Physical Constants:

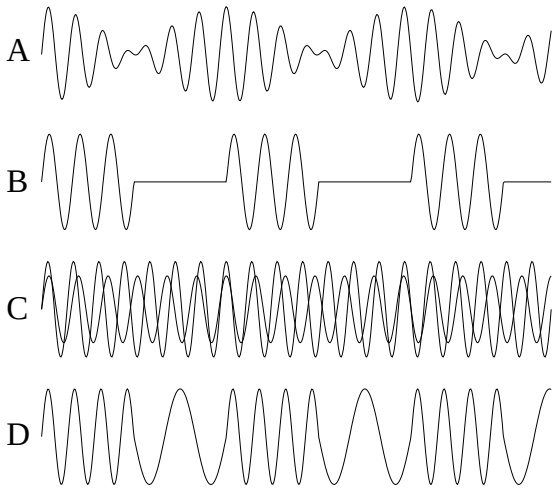
proton charge = $e = 1.60 \times 10^{-19}$ C
proton mass = $m_p = 1.67 \times 10^{-27}$ kg
electron mass = $m_e = 9.11 \times 10^{-31}$ kg
Coulomb constant = $k_e = 9 \times 10^9$ N $\cdot$ m^2/C^2
permittivity = $\epsilon_0 = 8.85 \times 10^{-12}$ C^2/(N $\cdot$ m^2)
sound velocity = $v = 343$ m/s

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

1. A train's horn sounds the musical note A at 440 Hz. How fast, and in which direction (towards or away from the listener) would the train need to move to be perceived as a B (494 Hz). (Select the situation nearest the correct value.)

   A. 32 m/s away from the listener
   B. 37 m/s toward the listener
   C. 42 m/s away from the listener
   D. 47 m/s toward the listener

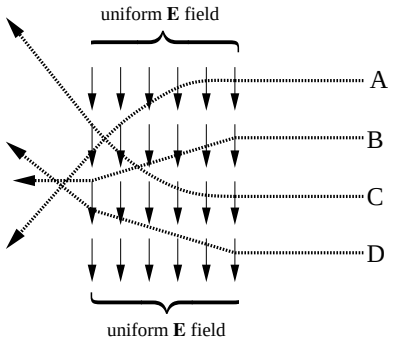
2. If two notes of nearly equal pitch are simultaneously present we call the result 'beats'. Which of the below graphs displays this phenomena.



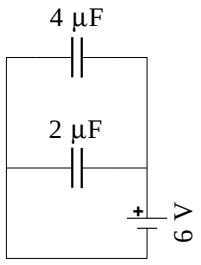
3. There is no net charge on a conducting sphere. A positively charged rod approaches (but does not touch) the sphere. The force on the conducting sphere is:

   A. zero
   B. attractive
   C. repulsive
   D. at first repulsive, but then attractive

4. An electron is moving at high speed through a field-free region. It enters (and soon exits) a region in which the electric field points down. Which path best represents the path of the electron?

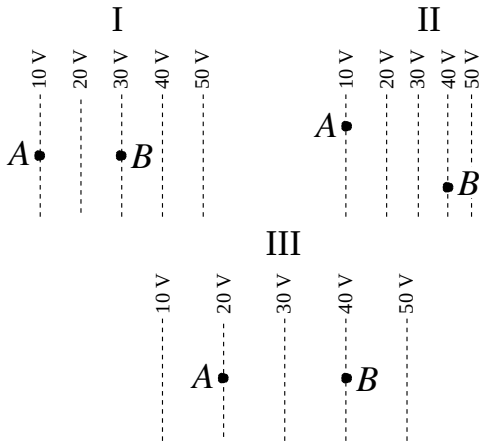


5. A 2 μF capacitor (C_1) and a 4 μF capacitor (C_2) are connected as shown below and attached to a 6 V battery. How does the voltage, V_1, across C_1 compare to the voltage, V_2, across C_2?



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

6. The following figures faithfully show (with one-to-one scale) the location of equipotential lines (displayed as the dotted lines with corresponding voltages). In each case, an object with charge $+1\ \mu$C is moved from A to B.



Which of the below statements best describes the amount of work needed to move this charge in the three cases.

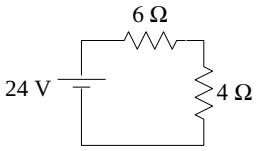
A. The smallest work is required in I.

