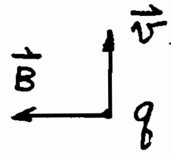
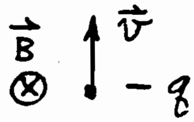
LORENTZ'S LAW FOR MAGNETIC FORCES OR A PAGE OF CHIROPRACTIC EXERCISES.

IN THE BLANK, PUT A "→, ←, ↑, ↓, ⊗, ⊙, OR ZERO" TO INDICATE THE DIRECTION OF THE F_M ON q OR i.

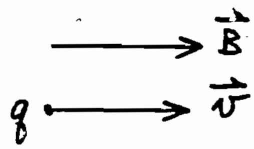
a) ______



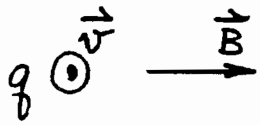
b) ______



c) ______

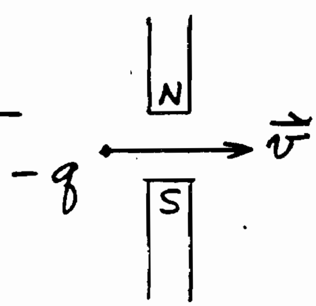


d) ______

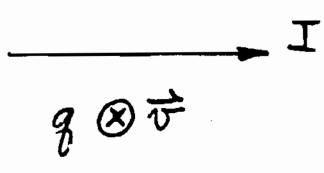


e) ______

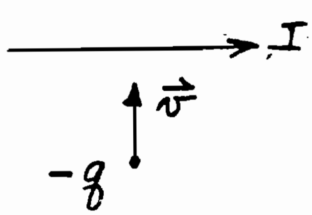
f) ______



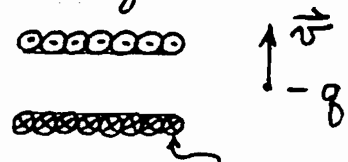
g) ______ F_M ON q



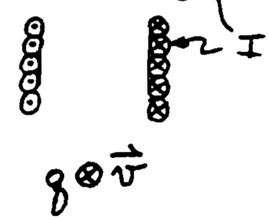
h) ______ F_M ON $-q$



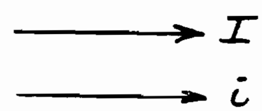
i) ______



j) ______

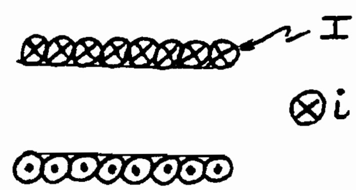


k) ______ F ON i

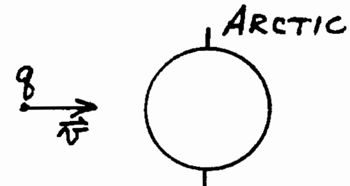


l) ______

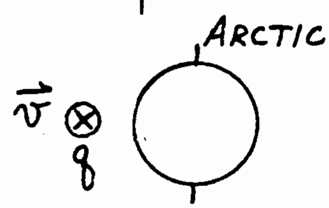
m) ______ FORCE ON i



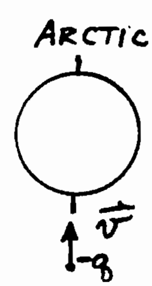
n) ______



o) ______



p) ______



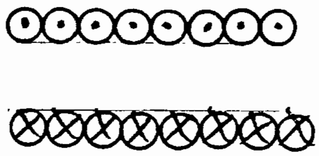
MAGNETIC FIELDS

1. IN EACH CASE, SKETCH THE MAGNETIC FIELD AND WRITE A FORMULA FOR THE FIELD.

A) SINGLE WIRE CARRYING CURRENT I.

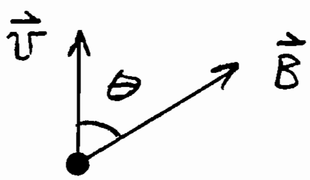
$B =$ ____________________

B) SOLENOID WITH N TURNS, LENGTH L AND CURRENT I.



$B =$ ____________________

2. FIND THE MAGNITUDE AND DIRECTION OF THE MAGNETIC FORCE ON THE MOVING CHARGE.



$q = 2\ C$

$m = 4\ KG$

$v = 13\ m/s$

$B = 5\ T$

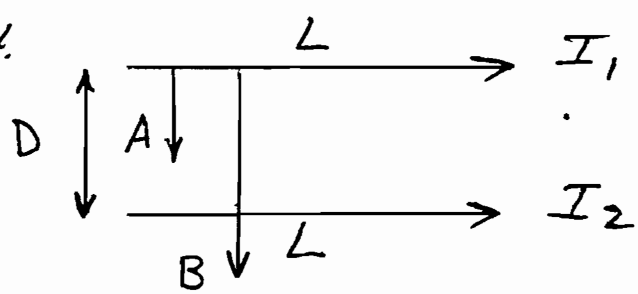
$\theta = 30.51^\circ$

3. $\vec{v} = (3, -4, 12)$ $\quad \vec{B} = (16, 18, 24)$ $\quad q = 2$

FIND: A) v $\quad$ B) B $\quad$ C) $\vec{F}_B$

D) F $\quad$ E) θ

4.



