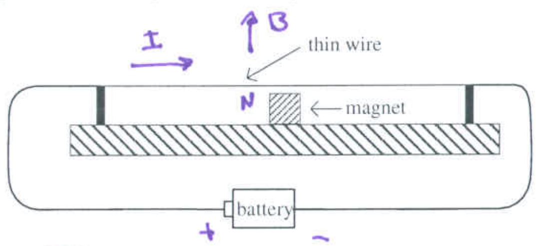
Physical Constants:
proton charge $= e = 1.60 \times 10^{-19}$ C
permeability $= \mu_0 = 4\pi \times 10^{-7}$ T · m/A

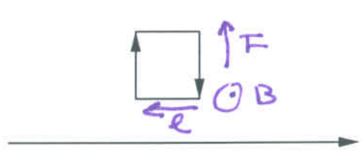
Unless otherwise stated, select the letter of the single best answer. Each question is worth 1 point.

1. The picture below shows a device very similar to one used in class. A battery drives a current through a thin wire which is suspended above a magnet. When the battery is connected the thin wire moves out of the page. What sort of pole is the top of the magnet?



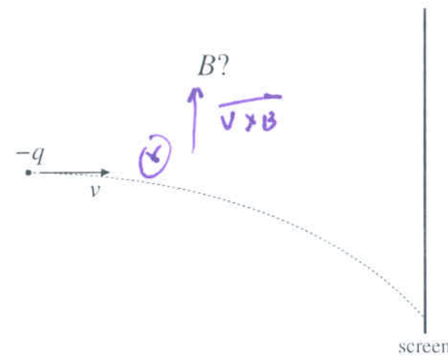
A. N
B. S
C. E
D. W

2. There is a current flowing clockwise around a square loop and also a current flowing to the right through a long straight wire that sits below the square. (The square loop and the wire sit in the plane of this sheet of paper as shown in the below figure.) The net force on the square points



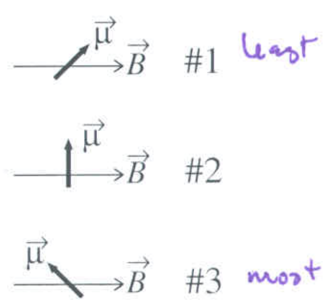
A. down the page
B. to the right
C. out of the page
D. up the page

3. An electron moves horizontally toward a screen. The electron moves along the dotted path because of a magnetic force caused by a magnetic field. In what direction does that magnetic field point?



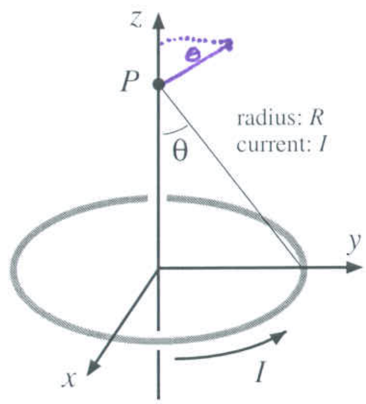
A. Toward the top of this page
B. Toward the bottom of this page
C. Into this page
D. Out of this page

4. The following figure shows three different configurations of a magnetic dipole $\vec{\mu}$ placed in a uniform magnetic field $\vec{B}$. Which of the below options best describes the relationship between the potential energy of the dipole in these configurations. (U_1 denotes the potential energy in configuration #1, etc.)



A. $U_1 > U_2 > U_3$
B. $U_1 < U_2 < U_3$
C. $U_2 < U_1 < U_3$
D. $U_1 = U_3 < U_2$

5. A current I flows around a circle (radius R) that sits in the xy plane with its center at the origin. Consider the problem of finding the magnitude of the magnetic field, B, directly above the center, i.e., on the z axis at a point $P = (0, 0, z)$.



A. Since all of the current elements are the same distance from P:

$$B = \frac{\mu_0 I 2\pi R}{4\pi(R^2 + z^2)}$$

B. Since $d\vec{\ell} \times \hat{\mathbf{r}} = d\ell \sin\theta$ ← angle btw $d\vec{\ell}$ & $\hat{r}$ = 90°

$$B = \frac{\mu_0 I 2\pi R \sin\theta}{4\pi(R^2 + z^2)}$$

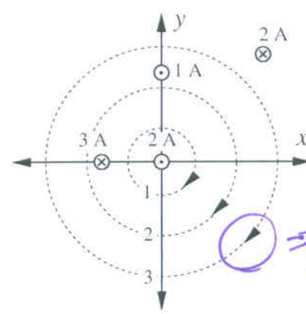
C. Since the net B field is in the z direction we need to include the angle:

$$B = \frac{\mu_0 I 2\pi R}{4\pi(R^2 + z^2)} \sin\theta$$

D. Since the net B field is in the z direction we need to include the angle:

$$B = \frac{\mu_0 I 2\pi R}{4\pi(R^2 + z^2)} \cos\theta$$ → says B = 0 at center: No way

6. The below figure shows where four infinitely long wires parallel to the z axis intersect the xy plane. The current in each wire is listed along with the flow direction: $\odot$ = out of page, $\otimes$ = into page. Consider various amperian loop integrals ($\mathcal{L} = \oint \vec{\mathbf{B}} \cdot d\vec{\mathbf{s}}$) along three circles centered on the origin with radii as shown in the figure. Which of the below options best describes the relationship between the integrals. ($\mathcal{L}_1$ denotes the loop integral for circle 1, etc. Negative numbers are smaller than any positive number.)



