## I. Lecture multiple choice (70 points – next 17 questions)

1) (4 pts) Two small, electrically charged spheres each have a positive charge $Q$ . When they are separated by a distance $d$ the electrostatic force between them has a magnitude $F$. Which of the following options would result in an electrostatic force of magnitude $4F$ between the spheres

   A. Decreasing the separation distance to $d/4$
   B. Decreasing the separation distance to $d/2$
   C. Increasing the charge on both spheres to $2Q$ and decreasing the separation distance to $d/2$
   D. Increasing the charge on one sphere to $2Q$ and decreasing the separation distance to $d/4$
   E. None of these

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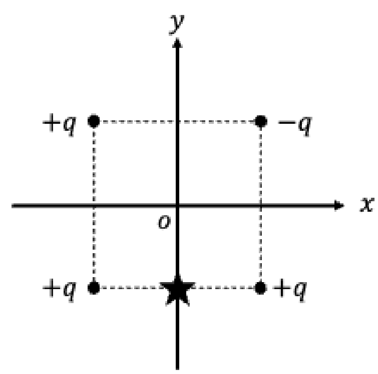
2) 4 points As shown, four particles are placed in an $x$-$y$ coordinate system at ($a$, $a$), (-$a$, $a$), (-$a$, -$a$), and ($a$, -$a$). The particle at ($a$, $a$) has charge -$q$, and the rest have +$q$. What is **the direction of electric force** on another particle with charge -$q$ located at the coordinate (0, -$a$), the position of the star?

   A. ↗
   B. →
   C. ↘
   D. ↓
   E. ←

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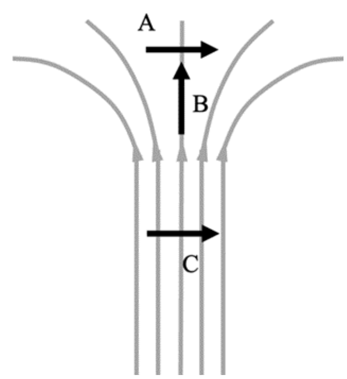
3) (4 pts) A small electric dipole is placed in an electric field. Consider three different locations that we can place the dipole labeled A, B, and C, as shown. At which location does the dipole experience a net force but no net torque?

   A. A only
   B. B only
   C. C only
   D. More than one of them.
   E. None of them.

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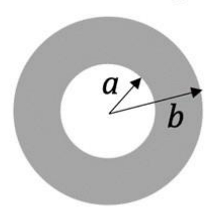
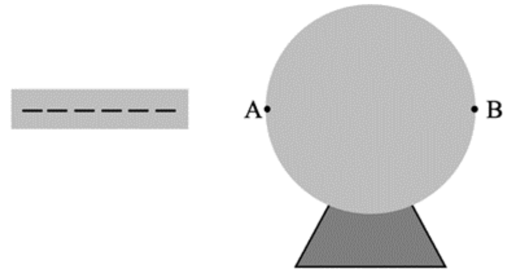
4) (4 pts) A hollow insulating **sphere** has inner radius $a$ and outer radius $b$, as shown. The insulating material has a uniform volume charge density $\rho_0$. What is the magnitude of the electric field at a point $a < r < b$?

Cross-section of **sphere**




A. $E(r) = \frac{\rho_0 r}{4\pi\epsilon_0}$
B. $E(r) = \frac{\rho_0 a^3}{3r^2\epsilon_0}$
C. $E(r) = \frac{\rho_0}{3r^2\epsilon_0}(r^3 - a^3)$
D. None of the above.

5) (4 pts) A negatively charged **conducting** sphere is supported on an insulating stand. A negatively charged rod is brought near, but doesn't touch, the sphere, as shown. Which of the following best describes the potential difference between points A and B **after** the charged rod is brought near?




A. $V_A - V_B > 0$
B. $V_A - V_B < 0$
C. $V_A - V_B = 0$
D. Not enough information given.

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Use the following scenario for the next two questions:

Consider a parallel-plate capacitor with a plate area of $1.0 \times 10^{-3}$ m$^2$ and separation between the plates of $1.0 \times 10^{-5}$ m. The capacitor is fully charged with a battery with an emf of 5.0 V. We remove the battery and then a material with a dielectric constant $\kappa = 3$ is inserted in the gap between the plates.