IN TERMS OF I_1, I_2, L, D, A AND B, FIND FORMULAS FOR:

a) TOTAL MAGNETIC FIELD AT LOCATION A.

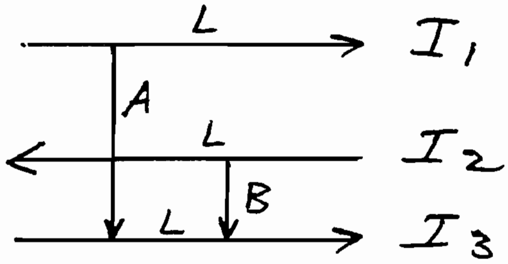
b) TOTAL MAGNETIC FIELD AT LOCATION B.

c) MAGNETIC FIELD ON WIRE 2 DUE TO WIRE 1.

d) MAGNETIC FORCE ON WIRE 2 DUE TO WIRE 1.

e) DO THEY ATTRACT OR REPEL?

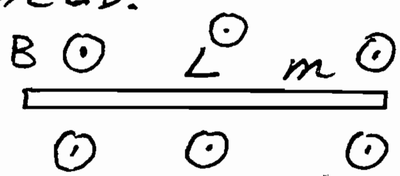
5.



IN TERMS OF I_1, I_2, I_3, A, B AND L, FIND A FORMULA FOR THE TOTAL MAGNETIC FORCE ON WIRE 3.

6. AN EXTERNAL MAGNETIC FIELD COMES OUT OF THE PAPER. A CURRENT FLOWS THROUGH A WIRE SO THAT IT HANGS SUSPENDED IN THIS FIELD.

L = LENGTH m = MASS

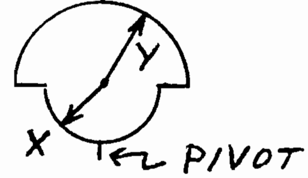


A) IN WHICH DIRECTION MUST THE CURRENT FLOW TO CREATE AN UPWARD MAGNETIC FORCE?

B) SKETCH THE MAGNETIC FIELD CREATED BY THIS CURRENT.

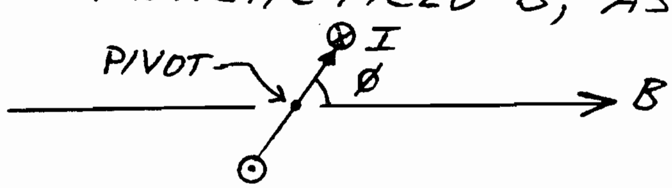
C) IN TERMS OF m, g, L AND B, FIND A FORMULA FOR THE CURRENT.

7. A LOOP OF WIRE WITH MULTIPLE TURNS HAS DIMENSIONS SHOWN. IT HAS N NUMBER OF TURNS AND CARRIES CURRENT I.



A) IN TERMS OF N, I, X AND Y, FIND A FORMULA FOR THE MAGNETIC DIPOLE MOMENT OF THIS LOOP.

B) THE LOOP IS ORIENTED IN AN EXTERNAL MAGNETIC FIELD B, AS SHOWN BELOW.



ON THE DIAGRAM, DRAW THE MAGNETIC DIPOLE VECTOR $\vec{\mu}$.

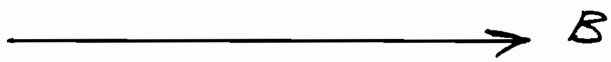
C) IN TERMS OF B, μ AND ϕ, FIND A FORMULA FOR THE MAGNITUDE OF THE TORQUE ON THE LOOP.

D) FIND THE DIRECTION OF THE TORQUE, $\vec{\tau}$.

E) IN TERMS OF μ, B AND ϕ, WRITE A FORMULA FOR THE POTENTIAL ENERGY OF THE LOOP AT ITS PRESENT LOCATION.

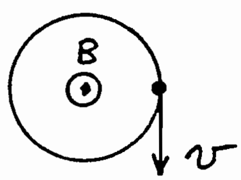
F) IN WHICH DIRECTION WILL IT ROTATE AS IT MOVES TOWARD EQUILIBRIUM.

G) IN THE MAGNETIC FIELD BELOW, DRAW THE LOOP IN ITS EQUILIBRIUM POSITION. SHOW THE DIRECTION OF THE CURRENT. SKETCH AND LABEL $\vec{\mu}$.

