Rules: This exam is to be completed by you unaided by textbook, web, notes, homework solutions, friends etc. . . . (You are of course encouraged to use a calculator.) The one external aid you may use during the exam is the unannotated 'Course Guide:' the formulas, definitions, etc that I recorded there may help you recall how to work a problem. If, during the exam, you think you need an additional formula or hint, ask me (via personal chat) and I may be willing to provide it. Remotes will enable video, have audio available but muted and be on screen 100% of the time. Questions may be asked via personal chat. You should also use the Hands Up feature to draw my attention to your question.

Clearly the above will hardly deter the determined cheater. Your personal integrity is the only real deterrent to cheating. To engage that, sign the below statement just before you turn in the exam.

In answering these questions I have used no external aids other then the unannotated 'Course Guide'.

Name: ________________________________

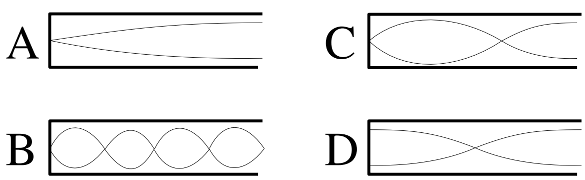
Physical Constants:

sound velocity $= v = 343$ m/s
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)
permeability $= \mu_0 = 4\pi \times 10^{-7}$ T$\cdot$m/A
speed of light $= c = 3 \times 10^8$ 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?

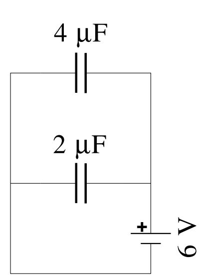


A. A
B. B
C. C
D. D

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

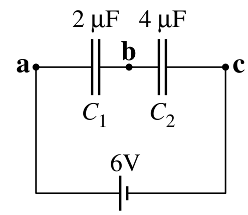
A. A
B. B
C. C
D. D

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?



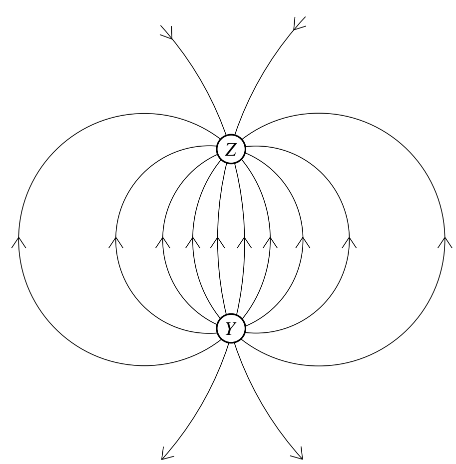
A. $Q_1 = 2Q_2$
B. $2Q_1 = Q_2$
C. $Q_1 = Q_2$
D. None of the above

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 ($V_2 = V_b - V_c$)?



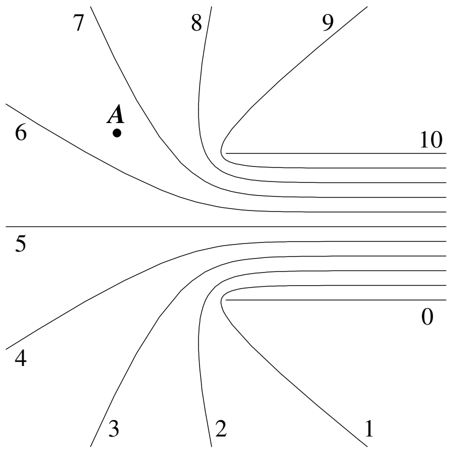
A. $V_1 = 2V_2$
B. $2V_1 = V_2$
C. $V_1 = V_2$
D. None of the above

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.

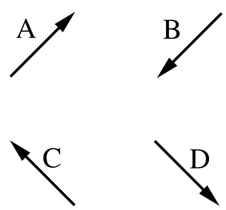


A. Y carries a positive charge; Z carries a negative charge.
B. The strongest electric field is midway between Y and Z.
C. Both of the above.
D. None of the above.

6. The below diagram shows the equipotentials that result near the edge of 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.



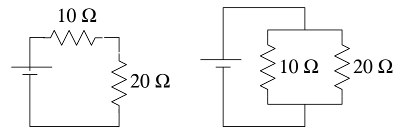
Consider an *electron* at the location **A**. Circle below the arrow that best describes the direction of the *force* on this electron.



