Part I. Multiple Choice/Short Answer (4 points each / 80 points total)
no explanation required, but no partial credit either. However, a bonus of up to two points may be awarded if an explanation is offered that is correct and consistent with your answer.

1. A neutral neon atom has 10 electrons. If four electrons are removed from the atom, its net charge will be

   (A) -6.4×10^{-19} C
   (B) -16×10^{-19} C
   (C) $+3.2 \times 10^{-19}$ C
   (D) -3.2×10^{-19} C
   (E) $+6.4 \times 10^{-19}$ C

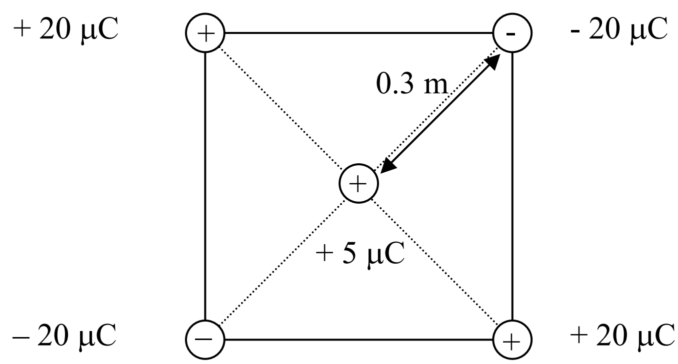
2. A neutral metal ball is hung from an insulating string. A positively charged plastic rod is brought near the ball without touching it. The ball is grounded for some time. The ground in then removed. Finally, the plastic rod is moved far away from the ball. The final charge state of the ball is

   (A) Positive (B) Neutral (C) Negative (D) dependent on the distance between the ball and the charge

3. Four point charges are at the corners of a square. Two are negative and two are postitive. The distance from each corner to the center is 0.3 m. At the center there is a + 5 μC point charge. The magnitude and direction of the net force on this + 5 μC charge in N, is

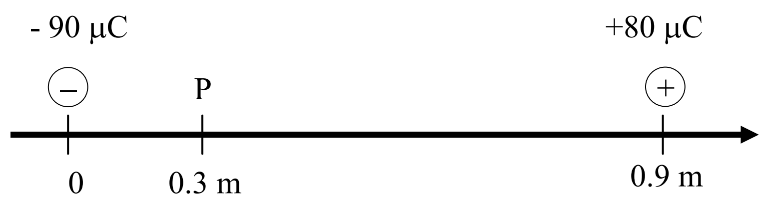
   (A) 28
   (B) 40
   (C) zero
   (D) 14
   (E) 20

   Direction ______

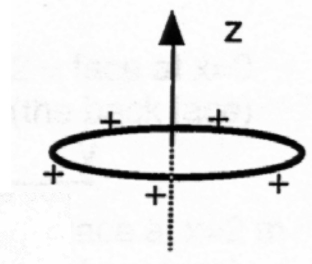


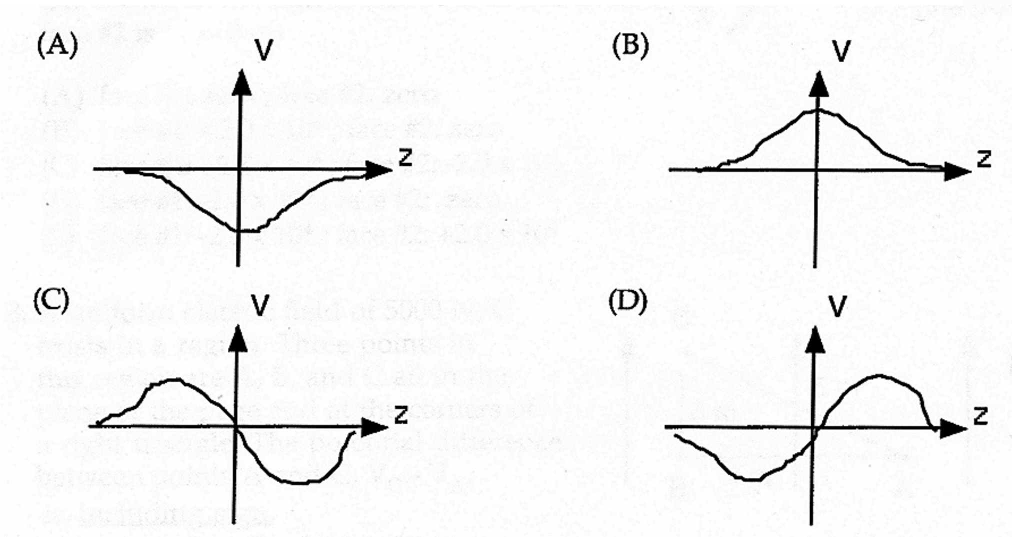
4. Two point charges are on the x-axis, as shown. One charge is at x = 0 and the other is at x = 0.9 m. The magnitude of the electric field at point P, which is at x = 0.3 m, is, in N/C