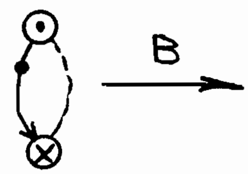


8. IN EACH CASE, A CHARGED PARTICLE IS MOVING IN A CURVED PATH IN A MAGNETIC FIELD. FIND ITS PARITY, THAT IS, ITS SIGN.

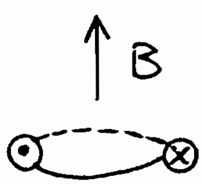
A)



B)



C)

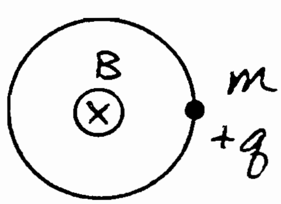


D)

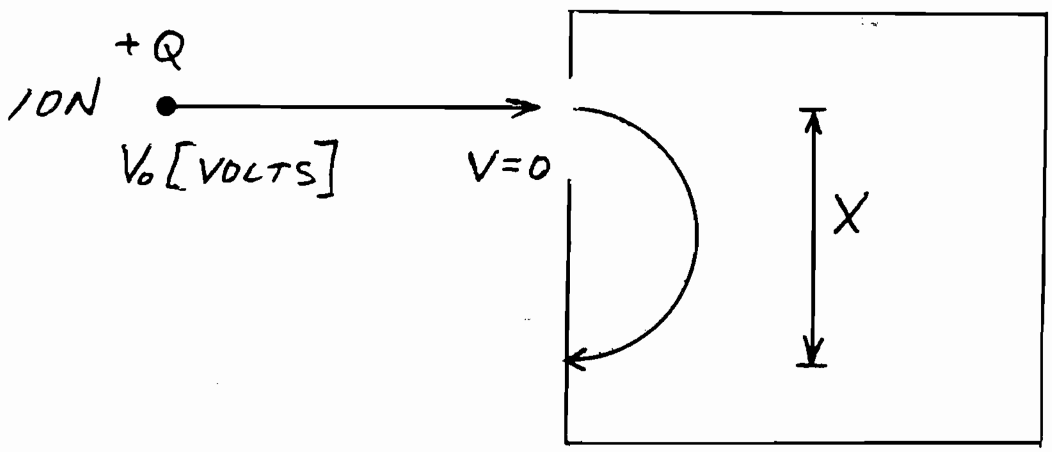
9. A CHARGE q WITH MASS m MOVES IN A CIRCULAR PATH OF RADIUS R IN A MAGNETIC FIELD B.

A) FIND THE DIRECTION OF THE PARTICLE'S MOTION.

B) IN TERMS OF q, m, R AND B, FIND A FORMULA FOR ITS KINETIC ENERGY.



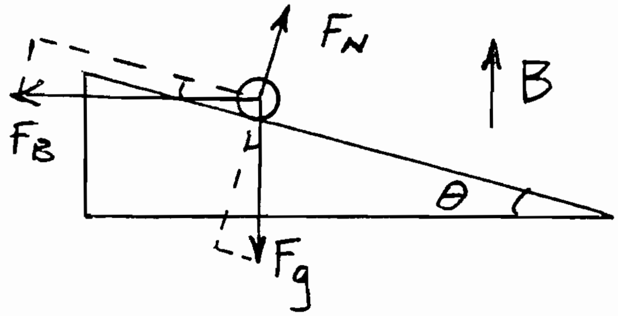
10. A MASS SPECTROMETER IS SHOWN BELOW. POSITIVE IONS OF CHARGE Q ARE ACCELERATED FROM VOLTAGE V_0 TO ZERO. THE IONS THEN ENTER A MAGNETIC FIELD B ORIENTED PERPENDICULAR TO THE PAPER. THE IONS CURVE AND STRIKE THE WALL AT LOCATION X.



A) IN THE SPECTROMETER, DRAW EITHER ⊙ OR ⊗ TO INDICATE THE DIRECTION OF THE MAGNETIC FIELD.

B) USE CONSERVATION OF ENERGY SIMULTANEOUSLY WITH DYNAMICS FOR UNIFORM CIRCULAR MOTION TO FIND A FORMULA FOR THE MASS OF THE ION. ONLY Q, V_0, B AND X ARE ALLOWED IN OUR ANSWER.

11. A WIRE OF LENGTH L AND MASS M IS PLACED ON A PLANE OF INCLINE θ. A VERTICAL MAGNETIC FIELD B EXERTS A FORCE ON THE CURRENT IN THE WIRE, i.



A) FIND THE DIRECTION OF THE CURRENT IN THE WIRE SO THAT THE F_B IS HORIZONTALLY BACKWARDS AS SHOWN.

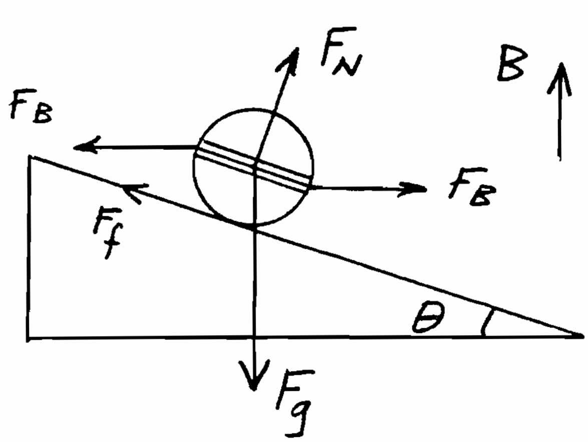
B) IN TERMS OF m, g, θ, i, L AND B, FIND A FORMULA FOR THE:

i) ACCELERATION OF THE WIRE ALONG THE INCLINE.

