Physics 114 Exam 3 Fall 2019

Name: ____

For grading purposes (do not write here):

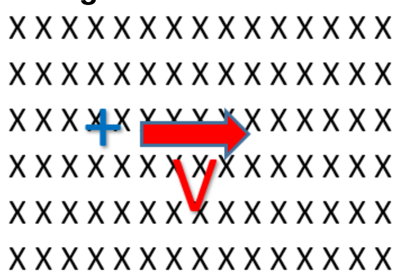
Question	Problem
1.	1.
2.	2.
3.	3.

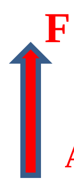
Points for each question and problem are indicated in red with the amount being spread equally among parts (a,b,c etc). Be sure to show all your work. Use the back of the pages if necessary.

Question 1 (10 points).

(a) Determine the direction of the force on the moving charges described below

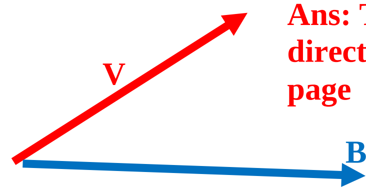
Magnetic field into paper, positive charge moving to the right





Ans: The force is upwards

Magnetic field and velocity vectors as shown with the charge being <u>negative</u>



Ans: The force is directly out of the page

(b) An electron moves in the plane of this paper toward the top of the page. A magnetic field is also in the plane of the page and directed toward the right. The direction of the magnetic force on the electron is described by which of the following?

(a) toward the top of the page
(b) toward the left edge of the page
(c) toward the bottom of the page
(d) toward the right edge of the page
(e) upward out of the page
(f) downward into the page

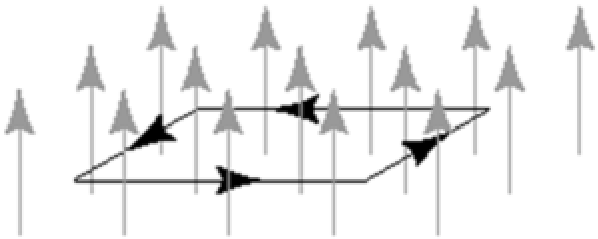
Ans: e. v X B is into the page but q is negative

(c) A wire carries current in the plane of this paper toward the top of the page. The wire experiences a magnetic force toward the right edge of the page. The direction of the magnetic field causing this force is which of the following?

(a) in the plane of the page and toward the left edge
(b) in the plane of the page and toward the bottom edge
(c) upward out of the page
(d) downward into the page
(e) None of the above

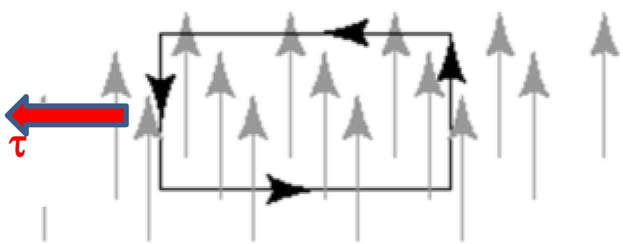
Ans: C. L is up. L X B isto the right if B is comining out of the page

Question 2 (10 points). (a) A rectangular loop is placed in a uniform magnetic field with the plane of the loop perpendicular to the direction of the field. If a current is made to flow through the loop in the sense shown by the arrows. Does the field exert a net force on the loop? Does it exert a new torque on the loop? If it does exert either one, what is the direction of the net force or torque (clearly draw it on the picture).



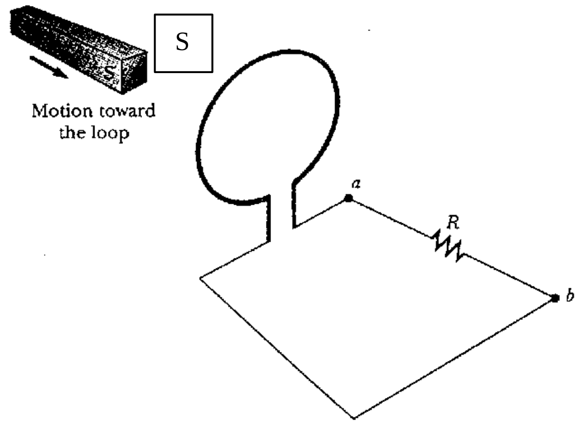
Ans: The net force on a closed loop in a uniform field is always **zero**. The torque here is also **zero**. $\tau = \vec{\mu} \times \vec{B}$ the magnetic moment is up, parallel to B so $\sin(\theta) = 0$

(b) Another rectangular loop is placed in a uniform magnetic field with the plane of the loop parallel to the direction of the field. If a current is made to flow through the loop in the sense shown by the arrows. Does the field exert a net force on the loop? Does it exert a new torque on the loop? If it does exert either one, what is the direction of the net force or torque (clearly draw it on the picture).