   (A) 9.0×10^{6}
   (B) 1.1×10^{7}
   (C) 2.0×10^{6}
   (D) 7.0×10^{6}
   (E) zero



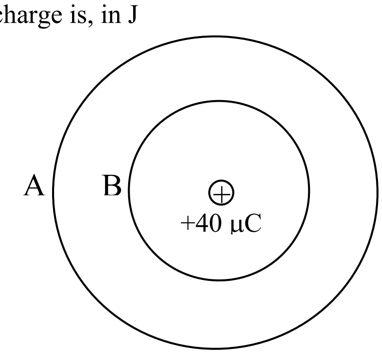
5. A uniformly charged ring is in the xy plane with the positive z axis through its center as shown. A rough sketch of the electrostatic potential for points along the z-axis is



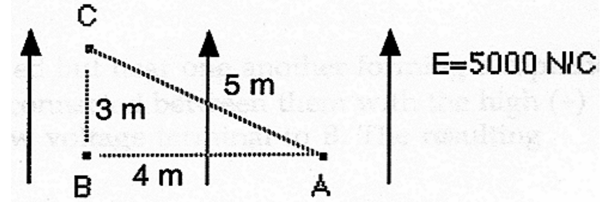


6. A +40 μC point charge is at the center of two Gaussian sphere of radii 6 m and 9 m. Point A is on the surface of the larger sphere, and B is on the surface of the smaller one. A proton ($q = + 1.6 \times 10^{-19}$ C) moves from B to A. The magnitude of the work done on the proton by the electric field of the point charge is, in J

(A) 3.2×10^{-15}
(B) 4.8×10^{-15}
(C) 1.6×10^{-14}
(D) 9.6×10^{-15}
(E) 8.0×10^{-15}



7. A uniform electric field of 5000 N/C exists is a region. Three points in this region are A, B, and C all in the plane of the page and at the corners of a right triangle. The potential difference between points A and C, $V_C - V_A$, is, <u>including sign</u>,



(A) $+1.5 \times 10^4$ V
(B) -1.5×10^4 V
(C) $+2.5 \times 10^4$ V
(D) -2.5×10^4 V
(E) -2.0×10^4 V

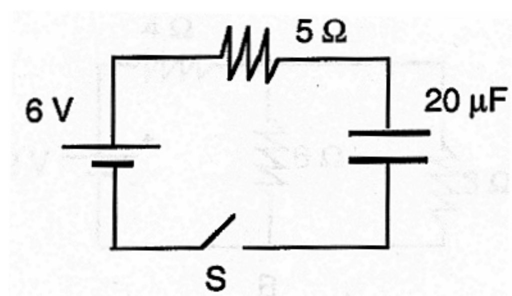
8. Two neutral conductors, A and B, are isolated but near one another forming a capacitor of capacitance 2 x 10-9 F. A 600 V battery is connected between them with the high (+) voltage terminal connected to A and the low voltage terminal connected to B. The resulting charges on A and B, in mC, are

   (A) QA)
   (B) Al;dfja;l
   (C) Aldfkj
   (D) Lafja;ldgjk
   (E) Al;dhja;lgj

9. A parallel plate capacitor with vacuum between its plates has a capacitance C_0. The capacitor is charged by a battery. While still connected to the battery, a slab of plastic is inserted filling the plates of the capacitor. If the plastic has a dielectric constant of 2, then

   (A) the charge on the plates is halved
   (B) the voltage across the plates is doubled
   (C) the voltage across the plates is halved
   (D) the charge on the plates is doubled
   (E) the charge on the plates and the voltage across the plates are both unchanged

10. An uncharged capacitor is connected to a 6 V battery using a 5 ohm resistor. The switch S is closed at time t = 0. At what later time t is the capacitor's charge equal to 60 μC? In microseconds,

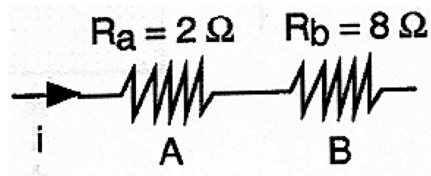


   (A) 12
   (B) 25
   (C) 50
   (D) 100
   (E) 69

11. A 100 m long wire has a resistance of 0.05 ohms. It is cut into five 20 m long pieces that are fused together side-by-side making a new resistor of length 20 m and cross sectional area five times the original. The resistance of the this new resistor, in ohms, is