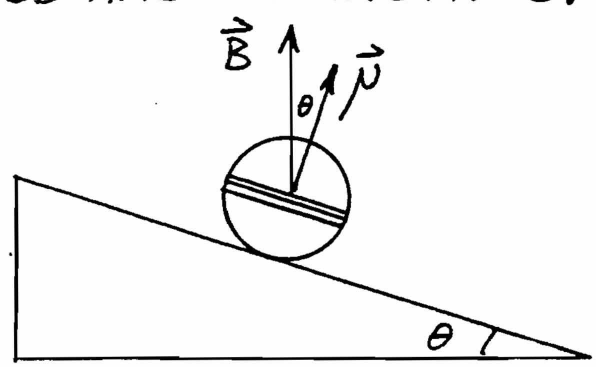
ii) NORMAL FORCE EXERTED ON THE WIRE.

C) IN TERMS OF m, g, θ, L AND B, FIND A FORMULA FOR THE CURRENT i_0 REQUIRED SO THAT THE WIRE IS STATIONARY.

12. A WOODEN CYLINDER OF MASS m AND RADIUS r SITS AT REST ON AN INCLINED PLANE OF ANGLE θ. THE CYLINDER HAS N LOOPS OF WIRE WRAPPED AROUND IT LONGITUDINALLY, PARALLEL TO THE INCLINE. EACH LOOP HAS AREA A AND CURRENT i. A VERTICAL EXTERNAL MAGNETIC FIELD HAS STRENGTH B.



FORCE DIAGRAM



MAGNETIC DIPOLE TORQUE DIAGRAM

A) FROM THE FORCE DIAGRAM, WRITE NEWTON'S EQUATIONS FOR THE X-AXIS AND FOR THE Y-AXIS.

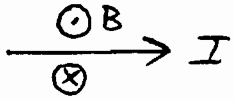
B) IN TERMS OF THE PHYSICAL TRAITS OF THE CYLINDER, WRITE A FORMULA FOR THE MAGNETIC DIPOLE MOMENT OF THE CYLINDER.

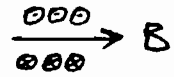
C) WRITE THE ROTATIONAL EQUATION FOR NEWTON'S LAW. NOTE THAT F_f AND N PRODUCE THE TWO TORQUES.

D) IN TERMS OF m, g AND θ, FIND A FORMULA FOR THE NORMAL FORCE.

E) USE THE X-EQUATION AND THE ROTATION EQUATION TO FIND A FORMULA FOR THE CURRENT i_0 SO THAT THE CYLINDER IS STATIONARY.

ANSWERS:

1. 

$B = \frac{\mu_0 I}{2\pi r}$ 

$B = \mu_0 \left(\frac{N}{L}\right) i$

2. $F_B = 66\,N$ $\otimes$

3. A) 13 m/s B) 34 T C) $(-624, 240, 236)\,N$
D) 709 N E) $53.3°$

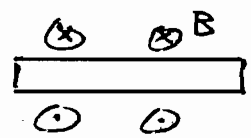
4. A) $B = \frac{\mu_0}{2\pi}\left[\frac{I_1}{A} - \frac{I_2}{D-A}\right]$

B) $B = \frac{\mu_0}{2\pi}\left[\frac{I_1}{B} + \frac{I_2}{B-D}\right]$

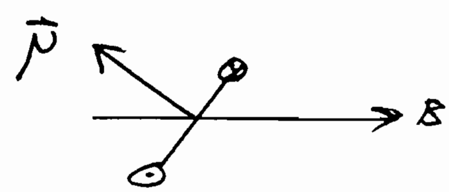
C) $B = \frac{\mu_0 I_1}{2\pi D}$ D) $F = \frac{\mu_0 I_1 I_2 L}{2\pi D}$

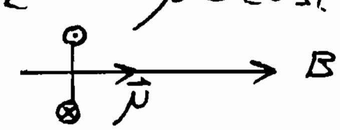
E) ATTRACT

5. $F = \frac{\mu_0 I_3 L}{2\pi}\left[\frac{I_2}{B} - \frac{I_1}{A}\right]$ REPULSIVE

6. A) TO THE LEFT B) 

C) $I = mg/LB$

7. A) $\mu = \frac{NI(x^2+y^2)\pi}{2}$ B) 

C) $\tau = \mu B \sin(\phi + 90°) = \mu B \cos\phi$ D) $\otimes$
E) $PE = -\mu B \cos(\phi + 90°) = \mu B \sin\phi$ F) CLOCKWISE
G) 