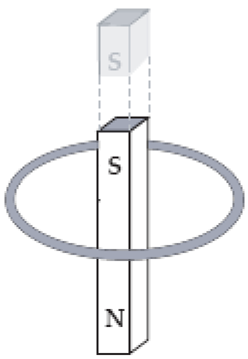


Ans: The net force on a closed loop in a uniform field is always **zero**. There is a torque. $\tau = \vec{\mu} \times \vec{B}$ The magnetic moment is out of the page, so the toque is to **the left.**

Question 3 (10 points). (a) A bar magnet is moved towards a loop with the south pole facing the loop as shown. (i) Is there a current induced in the loop?
Yes. Flux is changing
(ii) If so, is clockwise or counter-clockwise when looking through the loop at the magnet.
Flux increasing to left. Need increase flux to right **– CCW current**
(iii) Is V_b-V_a positive, negative or zero?
Kirchoff's law gives Vb-IR = Va. Vb – Va is **positive.**

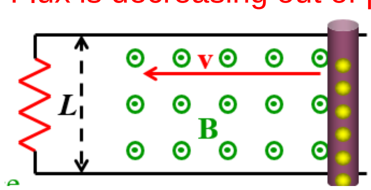


(b) A bar magnet is dropped from above and falls through the loop of wire shown below. The north pole of the bar magnet points downward towards the page as it falls. Which statement is correct?



a. The current in the loop always flows in a clockwise direction.
b. The current in the loop always flows in a counterclockwise direction.
c. The current in the loop flows first in a clockwise, then in a counterclockwise direction.
d. The current in the loop flows first in a counterclockwise, then in a clockwise direction.
This is the answer – d.
e. No current flows in the loop because both ends of the magnet move through the loop.

(c) Consider the circuit below with the constant magnetic field directed out of the page. The rod on the right moves at a constant velocity to the left. (i) Is there an induced current in the circuit – if so is it clockwise or counter-clockwise?
Flux is decreasing out of page so want to increase it out of page. Thus the current is **counter clockwise**



(ii) If and when this current is set up, does the magnetic field exert a force on the moving rod? If so what is the direction of that force?
The current in the rod is upward. Use L X B gives the field exerts a force to the **right**. This makes sense as it tries to stop the rod from moving
(iii) Is an external applied force needed to keep the bar moving or will it keep going on its own? Need external force (conservation of energy and Newton's laws)

Problem 1 A 2 C charge feels a magnetic force of $(-18\hat{i}+12\hat{j})$ N while it is traveling at 3 m/s along the z-axis. (a) (10 points). Determine the components of the magnetic field. If one of the components is undetermined state so. (b) (5 points). What is the angle between the magnetic force and the field?

(a) We have **F** = q**v** x **B. So**

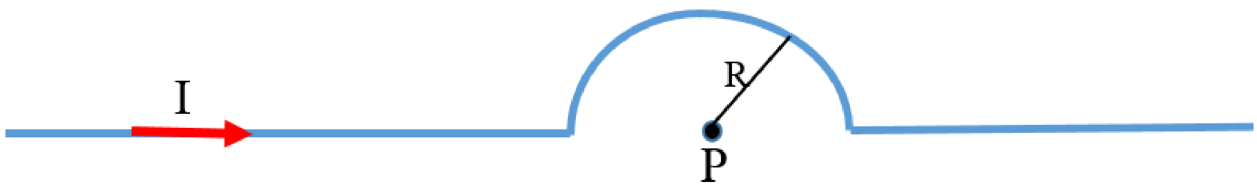
$$(-18\hat{i}+12\hat{j}) = (2)(3\hat{k}\times(B_x\hat{i}+B_y\hat{j}+B_z\hat{k}))$$
$$= (6)(B_x\hat{j}-B_y\hat{i}+B_z 0)$$

Thus B_z can be anything and is undetermined. Solving for each component we have the y component is 18/6 = 3 and the x component is 12/6 = 2. So

$\vec{B} = (2\hat{i}+3\hat{j})$

(b) The angle between the magnetic force and the magnetic field is **always 90 degrees.**

Problem 2. A long wire with a semicircular diversion as shown below carries a current of 2 A. The semicircle has a radius of 0.04 m. (a) (5 points Can Ampere's law be used to calculate the magnetic field at point P (at the center of the semi-circle)? (b) (10 points) Calculate the magnetic field at that point P by any means necessary. Include the direction