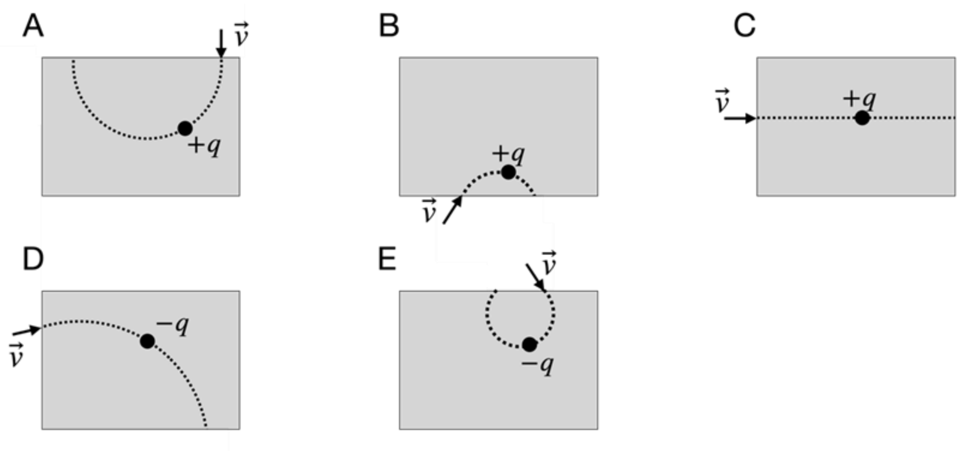
6) (4 pts) After inserting the dielectric, which statements correctly describe the changes in the charge and potential of the capacitor compared to their states before insertion? **Select all that apply.**

A. The magnitude of the free charge on the capacitor plates remains the same.
B. The magnitude of the free charge on the capacitor plates increases.
C. The potential difference between the plates decreases.
D. The potential difference between the plates remains the same.
E. Not enough information is given.

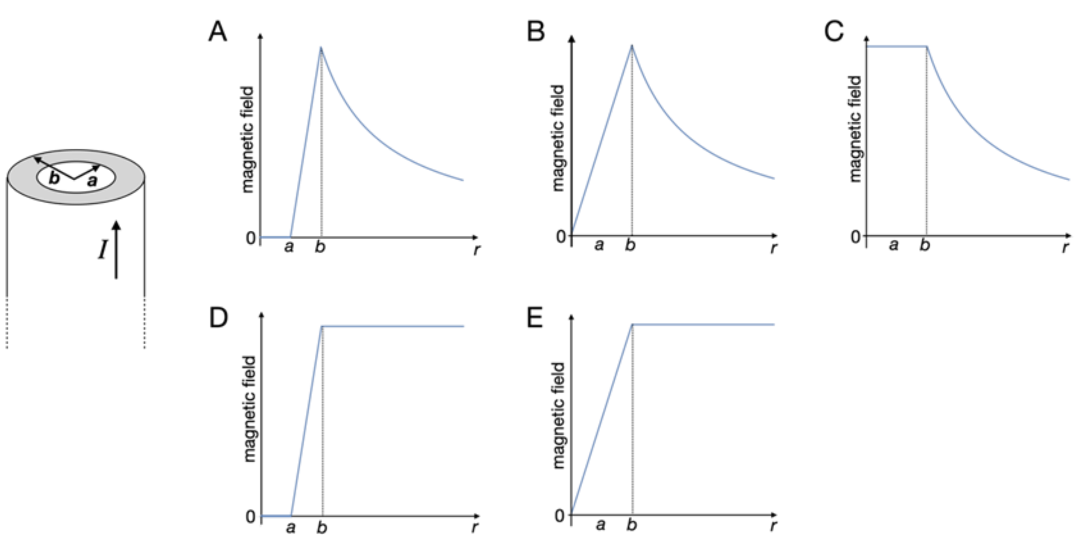
7) (4 pts) By what factor does the potential energy stored in the capacitor change after inserting the dielectric, $U_{\text{final}}/U_{\text{initial}}$?

A. 1/9
B. 1/3
C. 1
D. 3
E. 9

8) (4 pts) In the graphs shown, a charged particle with inertia (mass) $m$ and speed $v$ enters an area (shaded in gray), potentially containing a magnetic field. The charge and the velocity vector of the particle with which it enters the gray area are indicated in each graph. The trajectory of the particle in each graph is shown by a dotted line. In which cases is the magnetic field pointed **out of the page**? Note that there is no electric field in the gray region. **Select all that apply.**



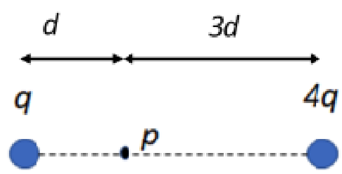

9) (5 pts) As shown, an infinitely long hollowed conducting cylinder with inner radius $a,$ and outer radius $b$ carries current $I$. Assume that the current is uniform across the conductor. Which graph best shows the magnitude of the magnetic field as a function of the radial distance $r$ from the center of the cylinder?