8. A) + B) − C) − D) −

9. A) COUNTERCLOCKWISE
B) $KE = \frac{q^2 B^2 r^2}{2m}$

10. $M = \frac{QB^2X^2}{8V_0}$ B $\odot$

11. A) $\odot$

B) $a_x = g\sin\theta - \frac{iLB}{m}\cos\theta$

$F_N = mg\cos\theta + iLB\sin\theta$

c) $i_0 = \frac{mg}{LB}\tan\theta$

12. A) $ma_x = F_g\sin\theta - F_f$

$ma_y = F_N - F_g\cos\theta$

B) $\mu = NiA$

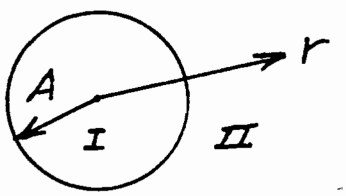
c) $I\alpha = \mu B\sin\theta - rF_f$

d) $F_N = mg\cos\theta$

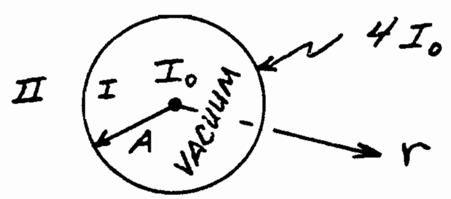
e) $i_0 = \frac{mgr}{NAB}$

AMPERE'S LAW

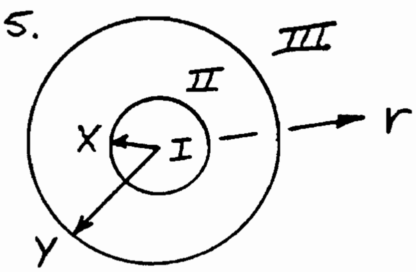
1. WRITE THE FORMULA FOR AMPERE'S LAW.
2. IN FOUR WORDS, STATE THE ESSENCE OF AMPERE'S LAW.
3. A SOLID CONDUCTOR OF RADIUS A HAS CURRENT DENSITY J UNIFORMLY DISTRIBUTED UPON ITS CROSS-SECTION. IN EACH ZONE, FIND A FORMULA FOR THE MAGNETIC FIELD AT OUR LOCATION r. ONLY J [AMP/m²], A AND r ARE ALLOWED IN OUR ANSWERS. SKETCH A GRAPH OF B VERSUS r.



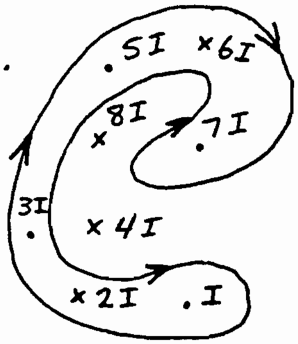
4. A CENTRAL WIRE CARRIES CURRENT I_0 OUT OF THE PAGE. A CONCENTRIC CONDUCTOR CARRIES CURRENT $4I_0$ INTO THE PAGE. IN EACH ZONE, FIND A FORMULA FOR THE MAGNETIC FIELD AT OUR LOCATION r. SKETCH A GRAPH OF B VERSUS r.



5. ZONE I IS HOLLOW. ZONE II HAS CURRENT DENSITY J [A/m²]. FIND A FORMULA FOR THE MAGNETIC FIELD IN EACH ZONE. ONLY J, X, Y AND r ARE ALLOWED IN OUR ANSWER. SKETCH A GRAPH OF B VERSUS r.

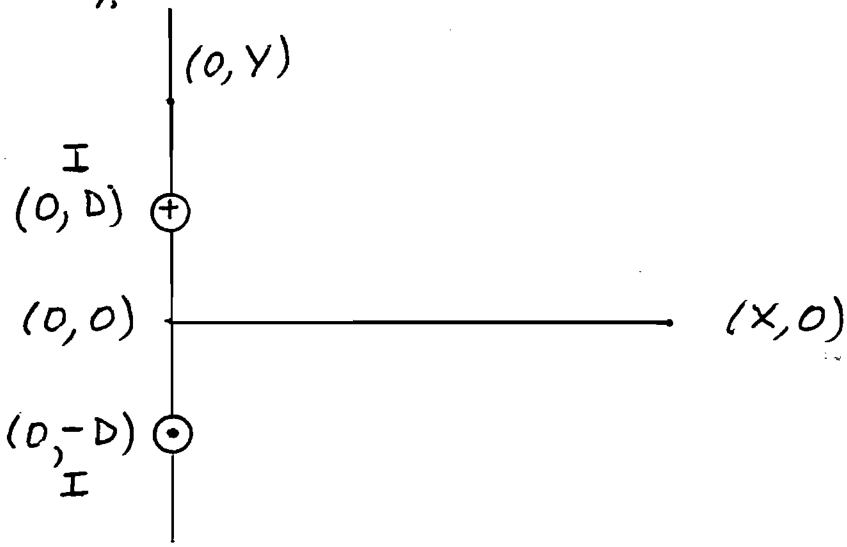


6. EVALUATE THE LINE INTEGRAL FOR $\vec{B}$. I IS ALLOWED IN OUR ANSWER.



$$\oint \vec{B} \cdot d\vec{l} = \underline{\hspace{6cm}}$$

7.