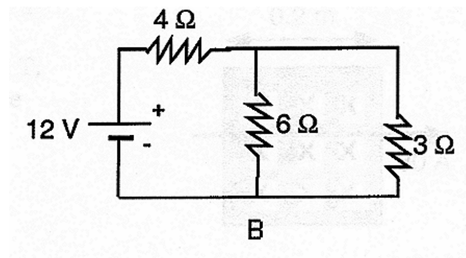
   (A) 0.0020 (B) 0.25 (C) 0.0050 (D) 0.050 (E) 1.25

12. Two resistors, A and B, are part of a complete circuit. If the current in A is 4 A, what is the voltage across B? In V,



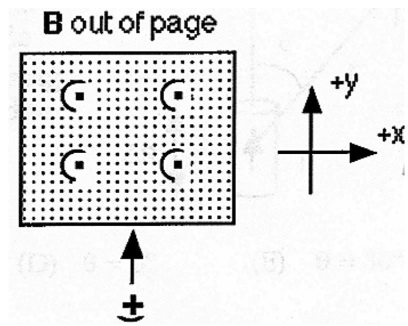
(A) 8
(B) 24
(C) 20
(D) 40
(E) 32

13. The voltage across the 4 ohm resistor is

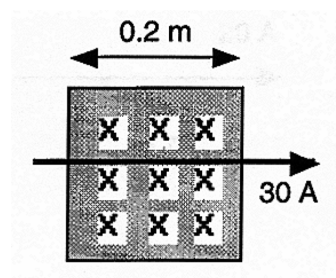


(A) 8 V (B) 12 V (C) 2 V (D) 4 V (E) 6 V

14. A proton, q = +e enters a region of uniform magnetic field directed out of the page. The proton enters the magnetic field moving in the +y direction. The direction of the magnetic force on the proton when it enters the field is _____? If the force is zero, state this explicitly

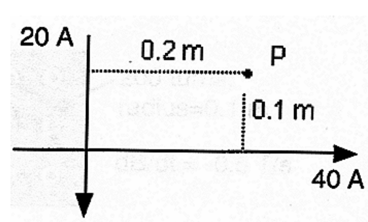


15. A straight wire carries 30 A between the poles of a magnet 0.2 m by 0.2 m as shown. The field in this region is uniform, of magnitude 0.4 T, and directed into the page. The magnitude and direction of the magnetic force on the wire is



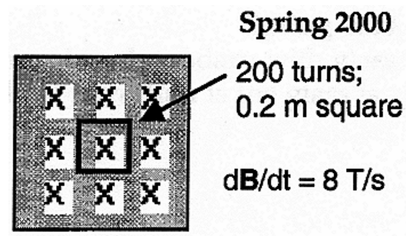
(A) 6.0 (B) 1.2 (C) 12 (D) 2.4 (E) zero

16. Two wires cross at right angles, as shown. A point P is 0.2 m from the 20 A wire and 0.1 m from the 40 A wire. The magnitude and direction of the total magnetic field at P due to both wires, in T, is



(A) 2.0×10^{-5}
(B) 3.0×10^{-5}
(C) 8.0×10^{-5}
(D) 1.0×10^{-4}
(E) 6.0×10^{-5}

17. A square coil with 200 turns is in a uniform magnetic field directed into the page and increasing at 8 T/s, as shown. The plane of the 0.2 m x 0.2 m coil is perpendicular to B. The magnitude of the induced emf, in V, is



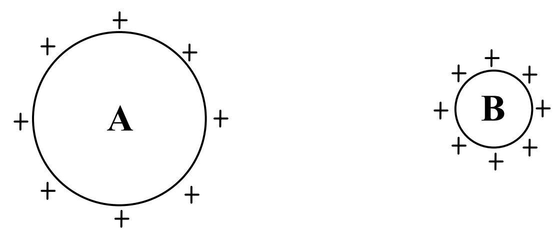
(A) 32 (B) 64 (C) 3.1 (D) 6.3
(E) 16 (F) 0

Direction (circle one):

Clockwise CW, Counter Clockwise CCW, or no direction because there is no induced current

18. Two conducting spheres (A and B) shown below have the same net charge (+*Q*), but different radii. How do the values of the electric potentials on the surfaces of the conductors compare?

