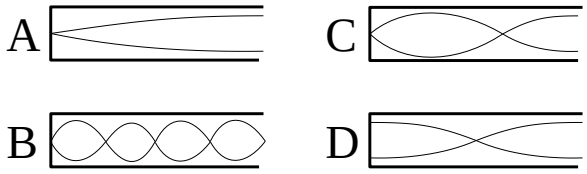
Physical Constants:

proton charge = $e = 1.60 \times 10^{-19}$ C
proton mass = $m_p = 1.67 \times 10^{-27}$ kg
electron mass = $m_e = 9.11 \times 10^{-31}$ kg
Coulomb constant = $k = 9 \times 10^9$ N $\cdot$ m^2/C^2
permittivity = $\epsilon_0 = 8.85 \times 10^{-12}$ C^2/(N $\cdot$ m^2)
sound velocity = $v = 343$ m/s

Circle the letter of the single best answer. (1 pt.)

1. The below figure shows standing waves of sound in four organ pipes of the same length. Each pipe has one end open and the other end closed. Warning: some of the figures show situations that are not possible. Which possible pipe sounds with the highest frequency?

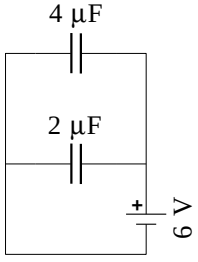


A. A
B. B
C. C
D. D

2. Which depicted standing wave (possible or impossible) shows a sound wave one octave above the fundamental of the open-closed organ pipe?

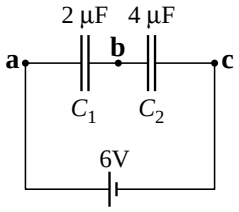
A. A
B. B
C. C
D. D

3. A 2 μF capacitor (C_1) and a 4 μF capacitor (C_2) are connected as shown below and attached to a 6 V battery. How does the charge, Q_1, stored on C_1 compare to the charge, Q_2, stored on C_2?



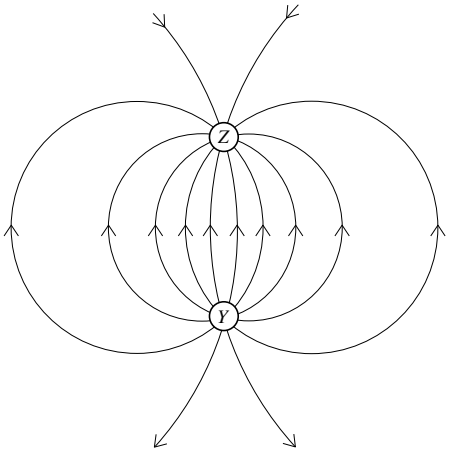
A. $Q_1 = 2Q_2$
B. $2Q_1 = Q_2$
C. $Q_1 = Q_2$
D. None of the above

4. A 2 μF capacitor (C_1) and a 4 μF capacitor (C_2) are connected as shown below and attached to a 6 V battery. How does the voltage drop across C_1 ($V_1 = V_a - V_b$) compare to the voltage drop across C_2 ($V_2 = V_b - V_c$)?



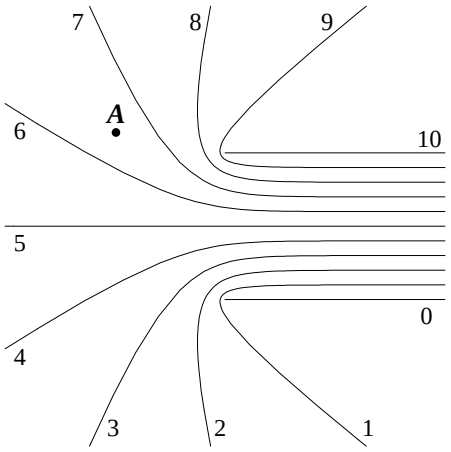
A. $V_1 = 2V_2$
B. $2V_1 = V_2$
C. $V_1 = V_2$
D. None of the above

5. The following diagram shows the electric field lines in a region of space containing two small charged spheres (Y and Z). Which of the below statements best describes this situation.