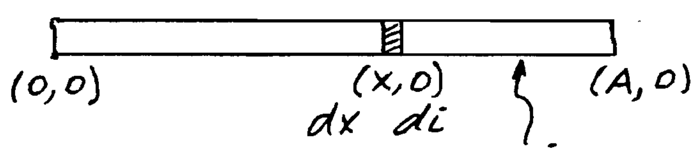


IN TERMS OF I, D, X AND Y, FIND A FORMULA FOR THE TOTAL MAGNETIC FIELD AT LOCATION:

A) $(X, 0)$ B) $(0, Y)$

8. FIND THE COMPONENTS OF $\vec{B}$ AT LOCATION $(0, Y)$.

$(Y, 0)$



THE SHEET IS INFINITE ALONG THE Z-AXIS.

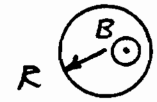
i IS COMING OUT OF THE PAGE.

NECESSARY INTEGRALS:

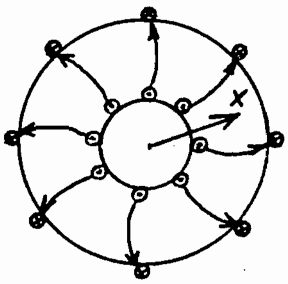
x: $$\int \frac{dx}{x^2 + y^2} = \frac{1}{Y} \tan^{-1}\left(\frac{X}{Y}\right)$$

y: $$\int \frac{x\,dx}{x^2 + y^2} = \frac{1}{2} \ln\left(x^2 + y^2\right)$$

9. A SOLENOID OF LENGTH L, TOTAL TURNS N AND RADIUS R, CARRIES CURRENT I. FIND A FORMULA IN TERMS OF THOSE QUANTITIES FOR THE MAGNETIC FLUX OF ITS INTERIOR CROSS-SECTIONAL AREA.



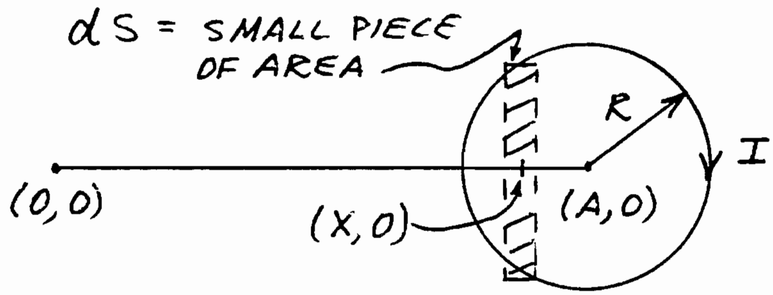
10. A TOROID OF N TURNS CARRIES CURRENT I.



A) INSIDE THE TOROID, DRAW THE DIRECTION OF $\vec{B}$.

B) USE AMPERE'S LAW TO FIND A FORMULA FOR THE MAGNETIC FIELD AT OUR LOCATION X. ONLY N, I AND X ARE ALLOWED IN OUR ANSWER.

C) A CROSS-SECTION OF THE TOROID IS SHOWN BELOW. INSIDE THE TOROID, DRAW THE DIRECTION OF THE MAGNETIC FIELD.

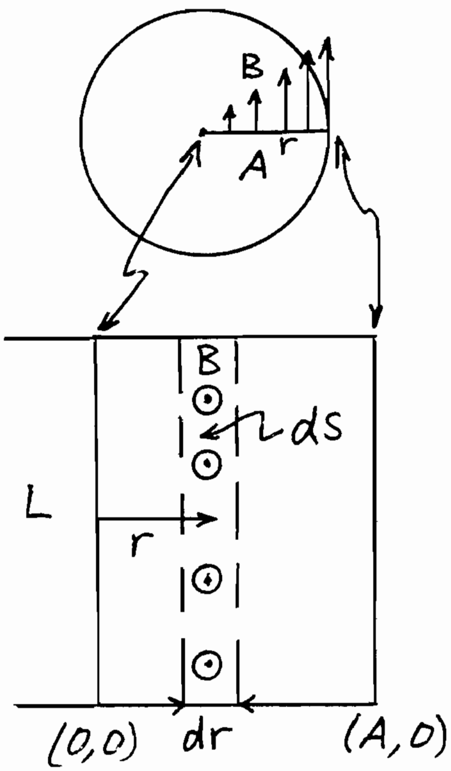


D) USING THE EQUATION IN (B), SKETCH A GRAPH OF THE MAGNETIC FIELD VERSUS X.

E) IN TERMS OF X, Y, A AND R, WRITE AN EQUATION FOR THE CIRCLE DRAWN IN PART (C).

F) WRITE AN INTEGRAL WITH LIMITS FOR THE MAGNETIC FLUX OF THE INTERIOR CROSS-SECTIONAL AREA OF THE TOROID. DO NOT EVALUATE THIS DEFINITE INTEGRAL. ONLY N, I, A, R AND X ARE ALLOWED IN OUR ANSWER.