⇒ $\vec{A}$ is into page so ⊗ is + ⊙ is −

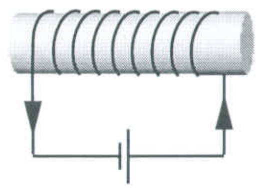
A. $\mathcal{L}_1 > \mathcal{L}_3 > \mathcal{L}_2$

B. $\mathcal{L}_1 > \mathcal{L}_2 > \mathcal{L}_3$

C. $\mathcal{L}_2 > \mathcal{L}_3 > \mathcal{L}_1$

D. $\mathcal{L}_3 > \mathcal{L}_2 > \mathcal{L}_1$

7. N turns of wire are wrapped around a cylinder of length L and radius r forming a solenoid. The wire carries a current I in the direction shown. Select the most complete combination of correct statements about this situation.



I. The magnetic field inside the solenoid points to the left.

II. Starting at the center of the solenoid and moving to the right along the axis of the solenoid, the magnetic field gradually diminishes, but always points in the same direction.

III. The magnetic field in the center of the solenoid is proportional to I.

IV. If the solenoid is "long" (i.e., $L \gg r$) the magnetic field in the center of the solenoid is proportional to N/L.

V. If the solenoid is "long" (i.e., $L \gg r$) the magnetic field in the center of the solenoid is inversely proportional to r^2.

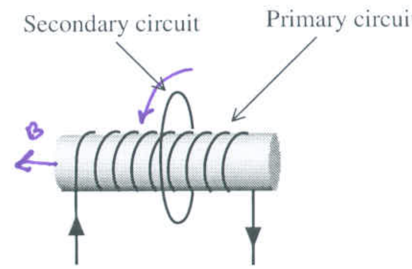
A. I, III

B. II, III, IV

C. III, IV, V

D. I, II, III, IV, V

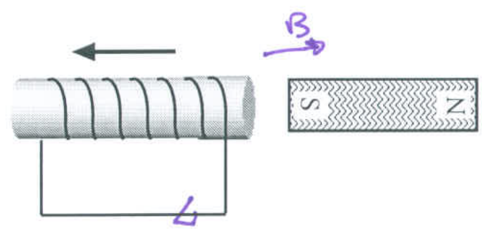
8. (**select two answers!**) The first circuit consists of a "primary" wrapped around a cylinder and a single-loop "secondary". The current in the primary started at zero but now an ever increasing current is flowing in the direction indicated. What current will be induced in the secondary? At the top of the secondary loop the induced current is flowing:



A. out of the page

B. into the page

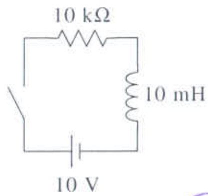
In the second circuit a solenoid is moving to the left, away from the south pole of a bar magnet. What induced current will be found in the straight horizontal wire attached to the solenoid? The induced current flows:



C. to the right

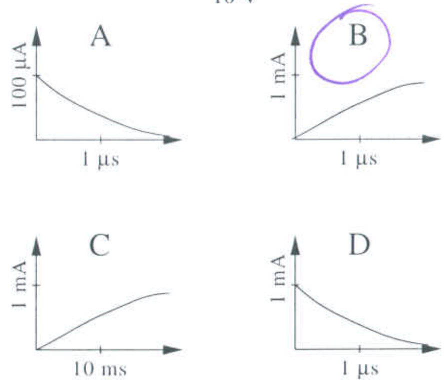
D. to the left

9. The below circuit shows a series LR circuit. The switch is closed at $t = 0$. Which graph best represents how the current changes in time?



start with $I = 0$

time const $\frac{L}{R} = \frac{10^{-2}}{10^{4}} = 10^{-6}$



10. The energy stored in an inductor is given by:

$$U = \frac{1}{2} LI^2$$

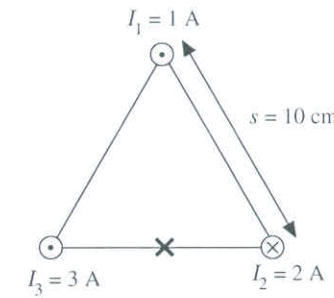
J → U; H = V/(A/s); A

In terms of units this equation is:

A. J = (V · s/A) × A^2
B. J = F × A^2
C. W = H × A^2
D. V = H × C^2

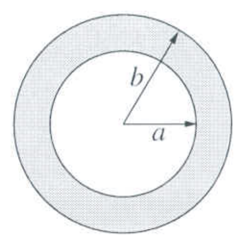
Turn in five of the following six problems (10 points each)

11. As shown in the diagram, three long parallel wires run perpendicular to this sheet of paper and pierce this sheet in an equilateral triangle with side 10 cm. The currents I_1 and I_3 come directly out of this page; I_2 goes into the page. Find the magnitude of the magnetic field vector at the spot marked with an X (i.e., the midpoint of the horizontal segment).



see 8-3

12. A current I flows through a long copper pipe with inner radius a and outer radius b. The current is distributed uniformly over the cross section of the pipe, and is directed out of this sheet of paper in the below diagram. Using Ampere's Law



A. Find the magnetic field for $r < a$

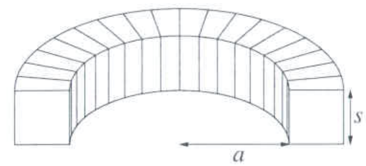
B. Show that for $a < r < b$ the magnetic field is given by:

$$B = \frac{\mu_0 I}{2\pi r}\frac{r^2 - a^2}{b^2 - a^2}$$

Be sure to report the direction of $\vec{B}$ in both cases!

See 8-5

13. A toroid has a square cross section (side s), an inner radius of a, and a total of N turns each carrying a current I. (The diagram to the left shows half of this toroid.)



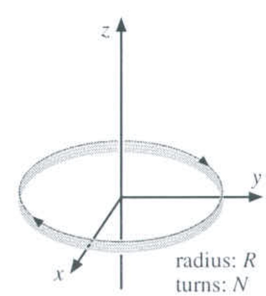
   A. By integration, show that the magnetic flux through a single square turn around the torus is given by

$$\Phi_B = \frac{\mu_0 N s I}{2\pi} \ln\left(\frac{a+s}{a}\right)$$

   B. Find the self inductance of this toroid where: $N = 200$, $a = 0.5$ cm, and $s = 0.5$ cm.

see 10-1

14. A coil, consisting of $N = 25$ turns of radius $R = .15$ m, sits in the xy plane with its center at the origin. As shown in the diagram, a clockwise current (as seen from above) $I = 2$ A flows through the coil.



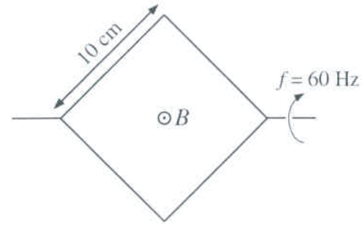
   A. Report the direction and magnitude of $\vec{B}$ on the z-axis at $z = +0.25$ m due to this current loop.
   B. This current loop acts as a magnetic dipole $\vec{\mu}$. What is the direction and magnitude of this dipole?
   C. If a uniform magnetic field $\vec{B} = (2\hat{\imath} + 3\hat{\jmath} + 4\hat{k})$ T is present, what torque is imposed on the loop. (Report your answer in unit vector notation.)

see 8-3

15. A generator consists of a square coil (side 10 cm) with 150 turns which is rotated at a frequency, f, of 60 revolutions/sec about a diagonal in a uniform 0.75 T magnetic field. Show that the induced emf is of the form:

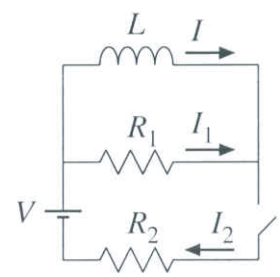
$$\mathcal{E} = \mathcal{E}_0 \sin(2\pi f t)$$

and calculate the numerical value of $\mathcal{E}_0$.



see 9-5

16. In the circuit shown the component values are: $V = 6$ V, $R_1 = 1$ kΩ, $R_2 = 2$ kΩ, and $L = 5$ mH. As shown initially the switch is open.



0 A. Report the current through the inductor the instant after the switch is closed.

B. Report the current through the inductor a 'long' time after the switch is closed.

C. In this circuit can 10^{-3} s be considered a 'long' time?

D. Calculation of the currents at intermediate times requires solving a differential equation. Write down one Kirchoff's loop rule equation for a loop that includes the inductor. (This should be a differential equation.)

B: In the end $\frac{dI}{dt} = 0$ so ΔV across $L = 0$ ⇒ ΔV across $R_1 = 0$ ⇒ $I_1 = 0$. Hence current runs: $V \to L \to R_2$ ∴ $I_2 = I = \frac{V}{R_2} = \frac{6}{2k\Omega} = 3$ mA

C: its not clear exactly which R to use, but either way $R \sim k\Omega$ $\tau_L = \frac{L}{R} = \frac{5\times10^{-3}}{10^{+3}} = 5\times10^{-6}$ s << 1 ms

Yes

D: $V - L\frac{dI}{dt} - R_2 I_2 = 0$

$-L\frac{dI}{dt} + R_1 I_1 = 0$