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)

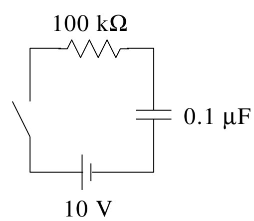
A. a, c, d, e
B. b, c, d, e
C. a, b
D. None of the above

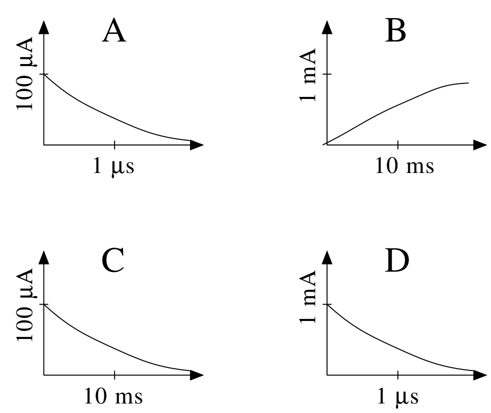
8. The same components (10 Ω and 20 Ω resistors) are used to make a series circuit and a parallel circuit. In each circuit, which resistor draws more electrical power?



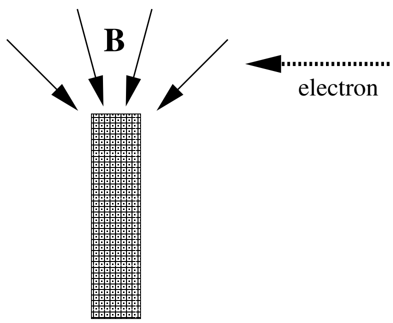
A. The 10 Ω draws the most power in both circuits.
B. The 20 Ω draws the most power in both circuits.
C. The 10 Ω draws the most power in the parallel circuit; the 20 Ω draws the most power in the series circuit.
D. The 20 Ω draws the most power in the parallel circuit; the 10 Ω draws the most power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

9. 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?





10. An electron approaches the pole of bar magnet at high speed. The arrows on this diagram show the direction of the magnetic field and the direction of the electron's initial velocity. What type of pole (N or S) is the electron approaching and in which direction will the electron move?

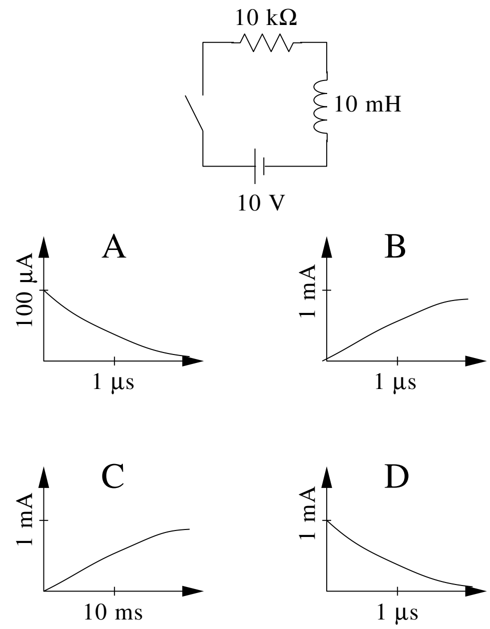


A. S, into page
B. S, out of page
C. N, into page
D. N, out of page

11. Consider two long straight parallel wires, each carrying a current. The currents are flowing in opposite directions and the current in one wire is twice the current in the other wire.

A. The two wires will attract each other and the large-current wire feels the larger force.
B. The two wires will repel each other and the large-current wire feels the larger force.
C. The force on the high-current wire will be the exact opposite of the force on the low-current wire.
D. None of the above.

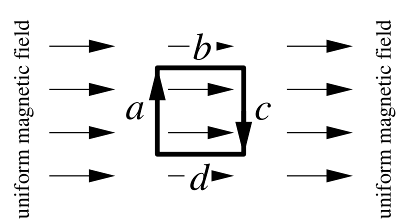
12. The below circuit shows a series LR circuit. The switch is closed at $t = 0$. Which graph best represents how the <u>current</u> changes in time?



13. The primary winding of a transformer has 200 turns and is connected to a normal U.S. household receptacle. The secondary has 1000 turns. The output (secondary) voltage is most nearly

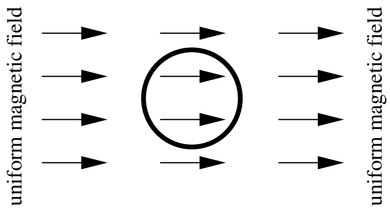
A. 600 V
B. 120 V
C. 25 V
D. 5 V

14. There is a current flowing clockwise around a square loop which is surrounded with a uniform magnetic field pointing to the right. The torque on this loop will try to rotate the loop so