10) (4 pts) Two long conducting wires are placed parallel to each other with a separation distance of $d$ between them. The wires carry currents of different magnitudes. The left wire exerts an attractive force $F$ on the unit length of the right wire. We increase the currents in both wires to twice their original magnitude, while simultaneously reducing the distance between them by half. What is the magnitude of the force by the left wire on the unit length of the right wire?

A. $F/2$
B. $2F$
C. $4F$
D. $8F$
E. Not enough information is given.

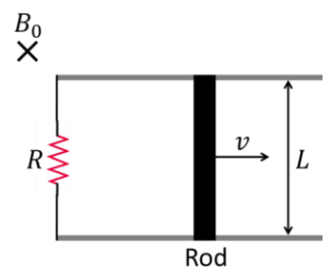
11) (4 pts) The potential energy of two particles shown is $U_1$, where the potential energy of two charged particles infinitely separated is defined to be zero. Now we bring a third particle with charge -$q$ to point $p$, and the total potential energy of the three particles is $U_2$. What is $U_2/U_1$?




A. -7/3
B. -4/3
C. 7/3
D. 0
E. None of the above

Use the following scenario for the next two questions:

In a region with a uniform and constant magnetic field of magnitude $B_0 = 1.5$ T directed into the page, a conducting rod with mass of 0.25 kg slides on two frictionless metallic rails. The rails are $L = 0.35$ m apart and are connected by a resistor as shown in the figure. At the instant when the rod moves to the right with a speed of $v = 7.0$ m/s there is an induced current of $I = 2.2$ A flowing in the rod.



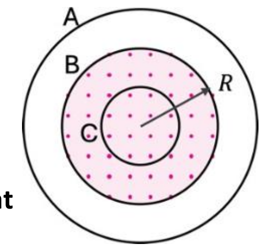

12) (5 pts) At the instant given, what is the acceleration of the rod?

A. 1.2 m/s$^2$ to the right
B. 1.2 m/s$^2$ to the left
C. 4.6 m/s$^2$ to the right
D. 4.6 m/s$^2$ to the left
E. More information is required.

13) (4 pts) What is the value of the resistance?

A. 0.60 Ω
B. 1.7 Ω
C. 3.7 Ω
D. 5.4 Ω
E. 8.1 Ω

14) (4 pts) A circular plate capacitor with radius $R$ is being **discharged.** Assume that the electric field is uniform between the plates and is zero elsewhere. As shown, the electric field is pointing out of the page, as the capacitor charges. Consider three concentric circular paths labelled A, B, and C, with radii of $3R/2$, $R$, and $R/2$, respectively. Which statements correctly describe the magnetic field along the three paths? **Select all that apply.**




A. The magnetic field is clockwise along all paths.

B. $B_A = B_B$

C. $B_B > B_A$

D. $B_B = B_C$

E. $B_B > B_C$

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15) (4 pts) Find the equivalent resistance and the equivalent capacitance of the circuit.

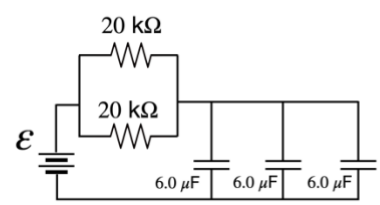
A. 40 kΩ, 2 μF

B. 10 kΩ, 2 μF

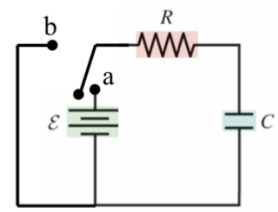
C. 40 kΩ, 18 μF

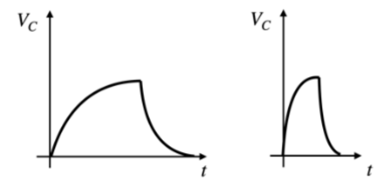
D. 10 kΩ, 18 μF

E. 20 kΩ, 6 μF



16) (4 pts) The potential across a capacitor in an RC circuit is measured as the capacitor is charged (with the switch in position a) and then discharged (with the switch in position b). The potential as a function of time is shown below, at the left. One change is made to the circuit, and then the potential is measured again. The potential as a function of time for this second circuit is shown below, at the right.

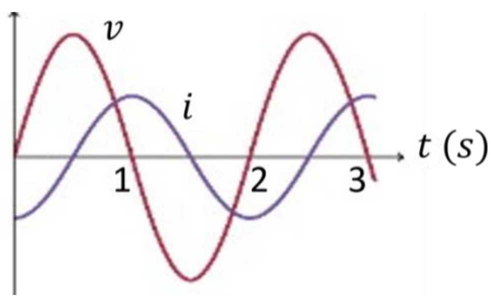



Which of the following changes could have resulted in the new potential function shown?