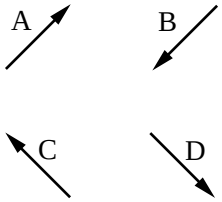


A. Y carries a positive charge; Z carries a negative charge.
B. The strongest electric field is midway between Y and Z.
C. Both of the above.
D. None of the above.

6. The below diagram shows the equipotentials that result from parallel line conductors. (This is very similar to the equipotentials you studied in lab, although here we have a different configuration of conductors.) The bottom conductor is at 0 V; the top is at 10 V. The voltage on each equipotential is labeled.



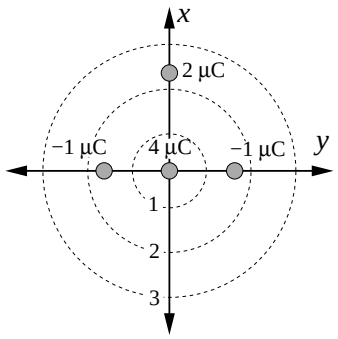
Consider an *electron* at the location **A**. Circle below the arrow that best describes the direction of the *force* on this electron.



7. The following three appliances are turned off but connected to the same 120 V house circuit: (a) 1500 W space heater, (b) 1000 W toaster, (c) 500 W blender, (d) 200 W desktop computer, and (e) 100 W lamp. Which of the below combinations would 'blow' (i.e., exceed) a circuit protected with a 20 A fuse. (Circle all that apply)

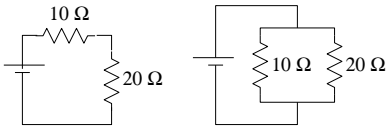
   A. a, c, d, e
   B. b, c, d, e
   C. a, b
   D. None of the above

8. The figure in the following column shows the location and charge on four tiny conductors sitting in the xy plane. Consider the electric flux, Φ_E through three Gaussian spheres centered on the origin with radii as shown in the figure. Which of the below options best describes the relationship between the flux through these three spheres. (Φ_1 denotes the electric flux through sphere 1, etc.)



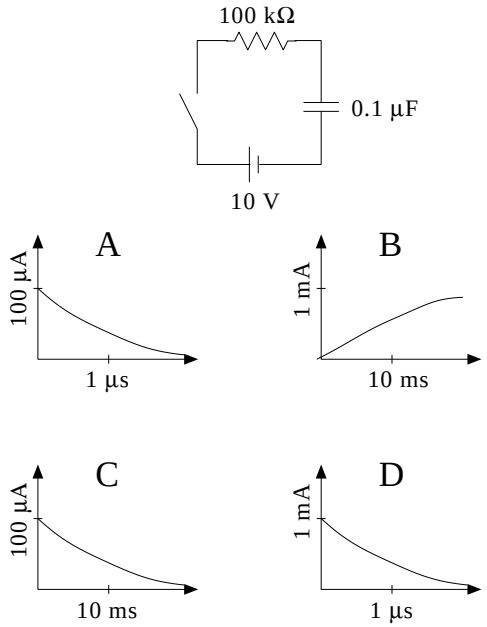
   A. $\Phi_2 < \Phi_1 < \Phi_3$
   B. $\Phi_1 < \Phi_2 < \Phi_3$
   C. $\Phi_1 = \Phi_2 = \Phi_3$
   D. $\Phi_2 < \Phi_1 = \Phi_3$

9. The same components (10 Ω and 20 Ω resistors) are used to make a series circuit and a parallel circuit. In each circuit, which resistor draws more electrical power?



   A. The 10 Ω draws the most power in both circuits.
   B. The 20 Ω draws the most power in both circuits.
   C. The 10 Ω draws the most power in the parallel circuit; the 20 Ω draws the most power in the series circuit.
   D. The 20 Ω draws the most power in the parallel circuit; the 10 Ω draws the most power in the series circuit.

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

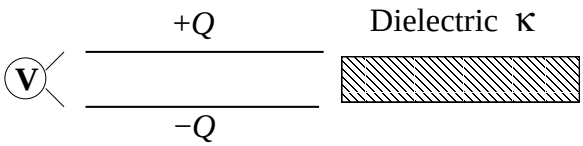


The following questions are worth 10 pts each

Record your steps! (Grade based on method displayed not just numerical result)

To receive full credit your answers should have exactly three significant figures

11. For the below questions circle the appropriate symbol to report if the quantity increases ($\Uparrow$) , decreases ($\Downarrow$) or stays the same ($\Leftrightarrow$).



