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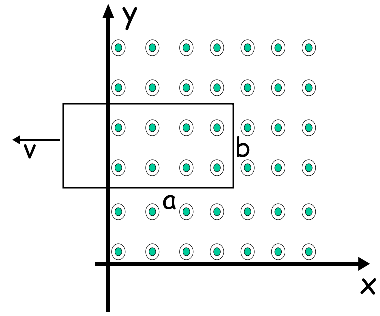
I. [25 Points] A loop of wire, of length *a=1m* and width *b=3cm*, is shown at left. There is a magnetic field, pointing out of the page, *B*=2T, that exists for ***y*>0, x>0**. The loop of wire is pulled to the left at a steady speed of **v=**3m/s. Initially, 75cm of the loop is in the field.



1. [3 pts] Which direction does the induced magnetic field point?
   A. Into the page
   B. Out of the page
   C. Towards the left of the page
   D. Towards the right of the page
   E. Towards the top of the page
2. [3 pts] Which direction does the induced current flow in the loop of wire?
   A. Clockwise
   B. Counter clockwise
   C. Not enough information to determine
3. [4 pts] If the loop's resistance is R=2Ω, calculate the magnitude of the current flowing in the loop.
   A. Not enough info to calculate, or 0.0 A
   B. 2.3×10^{-2} A
   C. 3.0×10^{-2} A
   D. 9.0×10^{-2} A
   E. 1.8×10^{-1} A
4. [4 pts] Is a force required to maintain the wire moving at a steady speed of ***v***? If so, calculate its magnitude.
   A. No, no force is required.
   B. 1.8×10^{-3} N
   C. 5.4×10^{-3} N
   D. 2.8×10^{-1} N
   E. 3.6×10^{-1} N
5. [4 pts] How much work is done pulling this wire loop over the course of 0.1 seconds?
   A. 1.8×10^{-4} J
   B. 1.6×10^{-3} J
   C. 8.3×10^{-3} J
   D. 1.1×10^{-1} J
6. [3 pts] Compare the magnitude of the induced current in this case to the case where the loop is pushed into the magnetic field with the same velocity ***v***.
   A. The induced current is greater.
   B. The induced current is less.
   C. The induced current is the same.

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7. [4 pts] If, instead of being pulled to the left with a velocity ***v***, the loop were to be pulled straight down (-*y* direction), what would the induced current be?
   A. Not enough info to calculate, or 0.0 A
   B. 2.3×10^{-2} A
   C. 3.0×10^{-2} A
   D. 9.0×10^{-2} A
   E. 1.8×10^{-1} A

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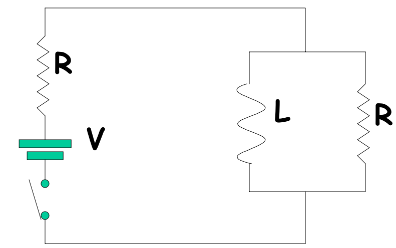
II. [25 points] In the circuit shown, an inductor and resistor are connected in parallel, which are then connected in series with another resister, a switch, and a battery. Both resisters are R=5Ω, the battery is V=10V, and the inductor is L=3H. Consider the battery and the inductor to be ideal (that is, they have no internal resistance).



8. [4 pts] At t=0 the switch closes. Right after the switch closes, what is the current that flows through the battery?
   A. 0.0 A
   B. 1.0 A
   C. 2.0 A
   D. 3.0 A
   E. 4.0 A

9. [4 pts] Calculate the current that flows through the battery a very long time after t=0.
   A. 0.0 A
   B. 1.0 A
   C. 2.0 A
   D. 3.0 A
   E. 4.0 A

10. [4 pts] What is the energy stored in the inductor a very long time after t=0?
    A. 0.0 J
    B. 1.5 J
    C. 6.0 J
    D. 24 J

11. [4 pts] At t = 1000s, the switch is opened. What is the value of the time constant of this circuit?
    A. 0.3 s
    B. 0.6 s
    C. 15 s
    D. 300 s
    E. 600 s

12. [5 pts] At a point t=1001 s, what is the energy stored in the inductor?
    A. 5.0×10^{-2} J
    B. 7.6×10^{-3} J
    C. 2.1×10^{-1} J
    D. 1.8 J
    E. 6 J

13. [4 pts] How much energy is dissipated by the resistor a very long time after the switch is opened?
    A. 0.0 J
    B. 1.5 J
    C. 6 J
    D. 24 J
    E. 2 5.0×10^{-4} A

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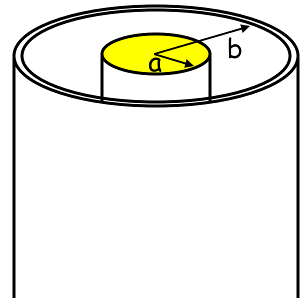
III. [25 points] The coaxial cable, shown, has a uniform inner copper conductor of radius ***a=1mm*** and the inner radius of the outer conducting copper shell is ***b=3mm***. The inner conductor carries a charge of 3μC/m, and the outer conductor –3μC/m. Assume the coax cable is infinite in length.