a) Sphere A has a greater potential on the surface
b) Sphere B has a greater potential on the surface
c) Sphere A and sphere B have the same potential on the surface
d) More information is needed to determine the answer



19. How do the electric fields just outside the surface of the two spheres shown in problem 3 compare?

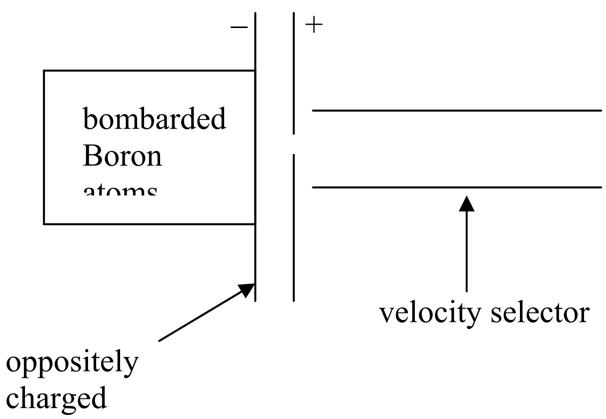
a) Sphere A has a greater Magnitude electric field outside the surface
b) Sphere B has a greater Magnitude electric field outside the surface
c) Sphere A and sphere B have the same electric field outside the surface
d) More information is needed to determine the answer

21. **GOAL Problem** (25 points): Use the GOAL protocol to solve this problem.

As part of an engineering design project to develop a process for adding boron atoms into silicon (a process in semiconductor manufacturing), you are asked to determine some of the operating parameters of the boron injector, a simple accelerator that will emit boron atoms at a specific speed. A picture of the accelerator is shown below. Boron gas is bombarded with electrons to give it an excess charge and then enters a space between two oppositely charged vertical conducting plates through tiny holes (the separation distance of the two plates is 2 cm). The charged boron atoms are accelerated by the electric field through a hole in the positively charged plate. The boron atoms then enter a velocity selector using electric and magnetic fields. An electric field of 1.50 kV/m is applied downward between the two horizontal plates. For the maximum Boron atom velocity of 10^6 m/s, find the following quantities:

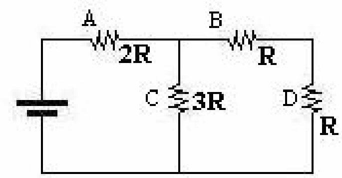
1. the magnitude of the accelerating potential ΔV between the two vertical plates assuming the Boron atoms have one excess electron
2. the magnitude and direction of the magnetic field needed so that Boron atoms pass through the velocity selector undetected.

(Boron atoms have a mass of 1.80×10^{-26} kg)



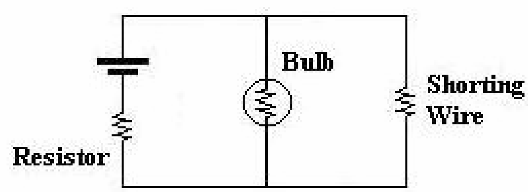
22. (25 points)

A. In the circuit at the right, rank the resistors according to the amount of *current* through them. Explain your reasoning.



B. Rank the resistors according to the *potential* across them. Explain your reasoning. (**Note**: The potential ranking may not match the current ranking).

C. An ideal 1.5 V battery, a 0.1 Ohm resistor, a bulb, and a shorting wire are connected as shown at the right. Assume that the bulb has a constant resistance of 5.0 Ohms and that the bulb is visibly lit only if the current through it is greater than 0.2 A. Find the resistance of the wire for which the bulb will barely light.



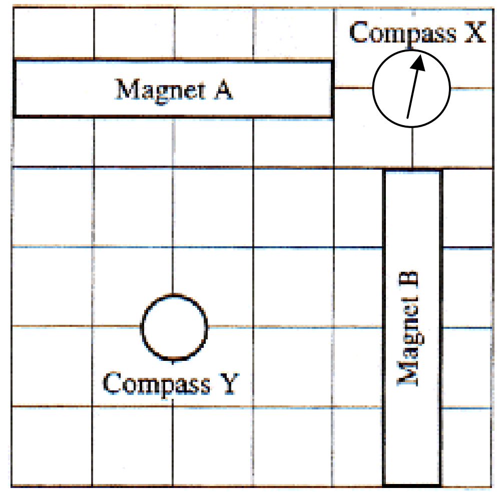
D. Suppose the resistance of the shorting wire in part C were increased. Would the brightness of the bulb *increase*, *decrease*, or *remain the same*? Explain your reasoning.