A closely-spaced parallel-plate capacitor is 'charged' (top plate carries $+Q$; bottom plate $-Q$) and disconnected (isolated; connected to no thing). Dielectric material is then inserted between the plates. How do the below quantities change when the dielectric is inserted?

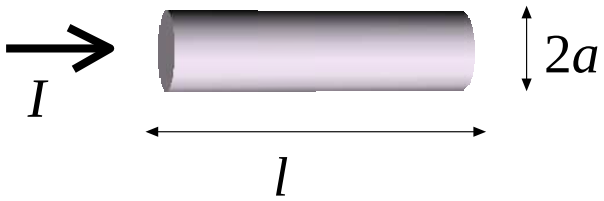
$\Uparrow \Downarrow \Leftrightarrow$ capacitance

$\Uparrow \Downarrow \Leftrightarrow$ potential difference (voltage)

$\Uparrow \Downarrow \Leftrightarrow$ charge on a plate

$\Uparrow \Downarrow \Leftrightarrow$ potential energy stored

$\Uparrow \Downarrow \Leftrightarrow$ electric field between plates



A resistor consists of a long cylinder of carbon (radius a, length ℓ) and carries a current I. If a bit of the carbon cylinder is cut off (reducing the length ℓ, but not changing the current I) report how the below quantities would change.

$\Uparrow \Downarrow \Leftrightarrow$ resistance

$\Uparrow \Downarrow \Leftrightarrow$ potential difference (voltage)

$\Uparrow \Downarrow \Leftrightarrow$ resistivity

$\Uparrow \Downarrow \Leftrightarrow$ electric field

$\Uparrow \Downarrow \Leftrightarrow$ drift velocity

12. You are on a pier watching for your parent's cruise ship depart. As you watch the now distant departing ship, you notice that the sound of its blowing whistle is 7 Hz lower than when the ship was at rest. On the pier there is a monitor that displays the ship's current speed: 5.5 m/s.

    A. What is the frequency of the whistle when the ship is stationary? (Hint: requires a bit of algebra.)

    B. The ship's whistle is 90 dB loud when the ship is 200 m away from the pier. How loud (in dB) will it sound when it is 400 m from the pier?

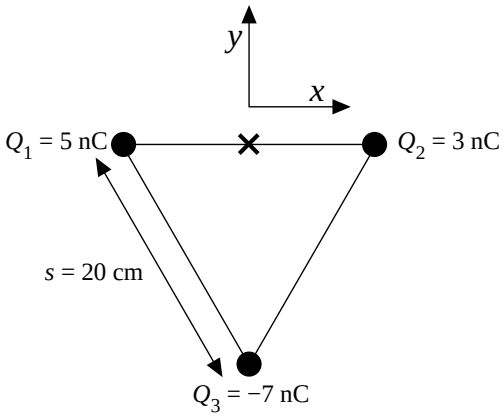
13. As shown three charges are arranged in an equilateral triangle with side 20 cm; we seek the electric field vector at the spot marked X (i.e., the midpoint of the horizontal segment).

    A. Directly on the diagram, draw (approximately) and label the electric field vector (including direction) at X due to each of the three charges. Label the electric field due to Q_1: $\mathbf{E}_1$, etc.

    B. Draw (approximately) the sum of these three electric field vectors. Label an angle that describes the direction of this net electric field vector.

    C. Calculate the electric field vector at the spot marked X, by finding its x and y components.

    D. Calculate the numerical value of the angle you labeled in part (B).



14. Using Kirchhoff's Rules find the current flowing in each wire of the given circuit. Use the supplied current arrows/names! Clearly show (by writing directly on the circuit diagram) each loop followed (including direction) and the resulting equation. Feel free to solve these equations using direct calculator methods like `rref`, but record exactly what you supplied to your calculator. (Otherwise it is very difficult to give partial credit.)