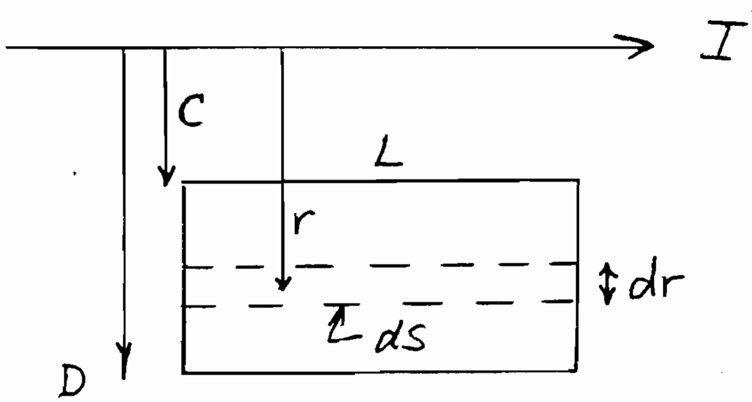
11. A SOLID CYLINDRICAL CONDUCTOR OF RADIUS "A" AND LENGTH L CARRIES CURRENT I OUT OF THE PAGE. A) USE AMPERE'S LAW TO FIND A FORMULA FOR THE MAGNETIC FIELD INSIDE THE WIRE AT OUR LOCATION r. ONLY A, I AND r ARE ALLOWED IN OUR ANSWER.



B) LOOKING DOWN ON THE WIRE, THE CYLINDER APPEARS TO BE A RECTANGLE. IN TERMS OF A, L AND I, FIND A FORMULA FOR THE MAGNETIC FLUX OF THE RIGHT SIDE OF THE LONGITUDINAL CROSS-SECTION OF THE CONDUCTOR.

C) WITHOUT ANY CALCULATIONS, FIND THE TOTAL MAGNETIC FLUX ACROSS THE ENTIRE CROSS-SECTION OF THE CYLINDER. DRAWING THE MAGNETIC FIELD ON THE LEFT SIDE OF THE CYLINDER IN THE UPPER CARTOON SHOULD PROVE TO BE INSIGHTFUL.

12. CURRENT I CREATES A MAGNETIC FIELD WHICH IS CAUGHT BY THE RECTANGULAR LOOP.

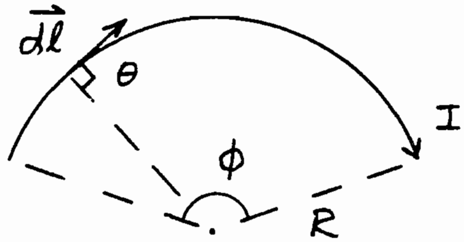


A) IN THE SMALL AREA ds, DRAW THE $\vec{B}$ CREATED BY I.

B) USE AMPERE'S LAW TO FIND A FORMULA FOR B AT OUR LOCATION r. ONLY I AND r ARE ALLOWED.

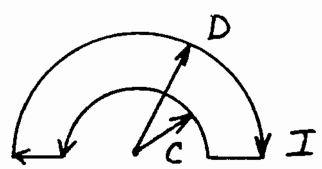
C) IN TERMS OF I, L, C AND D, FIND THE FORMULA FOR THE MAGNETIC FLUX OF THE LOOP.

13. WE STAND AT THE CENTER OF CURVATURE OF AN ARC OF WIRE OF RADIUS R AND ANGLE ϕ. A CURRENT I IN THE ARC CREATES A MAGNETIC FIELD. USE BIOT – SAVART'S LAW TO FIND $\vec{B}$ AT OUR LOCATION. ONLY I, R AND ϕ ARE ALLOWED IN OUR ANSWER. PLEASE ALSO FIND THE DIRECTION OF $\vec{B}$.

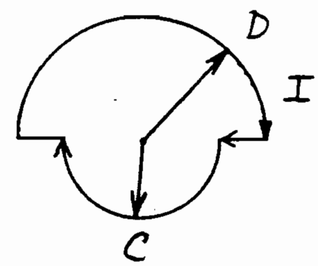


14. USING THE FORMULA DERIVED IN (13), FIND FORMULAS FOR THE MAGNITUDE AND DIRECTION OF THE MAGNETIC FIELD AT THE CENTER OF CURVATURE FOR EACH OF THE FOLLOWING.

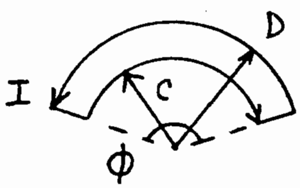
A)



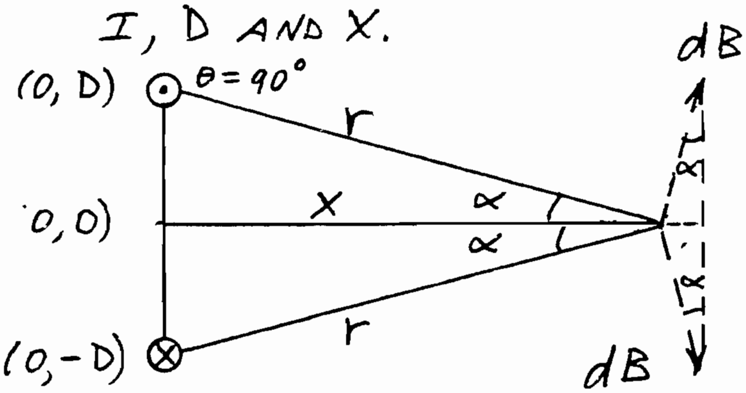
B)



C)



15. A RING OF WIRE WHOSE RADIUS IS D CARRIES CURRENT I. WE STAND ON ITS AXIS AT LOCATION (X, 0). FIND A FORMULA FOR THE MAGNITUDE AND DIRECTION OF THE MAGNETIC FIELD IN TERMS OF I, D AND X.