23. Essay (15 points): You may use diagrams, equations, and words, but no calculations to answer this problem.

Suppose you brought the north pole of the magnet near a coil of wire connected to a galvanometer (like you did in the induction lab) and then spun the magnet. What would happen to the needle of the galvanometer as you did this? Explain in words what is happening and why? You may refer to an equation, but you must explain it's meaning in words.

24. (15 points) Bar Magnets A and B are placed at right angles. Two compasses, X and Y, are placed so that they are equidistant from the two magnets as shown.

A. The arrow in compass X indicates the direction in which the north pole of the compass is pointing. Indicate the north and south of both bar magnets on the diagram. Explain how you know which pole is which.



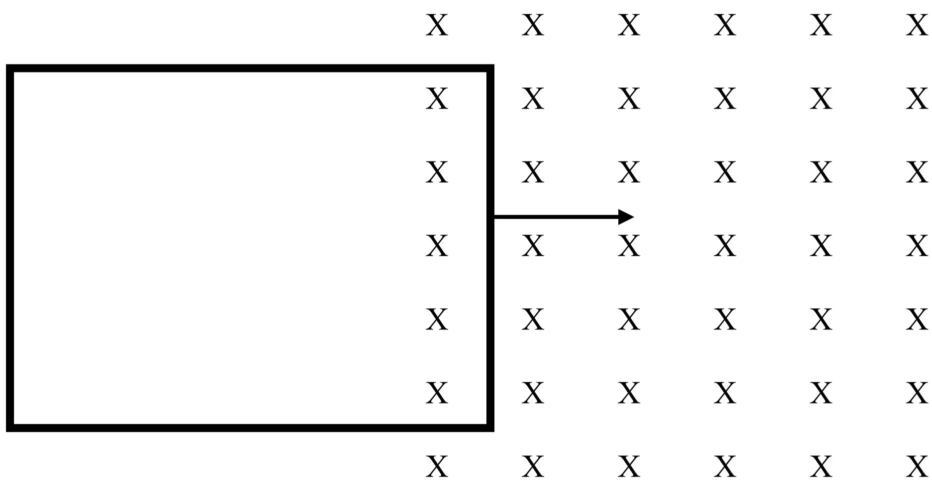
B. Which magnet is stronger? Explain your reasoning.

C. Compass Y is directly below the middle of magnet A and directly to the left of the middle of magnet B.

Draw an arrow in compass Y to show the direction in which the north pole of the compass would point. Explain how you determined your answer.

25. (15 points) Start calculations with equations in symbols, show substitutions, include units, and box your answers.

A one turn rectangular loop is moved through a uniform field at 2 m/s as shown.



(A) What is the maximum magnetic flux through the loop during its motion through the field? The loop is 5 cm long and 3 cm wide.

(B) The loop takes 100 ms to completely enter the field. Sketch the magnetic flux through the loop in the interval from t=0 to t=150 ms. Label values of flux.

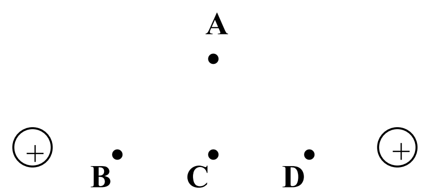
(C) Compute the emf in the loop while it is entering the field.

(D) Compute the emf in the loop in the time interval from t=100 ms to t=150 ms.

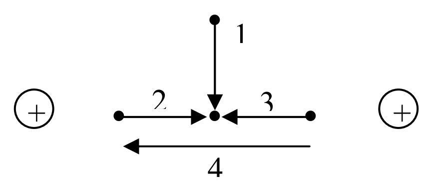
(E) Describe the direction of the induced current in the loop as it enters the field .

24. (25 points) Two +1 μC charges are fixed in space as shown below.

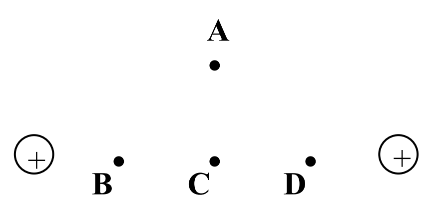
a) Sketch the direction of the electric fields at the locations shown below. Rank the magnitude of the electric fields at the various locations (A-D) around the point charges – explain why you ranked them as you did.



b) Rank the work done in moving a proton along various paths (1 – 4) around the two positive point charges shown below. Explain why you ranked them as you did.



c) Rank the value of the electric potential at the points (A – D) around the positive charges. Explain your ranking.



d) Calculate the value of the electric potential (with respect to infinity) at the point A. The charges both have a value of +1 μC. Point C is 1 meter from both charges and point A is ½ a meter from point C.