m, into the paper
(d) 0.288 N-m, out of the paper

$\tau = \mu B \sin\theta$

$= 0.24 \times 0.6 \sin 90^0 = 0.144\text{ N.m}$

Since the magnetic moment behaves like a compass needle pointing from S to N into the paper, the B field will cause to top wire to move out of the paper.

10. The diagram below is a circular ring of radius 2.0cm carrying a counter-clockwise current of 5.0A. Find the magnetic field at the center and indicate its direction in the diagram.

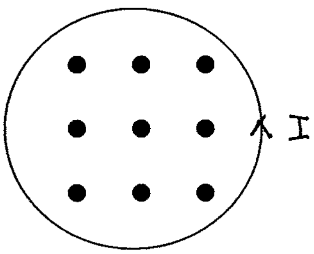


$B_{center} = \frac{\mu_0 I}{2R}$ ~~$= \frac{4\pi \times 10^{-7} \times 5}{2 \times (0.02)^2 \pi}$~~

$= \frac{4\pi \times 10^{-7} \times 5}{2 \times 0.02} = 1.6 \times 10^{-4}\text{ T} = 1.6\text{ G}$

(a) 1.6G
(b) 3.2G
(c) 16 G
(d) 32 G

11. The diagram below is an end on view of a 75 turn solenoid 5.0cm in length, with a radius of 0.5 cm. The magnetic field inside the solenoid is 50 G and is directed out of the paper. Find the current and indicate its direction in the diagram.

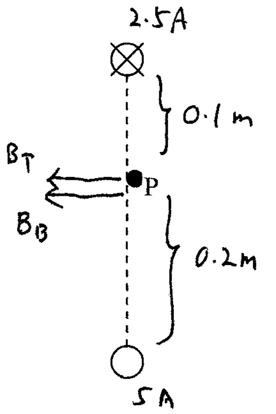


$$B = \mu_0 \frac{N}{l} I$$

$$I = \frac{B l}{\mu_0 N} = \frac{50\times10^{-4}\times0.05}{4\pi\times10^{-7}\times75} = 2.7\text{ A}$$

(a) 1.3A clockwise
(b) 1.3A counter clockwise
(c) 2.7A clockwise
(d) 2.7A counter clockwise

12. The diagram below shows two very long current carrying straight wires 0.3 m apart. The top wire carries 2.5 A into the paper, while the bottom carries 5.0 A out of the paper. Find the magnitude of the magnetic field at a point P between the wires which is 0.1m from the top wire.



Field due to top wire

$$B_T = \frac{4\pi\times10^{-7}\times2.5}{2\pi\times0.1} = 5\times10^{-6}\text{ T}$$

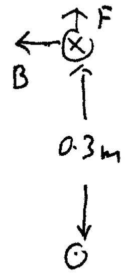
Field due to bottom wire

$$B_B = \frac{4\pi\times10^{-7}\times5}{2\pi\times0.2} = 5\times10^{-6}\text{ T}$$

$$B = B_T + B_B = 10^{-5}\text{ T}$$

(a) 3.0×10^{-5} T
(b) 2.0×10^{-5} T
(c) 1.0×10^{-5} T
(d) 0

13. If the length of the top wire is 3.0m in the previous problem, what is the magnitude and direction of the force on the top wire due to the current of the bottom wire?



(a) 2.5×10^{-5} N, downward
(b) 2.5×10^{-5} N, upward
(c) 4.3×10^{-5} N, downward
(d) 4.3×10^{-5} N, upward

Magnetic field at the top wire due to the bottom wire

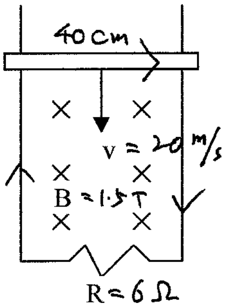
$$B = \frac{4\pi\times10^{-7}\times5}{2\pi\times0.3} = 3.3\times10^{-6}\text{ T}$$

Force on top wire $F = ILB = 2.5\times3\times3.3\times10^{-6}$
$= 2.5\times10^{-5}$ N

14. The principle of operation of a DC electric motor is based on which of the following factors:

(a) The induced current in a wire loop due to changing magnetic flux
(b) The force on moving charged particles in a magnetic field
(c) The toque on a current carrying coil in a steady magnetic field
(d) The motional emf in a coil rotating in a magnetic field

15. In an arrangement that demonstrates motional emf, a 40cm long metal rod glides freely down a pair of vertical conducting rails connected to a 6Ω resistance. The whole assembly is immersed in a 1.5T magnetic field pointing into the paper as shown. Find the induced current and its direction if the velocity of the rod is 20 m/s.



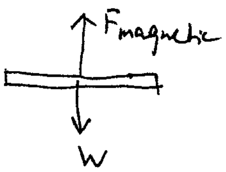
$\mathcal{E}_{motional} = vLB = 20 \times 0.4 \times 1.5 = 12V$

$I = \frac{\mathcal{E}}{R} = \frac{12}{6} = 2A$

(a) 3A, counter clockwise
(b) 3A, clockwise
(c) 2A, counter clockwise
(d) 2A, clockwise

16. If the velocity of the rod in the previous problem is maintained by gravity, and air resistance can be neglected, what is the weight of the rod?