Solutions

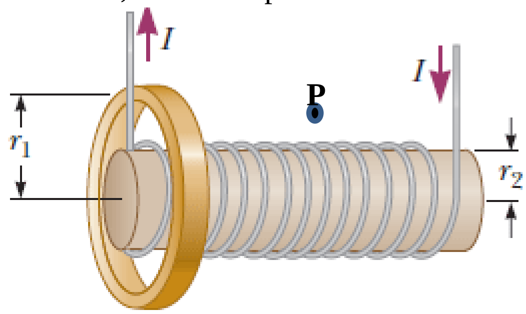
(a) No, there is not enough symmetry here to ue Ampere's law.
(b) We use Biot-Sarvart.

$\mathbf{B} = \frac{\mu_0 I}{4\pi}\int \frac{d\mathbf{s}\times\hat{\mathbf{r}}}{r^2}$. The cross product in the numerator is zero for the two straight parts since the vectors are in the same direction. For the semi-circle, the integral s/R^2 and s = πR. Thus,

$\mathbf{B} = \frac{\mu_0 I}{4\pi}\frac{\pi R}{R^2} = \frac{\mu_0 I}{4R}$ = (2.51E-6)/0.16 = 1.57 X 10^{-5} T

The direction is into the page.

Problem 3 (15 points). An aluminum ring of radius r_1 = 5.00 cm and a resistance of 3.60 $\times 10^{-4}$ Ω is placed around one end of a long air-core solenoid with 1, 065 turns per meter and radius r_2 = 3.00 cm as shown in the figure below. Assume the axial component of the field produced by the solenoid is one-half as strong over the area of the end of the solenoid as at the center of the solenoid. Also assume the solenoid produces negligible field outside its cross-sectional area. The current in the solenoid is increasing at a rate of 270 A/s.



(a) What is the magnitude of the induced current in the ring?
(b) What is the direction (clockwise or counterclockwise as viewed from the left).
(c) What is the magnitude of the electric field that induced at point P which is directly above the center of the solenoid a distance of r_3 = 4 cm from the center axis of the solenoid.
(d) What is the direction of the electric field at point P?

Solution

(a) We will get the current from the induced emf, I = ε/R. The magnetic field from the solenoid is $\mu_0 nI$, and it is half of that at the ring. The area is πr_2^2 since there is only flux inside the cross sectional area of the solenoid.

, =

$$|\mathcal{E}| = \frac{d(BA)}{dt} = \frac{1}{2}\frac{d}{dt}(\mu_0 nI)A = \frac{1}{2}\mu_0 n \frac{dI}{dt}\pi r_2^2 = \frac{1}{2}\mu_0 n\pi r_2^2 \frac{\Delta I}{\Delta t}$$ = 5.11 X 10^{-4} V

I = 5.11 X 10^{-4} / 3.60 $\times 10^{-4}$ = **1.42 A**

(b) The original flux is increasing to the right. Thus, the induced emf ust be to the left. This requires a counter clockwise current as viewed from the left end.

(c) Now we use the generalized version of Faraday's law

$\oint \vec{E}.d\vec{s} = -{d\Phi_B}/{dt}$. The right hand side is the same as what we got in part a except without the factor or ½. So it is 1.02 X 10^{-3} V

The left hand side we get $E2\pi r_3$, solving for E we get 4.07 X 10^{-3} V/m.