14. [4 pts] What is the electric field at a radius of 2mm?
    - A. 0.0
    - B. 2.7 x 10^4 N/C
    - C. 5.4 x 10^5 N/C
    - D. 2.7 x 10^6 N/C
    - E. 5.4 x 10^6 N/C
15. [4 pts] What is the electric flux through a cylinder with radius 2mm and length 20cm?
    - A. 0.0 Nm^2/C
    - B. 6.8 x 10^4 Nm^2/C
    - C. 1.4 x 10^5 Nm^2/C
    - D. 1.7 x 10^5 Nm^2/C
    - E. 3.4 x 10^5 Nm^2/C
16. [4 pts] Which statement best describes the flux through this cylinder?
    - A. The net flux is positive
    - B. The net flux is negative
    - C. The net flux is zero
17. [4 pts] What is the potential difference between the inner and outer conductors?
    - A. 0.0 V
    - B. 5.4 x 10^4 V
    - C. 5.9 x 10^4 V
    - D. 1.2 x 10^5 V
18. [4 pts] What is the capacitance per unit length of this coaxial cable?
    - A. 1.5 x 10^{-17} F/m
    - B. 1.0 x 10^{-12} F/m
    - C. 5.1 x 10^{-12} F/m
    - D. 5.6 x 10^{-11} F/m

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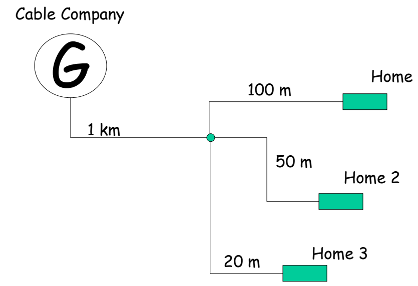
19. [5 pts] There are many design considerations when laying out a Cable TV system; here we consider the size of the signal generator at the cable company. The cable system shown in the figure must be put together. The generator and the individual homes are all connected with a coax cable similar to the one shown at the start of this problem, however it has a capacitance per unit length of 5μF/m. In order for each set-top box to operate, it needs a signal of 5V. The source for the cable TV signal (labeled **G** in the figure) puts out a certain amount of charge to generate this signal. For the system shown, how much charge must the generator put out to satisfy this requirement?



A. 3.6×10^{-3} C
B. 2.1×10^{-2} C
C. 2.9×10^{-2} C
D. 3.1×10^{-1} C

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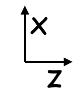
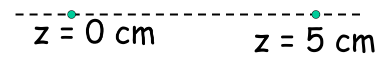
IV. [25 points] An electric field fills space, and its magnitude and direction are given by $\mathbf{E} = \mathbf{-Cz^2}$**,** in the *z* direction (the negative sign means the negative *z* direction). $\mathbf{C=1 \times 10^5}$ N/C.



20. [4 pts] We define the absolute potential at the origin to be 5V. What is the absolute potential at $z=5$cm?



   A. 0.8 V
   B. 5.0 V
   C. 9.2 V
   D. 18 V
   E. 2.6×10^2 V

21. [5 pts] A charged particle, $q=+5\mu$C is released from rest at $z=5$ cm ($x, y = 0$). Ignoring gravity, what is its speed at $z=0$ cm. The particle's mass is 0.1g.
   A. It moves the other direction
   B. 2.1×10^{-2} m/s
   C. 6.5×10^{-1} m/s
   D. 9.6×10^{-1} m/s
   E. 2.9×10^2 m/s

22. [4 pts] And, at that same point $z=0$ cm, what is the particle's acceleration?
   A. 0.0 m/s^2
   B. 1.3×10^{-3} m/s^2
   C. 1.3×10^{-2} m/s^2
   D. 1.3×10^{1} m/s^2

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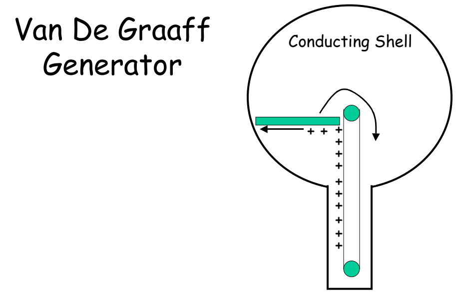
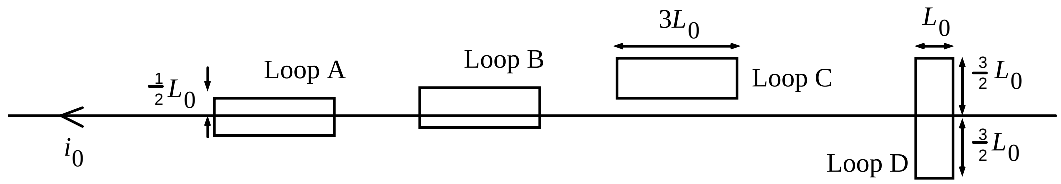
For the second half of this problem, consider the Van De Graaff generator shown to the right. A belt carries and deposits charge on the inside of a spherical shell at the top of an insulating post. Charge is carried by the belt and deposited on the shell at a rate of 100 μC/sec (as shown in the figure). When the Van De Graaff generator is initially started, assume there are 50 μC of charge already evenly distributed on the outside of the conducting sphere.