A. The resistor was exchanged with one that has half the cross-sectional area, and is otherwise the same.
B. The capacitor was exchanged with one that has half the dielectric strength, and is otherwise the same.
C. A second battery was added in series.
D. The resistor was changed to one with resistance $2R$ and the capacitor was changed to one with capacitance $C/2$
E. None of these would work.

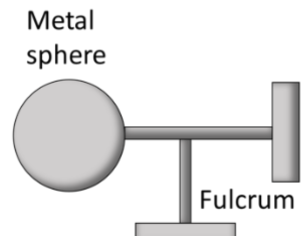
17) (4 pts) An AC circuit contains a resistor and an unknown element in series. The figure shows curves for the current through the unknown element and voltage across it as a function of time. Note that the frequency of oscillation is 0.5 Hz. The maximum potential difference across the unknown element is 3.0 V and the maximum current through the element is $1.5 \times 10^{-3}$ A. What is the unknown element?




A. A $1.6 \times 10^{-4}$-H inductor
B. A $6.4 \times 10^{2}$-H inductor
C. A $5.0 \times 10^{-4}$-Ω resistor
D. A $1.6 \times 10^{-4}$-F capacitor
E. A $6.4 \times 10^{2}$-F capacitor

**II. Lab multiple choice (15 points – next 4 questions)**

18) (3 pts) In lab A1 you placed an initially uncharged metal sphere on a fulcrum, as shown. You rubbed an acrylic rod with a wool cloth and then touched the acrylic rod to the metal sphere. You then rubbed the acrylic rod with the wool cloth again, before bringing the rod close to the metal sphere, without touching it. You observed that the metal sphere and the acrylic rod were attracted to each other. Which of the following explanations is most likely correct?




A. The metal sphere and the acrylic rod have like charges, but the metal sphere was polarized, which is why they attracted.
B. The metal sphere and the acrylic rod have opposite charges, but the metal sphere was polarized, which is why they attracted.
C. The metal sphere and the acrylic rod have opposite charges, which is why they attracted.
D. The metal sphere and the acrylic rod have like charges, which is why they attracted.

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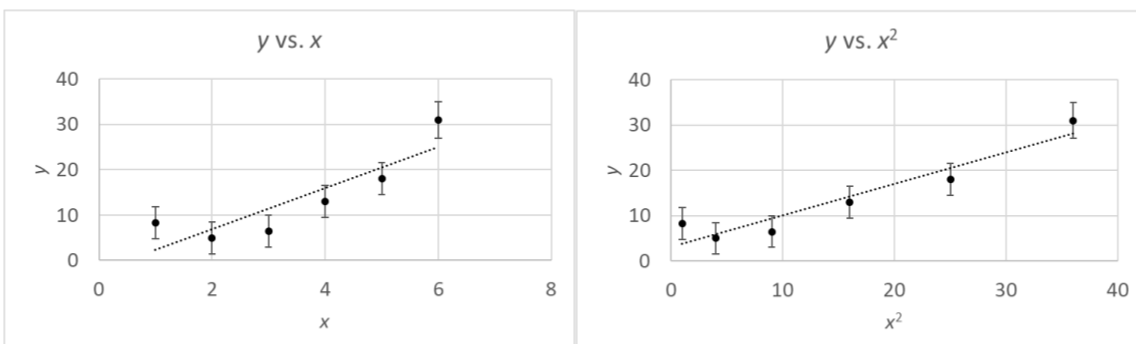
19) (4 pts) Suppose that the graphs below show the data you obtained for values of $x$ and $y$. The left graph shows $y$ versus $x$, and the right graph shows $y$ versus $x^2$. Each graph has a linear best-fit line.

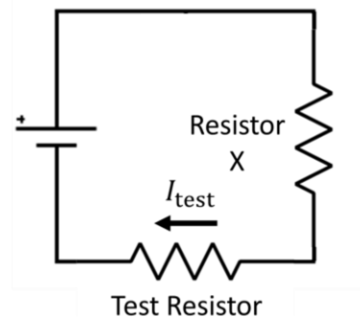



Suppose that you are testing two models below, where $m$ and $b$ are arbitrary constants.
Model 1: $y = mx + b$
Model 2: $y = mx^2 + b$

Based on these graphs, what can you conclude? **Select all that apply.**

A. The data supports Model 1.
B. The data supports Model 2.
C. The data does not support either Model 1 or Model 2.
D. We do not have enough information to conclude anything.