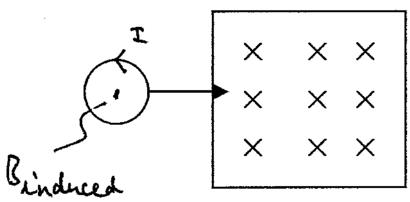
(a) 1.2N
(b) 2.4N
(c) 3.6N
(d) 4.8N



$W = F_{magnetic} = ILB$

$= 2 \times 0.4 \times 1.5 = 1.2\ N$

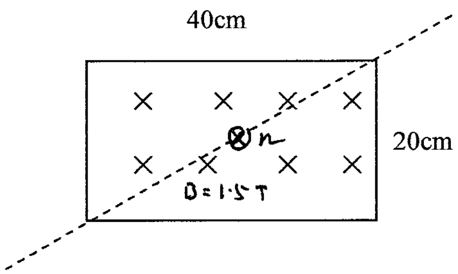
17. A metallic ring is pulled into a region where the magnetic field is into the paper as shown. Which is the direction of the current induced?



According to Lenz law, since the flux through the ring is increasing into the paper, the induced current must give an induced magnetic field out of the paper

(a) clockwise (b) counter clockwise

18. A rectangular wire frame with dimensions indicated is immersed in a magnetic field of 1.5T into the paper. It is then flipped through 180° about a diagonal in 30ms. Determine the average emf induced.



Choose normal direction into the paper

$\Phi_i = B_n A = 1.5 \times 0.4 \times 0.2 = 0.12$ Wb

$\Phi_f = -1.5 \times 0.4 \times 0.2 = -0.12$ Wb

$\mathcal{E}_{induced} = -\frac{\Delta\phi}{\Delta t} = -\frac{-0.12 - 0.12}{30 \times 10^{-3}}$

$= 8$ V

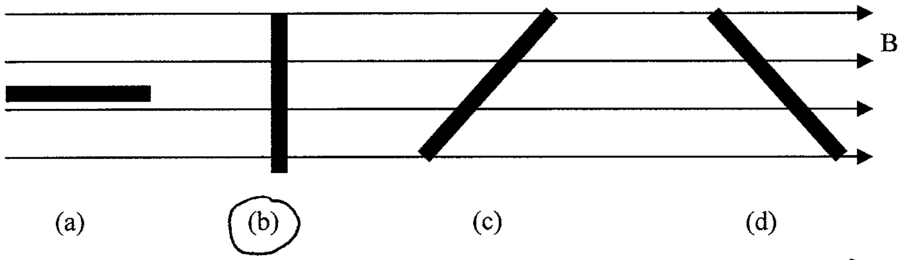
(a) 4 V
(b) 6 V
(c) 8 V
(d) 10 V

19. An ideal transformer is used to step voltage down from 2,400V to 120 V. The number of turns in the secondary circuit is 180. What must be the number of turns in the primary circuit?

(a) 2400
(b) 3600
(c) 18
(d) 9

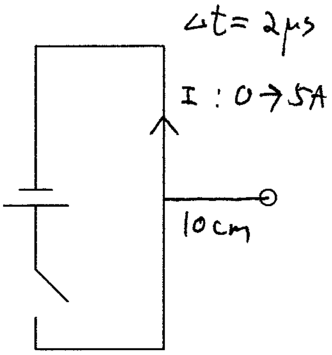
$\frac{\mathcal{E}_s}{\mathcal{E}_p} = \frac{N_s}{N_p}$ $\quad \therefore N_p = \frac{\mathcal{E}_p}{\mathcal{E}_s} N_s = \frac{2400}{120} \times 180 = 3600$

20. Four identical current carrying coils are placed in a uniform magnetic field. When viewed edge on, the orientations of the coils with respect to the magnetic field are as shown. Which coil will remain



stationary? Because its magnetic moment is parallel to $\vec{B}$

21. (BONUS) A circular wire loop is placed near a very long straight wire as shown. The radius of the loop is 1.0mm, and its center is 10 cm from the straight wire. When the power supply is turned on, the current in the straight wire increases to 5.0A in 2.0μs. What is the averaged current induced in the loop if its resistance is 10 Ω?



Magnetic field at the loop due to the wire current

$$= \frac{\mu_0 I}{2\pi r} = \frac{4\pi \times 10^{-7} \times 5}{2\pi \times 0.1} = 10^{-5}\ \text{T}$$

$$\Delta B = 10^{-5}\ \text{T.} \quad (\text{Change from } 0)$$

$$\Delta \Phi = (\Delta B) A$$

$$= 10^{-5} \times \pi (1 \times 10^{-3})^2 = \pi \times 10^{-11}$$

$$|\mathcal{E}_{ind}| = \frac{|\Delta \Phi|}{\Delta t} = \frac{\pi \times 10^{-11}}{2 \times 10^{-6}} = \frac{\pi}{2} \times 10^{-5}\ \text{V} = 1.6 \times 10^{-5}\ \text{V}$$

$$I = \frac{\mathcal{E}}{R} = \frac{1.6 \times 10^{-5}}{10} = 1.6 \times 10^{-6}\ \text{A} = 1.6\ \mu\text{A}$$