23. [4 pts] After one minute of charging, how much charge is there on the inside of the shell?
    A. 0 μC
    B. 50 μC
    C. 100 μC
    D. 6.0×10^3 μC
    E. 6.1×10^3 μC
24. [4 pts] After one minute of charging, how much charge is there on the outside of the shell?
    A. 0 μC
    B. 50 μC
    C. 100 μC
    D. 6.0×10^3 μC
    E. 6.1×10^3 μC
25. [4 pts] How many seconds does it take before the electric potential 10cm from the surface of the sphere is 5×10^6 V? Ignore any effects of the post or belt in your calculation, and tread the conducting sphere as a complete sphere. Use the usual definition of $V(\infty) = 0V$.
    A. 2.8×10^{-2} s
    B. 5.6×10^{-2} s
    C. 5.6×10^{-1} s
    D. 5.6 s

Name ____ Total Points ________
last *first*

V. [25 pts total] Four copper loops of identical size and shape (labeled A-D) are positioned near a long wire carrying steady current i_0. (*Note:* For this problem, ignore interactions between the loops, and assume that the loops and the long wire are essentially in the same plane, *i.e.*, that of the paper.)



At the instant shown in the diagram above, the long wire is moving toward the top of the page.

26. [7 pts] For each loop listed below, determine whether the induced current at the instant shown in the diagram is *clockwise, counterclockwise,* or *zero.* Explain your reasoning.
    - loop B
    - loop C

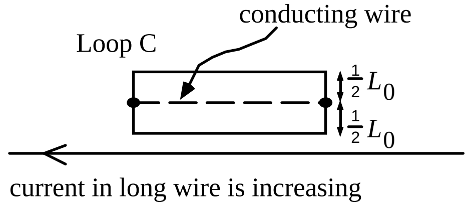
27. [6 pts] At the instant shown, is the absolute value of the current induced in loop A *greater than, less than,* or *equal to* the absolute value of the current induced in loop D? Explain.

Suppose the long wire is at rest and in the position shown in the diagram (rather than moving toward the top of the page). Now, the current in the wire is increased at a constant rate.

28. [7 pts] For each loop listed below, determine whether the induced current is *clockwise, counterclockwise,* or *zero.* Explain your reasoning.
    - loop A
    - loop B

During the interval in which the current in the long wire is increasing, a segment of conducting wire is inserted into loop C as shown.

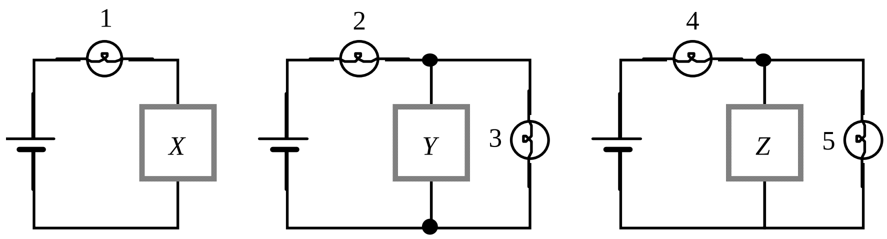
29. [5 pts] Is the current in the new segment of conducting wire *to the left, to the right,* or *zero?* Explain.



Name ____ Total Points ________

last *first*

VI. [25 pts total] In the circuits below, bulbs 1-5 are identical, and the batteries are identical and ideal. Boxes *X*, *Y*, and *Z* contain unknown arrangements of bulbs. It is observed that bulbs 1 and 2 are equally bright, and brighter than bulb 4.



30. [8 pts] Rank the potential difference across box *X*, box *Y*, and box *Z* in order of increasing absolute value. Explain your reasoning.

31. [3 pts] Is the brightness of bulb 3 *greater than, less than*, or *equal to* the brightness of bulb 5? Explain.

32. [6 pts] Rank the resistance of box *X*, box *Y*, and box *Z* in order from greatest to smallest. Explain.

33. [8 pts] Suppose box *Z* is disconnected from the circuit. Determine whether the brightness of each of the bulbs below will *increase, decrease,* or *remain the same.* Explain.

- bulb 4

- bulb 5