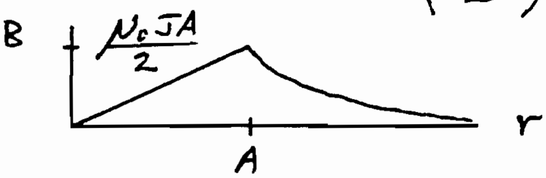


ANSWERS:

1. $\oint \vec{B} \cdot d\vec{\ell} = \mu_0 \, i_{\text{ENCLOSED}}$

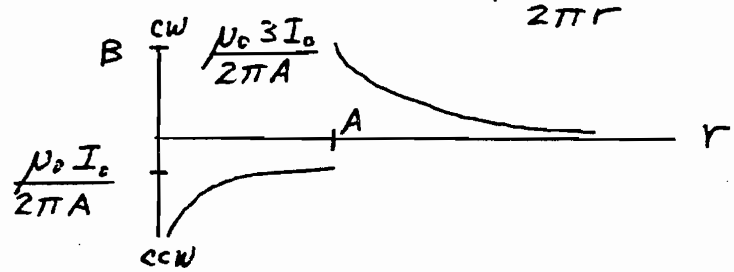
2. CURRENTS CREATE MAGNETIC FIELDS.

3. ZONE I: $B = \left(\frac{\mu_0 J}{2}\right) r$ ZONE II: $B = \frac{\mu_0 J A^2}{2r}$



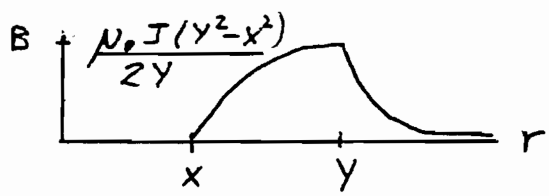
4. ZONE I: $B = \frac{\mu_0 I_0}{2\pi r}$ CCW

ZONE II: $B = \frac{\mu_0 3 I_0}{2\pi r}$ CW



5. ZONE I: $B = 0$ ZONE II: $B = \frac{\mu_0 J}{2}\left(r - \frac{X^2}{r}\right)$

ZONE III: $B = \frac{\mu_0 J}{2r}(Y^2 - X^2)$



6. $\oint \vec{B} \cdot d\vec{\ell} = -8\mu_0 I$

7. A) $B = \frac{-\mu_0 I D}{\pi (X^2 + D^2)}$ DOWN X-AXIS B) $B = \frac{\mu_0 I D}{\pi (Y^2 - D^2)}$ POINTING RIGHT

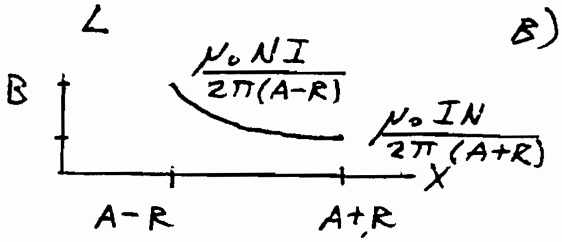
8. $B_X = \frac{-\mu_0 i}{2\pi A} \tan^{-1}\left(\frac{A}{Y}\right)$ $B_Y = \frac{-\mu_0 i}{4\pi A} \ln\left(\frac{A^2 + y^2}{y^2}\right)$

9. $\Phi_B = \frac{\mu_0 N I \pi R^2}{L}$

10. A) COUNTERCLOCKWISE

B) $B = \frac{\mu_0 N I}{2\pi X}$

C) ⊗ D)



E) $(X-A)^2 + y^2 = R^2$

F) $\Phi_B = \frac{\mu_0 N I}{\pi} \int_{A-R}^{A+R} \left(\frac{\sqrt{R^2 - (X-A)^2}}{X}\right) dX$

11. A) $B = \left(\frac{\mu_0 I}{2\pi A^2}\right) r$ B) $\Phi_B = \frac{\mu_0 I L}{4\pi}$ C) ZERO

12. A) $\otimes$ B) $B = \frac{\mu_0 I}{2\pi r}$ C) $\Phi_B = \frac{\mu_0 I L}{2\pi} \ln\left(\frac{D}{C}\right)$

13.

$B = \frac{\mu_0 I \phi}{4\pi R}$ $\otimes$

14. A) $B = \frac{\mu_0 I}{4}\left(\frac{1}{C} - \frac{1}{D}\right)$ $\odot$

B) $B = \frac{\mu_0 I}{4}\left(\frac{1}{C} + \frac{1}{D}\right)$ $\otimes$

C) $B = \frac{\mu_0 I \phi}{4\pi}\left(\frac{1}{C} - \frac{1}{D}\right)$ $\otimes$

15. $B = \frac{\mu_0 I D^2}{2(X^2 + D^2)^{3/2}}$ POINTING RIGHT