B. The largest work is required in II.

C. The largest work is required in III.

D. All three require the same amount of work.

7. What is the voltage across the 6 Ω resistor? (Select the nearest result)



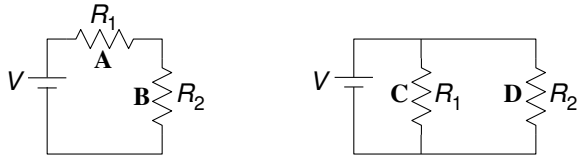
A. 4 V

B. 8 V

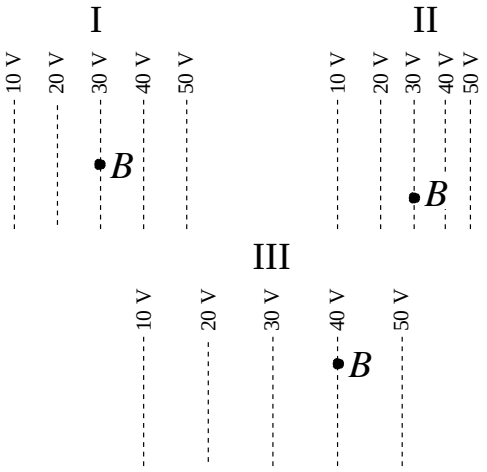
C. 14 V

D. 24 V

8. Two circuits are made with identical components: battery (V) and resistors R_1 and R_2 (with $R_1 < R_2$). Circle the letter of the **one** resistor through which the largest current flows.



9. The following figures faithfully show (using the same scale) the location of equipotential lines (displayed as the dotted lines with corresponding voltages). How does the magnitude of the electric field at B compare in the three cases? (E_I denotes the magnitude of electric field at B in figure I, etc.)



A. $E_{III} > E_{II} > E_I$

B. $E_I > E_{III} > E_{II}$

C. $E_I = E_{II} > E_{III}$

D. $E_{II} > E_I > E_{III}$

10. The following three appliances are turned off but connected to the same 120 V house circuit: (a) 2500 W space heater, (b) 840 W toaster, (c) 360 W desktop computer, (d) 120 W lamp, and (e) 60 W laptop. Which of the below combinations could be simultaneously turned on given that the circuit is protected with a 20 A fuse. (Circle all that would work.)

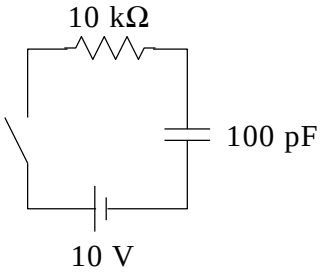
A. a alone

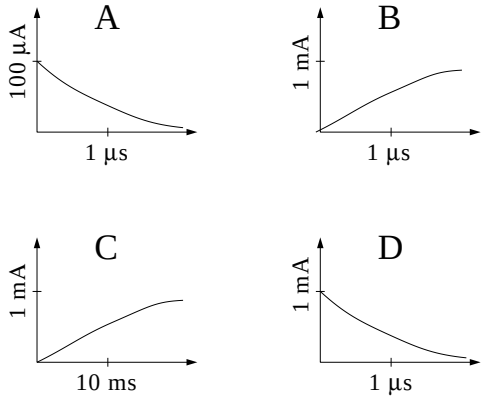
B. a and e

C. b, d, and e

D. b, c, d, and e

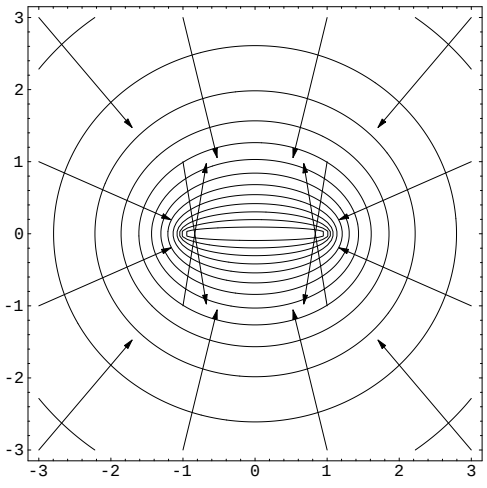
11. The below circuit shows a series RC circuit. The switch is closed at $t = 0$. Which graph (look right) best represents how the current changes in time?



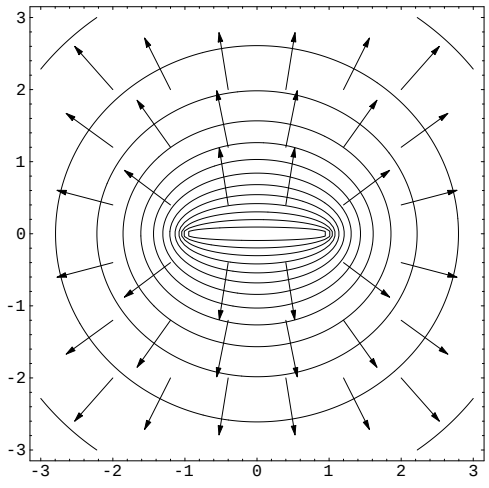


12. In below plots the elliptical loops are equipotentials. Adjacent loops have the same voltage difference (e.g., consecutive loops might be at voltages: 0, 10, 20, 30, ... volts.). At each point corresponding to the tail of the vector the electric field has been calculated and is displayed as an arrow. Which plot properly displays the relationship between electric potential (voltage) and electric field?