20) (4 pts) You construct the circuit shown to measure the current through a test resistor as a function of the potential difference across the test resistor. Resistor X is an Ohmic resistor with a resistance of 10.0 Ω. You believe the test resistor is **non Ohmic** and that the potential difference across it is given by




$$V_R = I(a + bI)$$

where $a = 10.0\ \Omega$ and $b = 5.00\ \Omega/\mathrm{A}$. If the model for the test resistor is correct, and you measure a current of $I = 0.100$ A through the test resistor, what is the EMF of the battery used in your circuit?

A. 1.00 V
B. 1.95 V
C. 2.00 V
D. 2.05 V
E. More information is required.

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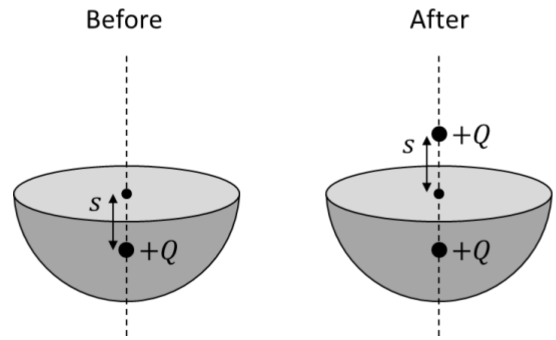
21) (4 pts) You measure the potential difference across a resistor to be $V_R = 6.0 \pm 0.2$ V. You need to calculate $y = \ln V_R$. How should you report your value of $y$ including uncertainty according to the rules we use in PHYS 122?

A. $1.79 \pm 0.033$
B. $1.79 \pm 0.03$
C. $1.79 \pm 0.060$
D. $1.79 \pm 0.06$

**III. Tutorial multiple choice (15 points – next 4 questions)**

22) (3 pts) Consider a hemispherical Gaussian surface that encloses a particle with charge $+Q$. The particle is located a distance $s$ directly below the center of the flat circular surface. Another particle with charge $+Q$ is added a distance $s$ above the center of the circle as shown. As the new particle is added, does the electric flux through the **curved surface** of the Gaussian surface *increase*, *decrease*, or *remain the same*?




A. Increase
B. Decrease
C. Remain the same.
D. Not enough information is given.

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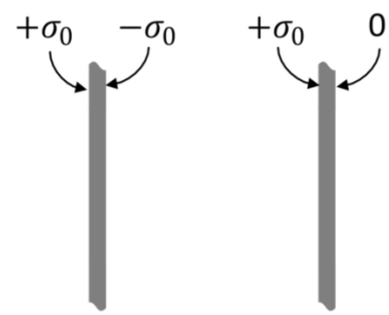
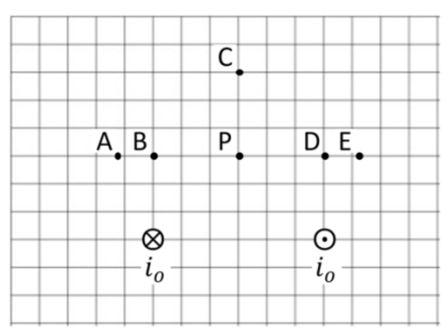
23) (4 pts) Two **conducting** plates are placed close together. At an instant, the uniform area charge densities on the surfaces of the plates are as shown. Which of the following statements is correct?




A. The charge distribution on both plates is in equilibrium because the net charge on the inner two surfaces is zero.
B. Only the charge distribution on the left plates is in equilibrium because the electric field inside the right plate is zero.
C. The charge distributions on both plates are not in equilibrium because the electric fields inside both plates are not zero.
D. Not enough information is given.

24) (4 pts) Shown at right is a cross-sectional view of two long, straight wires that are parallel to each other, placed near position P. One wire carries a current $i_o$ out of the page; the other wire carries a current $i_o$ into the page. Suppose that a third wire, carrying current $i_o$ out of the page, is introduced such that the net magnetic field at position P is zero. Where is the third wire located?




A. Position A
B. Position B
C. Position C
D. Position D
E. Position E

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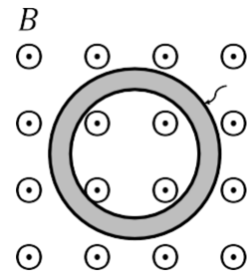
25) (4 pts) A conducting wire loop is in a region with uniform magnetic field out of the page as shown. As the strength of the magnetic field is decreased what do you observe?




A. There is no current induced in the loop.
B. There is a clockwise current induced in the loop.
C. There is a counterclockwise current induced in the loop.
D. More information is required.