(d) The electric field points into the page – like the current in the ring

Possibly Useful Information

$$F = \frac{1}{4\pi\varepsilon_0}\frac{|q_1||q_2|}{r^2}$$

$$\varepsilon_0 = 8.85 \text{ X } 10^{-12} (C^2 / N - m^2)$$

$e = 1.6 \text{ X } 10^{-19}$ C

$$\vec{E} = \vec{F}/q_0$$

$$E = \frac{|q|}{4\pi\varepsilon_0 r^2}$$

$$\varepsilon_0 \Phi = \varepsilon_0 \oint \vec{E}.d\vec{A} = q_{enc}$$

$\Delta x = x_2 - x_1$, $\Delta t = t_2 - t_1$

$\bar{v} = \Delta x / \Delta t$

$\bar{s} = (\text{total distance}) / \Delta t$

$v = dx/dt$

$\bar{a} = \Delta v / \Delta t$

$a = dv/dt = d^2x/dt^2$

$v = v_o + at$

$g = 9.8 \text{ m/s}^2$

$x - x_o = v_o t + (½)at^2$

$\vec{r} = x\hat{i} + y\hat{j} + z\hat{k}$

$v^2 = v_o^2 + 2a(x - x_o)$

$\Delta\vec{r} = \vec{r}_2 - \vec{r}_1$

$x - x_o = ½(v_o + v)t$

$\Delta\vec{r} = (x_2 - x_1)\hat{i} + (y_2 - y_1)\hat{j} + (z_2 - z_1)\hat{k}$

$x - x_o = vt - 1/2at^2$

$\bar{\vec{v}} = \Delta\vec{r} / \Delta t$, $\vec{v} = d\vec{r} / dt$

$\vec{a} = d\vec{v} / dt$

$\bar{\vec{a}} = \Delta\vec{v} / \Delta t$

$\Delta U = U_f - U_i = -W$

$U = -W_\infty$

$\Delta V = V_f - V_i = -W/q_0 = \Delta U/q_0$

$V = -W_\infty/q_0$

$$V_f - V_i = -\int_i^f \vec{E}.d\vec{s}$$

$$V = -\int_i^f \vec{E}.d\vec{s}$$

$$V = \frac{1}{4\pi\varepsilon_0}\frac{q}{r}$$

$$V = \sum_{i=1}^{n} V_i = \frac{1}{4\pi\varepsilon_0}\sum_{i=1}^{n}\frac{q_i}{r_i}$$

$$V = \frac{1}{4\pi\varepsilon_0}\int \frac{dq}{r}$$

$$E_s = \frac{\partial V}{\partial s}$$

$$E_x = -\frac{\partial V}{\partial x}; E_y = -\frac{\partial V}{\partial y}; E_z = -\frac{\partial V}{\partial z}$$

$$E = \frac{\Delta V}{\Delta s}$$

$$U = -W = \frac{1}{4\pi\varepsilon_0}\frac{q_1 q_2}{r_{12}}$$

$Q = CV$

$$C = \frac{\varepsilon_0 A}{d}$$

$$C = 2\pi\varepsilon_0 \frac{l}{\ln(b/a)}$$

$$C = 4\pi\varepsilon_0 \frac{ab}{b - a}$$

$C = 4\pi\varepsilon_0 R$

$C_{eq} = \sum C_j$ (parallel)

$$\frac{1}{C_{eq}} = \sum \frac{1}{C_j} \text{ (series)}$$

$$U = \frac{Q^2}{2C} = \tfrac{1}{2} CV^2$$

$u = \tfrac{1}{2} \varepsilon_0 E^2$

$C = \kappa C_0$

I= dQ/dt

$\rho = 1/\sigma$

$R = \rho L / A$

V = IR

P = IV

$P = I^2R = V^2/R$

$I = \varepsilon / (R + r)$

$P_{emf} = I\varepsilon$

$R_{eq} = \sum R_j$ (series)

$$\frac{1}{R_{eq}} = \sum \frac{1}{R_j} \text{ (parallel)}$$

$q(t) = Q(1-e^{-t/RC})$

$I = (\varepsilon/R)e^{-t/RC}$

$q(t) = Qe^{t/RC}$

$I = (Q/RC)e^{-t/RC}$, $I_0 = (Q/RC)$

$\vec{F} = q\vec{v} \times \vec{B}$

r = mv/qB, ω = qB/m

$\vec{F} = I\vec{L} \times \vec{B}$

$d\vec{F} = Id\vec{s} \times \vec{B}$

$\tau = \vec{\mu} \times \vec{B}$

$U = -\vec{\mu} \bullet \vec{B}$

$\vec{\mu} = NI\vec{A}$

$d\vec{B} = \frac{\mu_0}{4\pi} \frac{Id\vec{s} \times \vec{r}}{r^3}$, $\mu_0 = 4\pi \times 10^{-7}$ T·m/A

$$\mathbf{B} = \frac{\mu_0 I}{4\pi} \int \frac{d\mathbf{s} \times \hat{\mathbf{r}}}{r^2}$$

$$B = \frac{\mu_0 I}{4\pi a}(\cos\theta_1 + \cos\theta_2)$$

$B = \mu_0 I/2\pi r$

$B = \mu_0 nI$ (solenoid)

$F/l = (\mu_0 I_1 I_2)/2\pi a$

$\oint \vec{B}.d\vec{s} = \mu_0 I_{enc}$

$$\varepsilon = \oint \vec{E}.d\vec{s} = -\frac{d\Phi_B}{dt}$$

$\Phi_B = \int \vec{B}.d\vec{A}$

ε= Blv

$\Phi_B = \oint \vec{B}.d\vec{A} = 0$