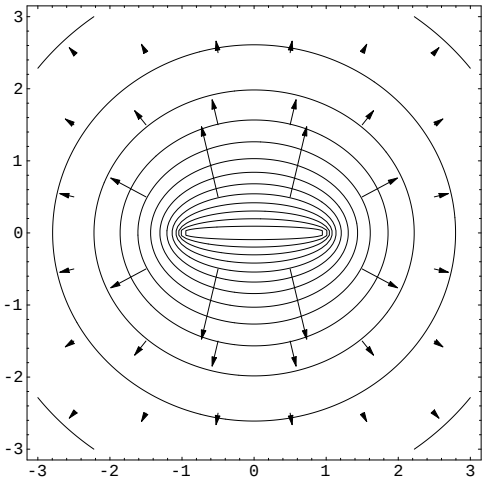
(A)



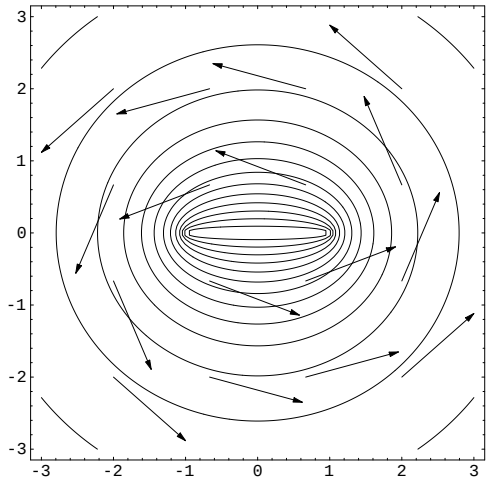
(B)



(C)



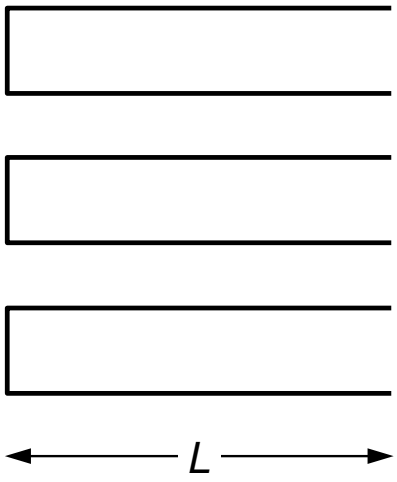
(D)



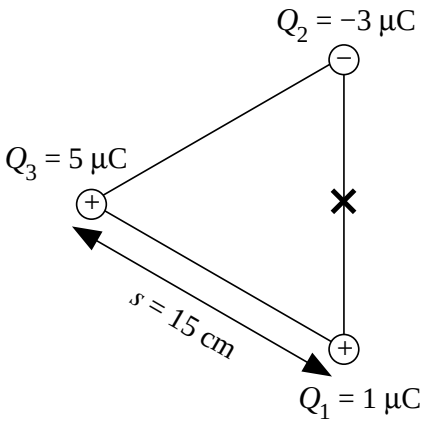
The following questions are worth 12 pts each

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

13. An open-closed organ pipe sounds producing a fundamental standing wave at a frequency of 400 Hz and the next two overtones. Find the length of the organ pipe and the frequencies of the two overtones. In the below sketches of the organ pipe, draw each of these standing wave displacment patterns. Label a node and an antinode.



14. As shown three charges are arranged in an equilateral triangle with side 15 cm; we seek the electric field vector at the spot marked X (i.e., the midpoint of the vertical segment).



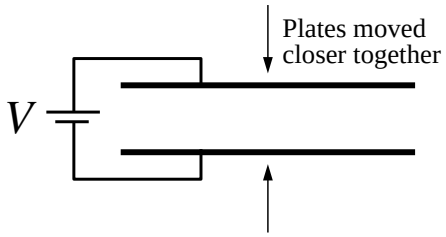
    A. Directly on the diagram, draw (approximately) and label the electric field vector (including direction) at X due to each of the three charges. Label the electric field due to Q_1: $\mathbf{E}_1$, etc.

    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).

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



A parallel-plate capacitor is connected to a battery of fixed voltage V. The separation between the parallel plates is decreased slightly. Report how the below quantities would change.

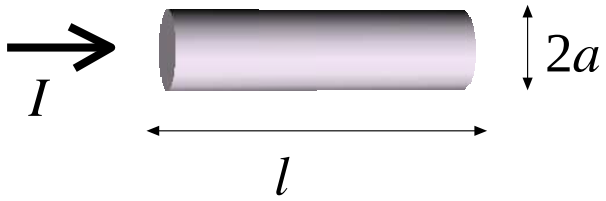
$\Uparrow \Downarrow \Leftrightarrow$ capacitance

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

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

$\Uparrow \Downarrow \Leftrightarrow$ 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 the current I is decreased slightly 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

16. Using Kirchhoff's Laws find the equations that determine 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. Report the matrix (equivalent to your equations) that you would enter to solve these equations by row reduced echelon form `rref`. You need not solve these equations!