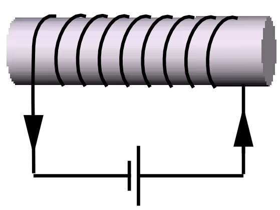
A. side a moves out of the page
B. side b moves out of the page
C. side c moves out of the page
D. side d moves out of the page

15. A loop of wire (with radius r) and a uniform magnetic field ($\mathbf{B}$) share the plane of this piece of paper. The magnetic flux through the loop is:



A. $+2\pi rB$
B. $+\pi r^2 B$
C. $-\pi r^2 B$
D. zero.

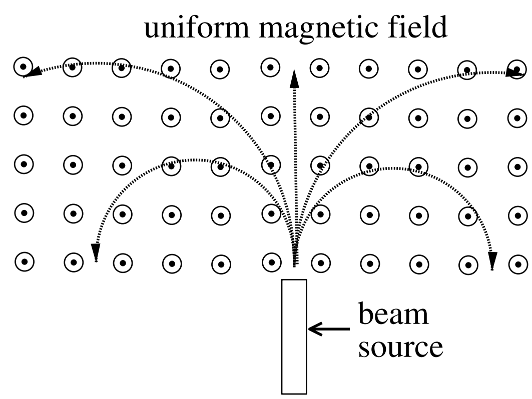
16. N turns of wire are wrapped around a cylinder of length L and radius r forming a solenoid. The wire carries a current I in the direction shown. Select the most complete combination of correct statements about this situation.



I. The magnetic field inside the solenoid points to the left.
II. Starting at the center of the solenoid and moving perpendicular to the axis of the coil the magnetic field reverses direction only as you penetrate the coil and then continue outside the coil.
III. Starting at the center of the solenoid and moving to the right along the axis of the solenoid, the magnetic field gradually diminishes, but always points in the same direction.
IV. The magnetic field in the center of the solenoid is proportional to N and I and inversely proportional to L.

A. I, III
B. II, III, IV
C. III, IV
D. I, II, III, IV

17. A beam consists of a mix of protons, deuterons (an isotope of hydrogen: twice the mass of a proton, but with the same charge), α particles (He nuclei: four times the mass of a proton and twice the charge of a proton), and electrons. All the particles have the same momentum (of course, since the particles have different masses, they have different speeds). The beam directs the particles into a region of uniform magnetic field (pointing out of the page—much like a mass spec). The below figure displays some possible paths for particles. Which combination of the below statements is correct?



I. The proton and deuteron follow the same path; the α follows a smaller radius path.
II. The radius of the electron's path is much smaller than the radius of the proton's path.
III. The radius of the electron's path is the same as the radius of the proton's path, but it curves in the opposite direction.
IV. The proton, deuteron and α all follow different paths, with the more massive particles having the largest radius path.

A. II, IV
B. I, III
C. II, IV
D. IV

The following questions are worth 10 pts each

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

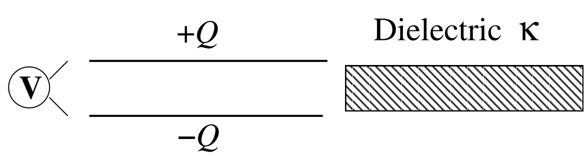
To receive full credit your numerical answers should have exactly three significant figures.

18. You are on a pier watching your parent's cruise ship depart. When it was at rest its horn sounded 55 Hz (second lowest A on a piano). As it was departing the horn sounded 53 Hz (almost A♭).

    A. How fast was the ship moving?

    B. The ship's whistle is 90 dB loud when the ship is 100 m away from the pier. How loud (in dB) will it sound when it is 200 m from the pier?

19. For the below questions circle the appropriate symbol to report if the quantity increases (⇑) , decreases (⇓) or stays the same (⇔).



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?

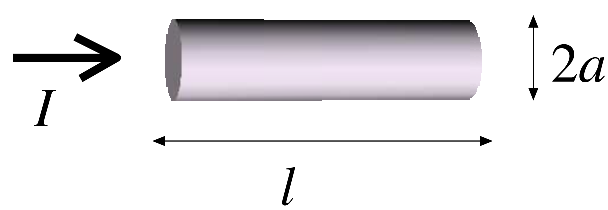
⇑ ⇓ ⇔ capacitance

⇑ ⇓ ⇔ potential difference (voltage)

⇑ ⇓ ⇔ charge on a plate

⇑ ⇓ ⇔ potential energy stored

⇑ ⇓ ⇔ 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.

⇑ ⇓ ⇔ resistance

⇑ ⇓ ⇔ potential difference (voltage)

⇑ ⇓ ⇔ resistivity

⇑ ⇓ ⇔ electric field

⇑ ⇓ ⇔ drift velocity

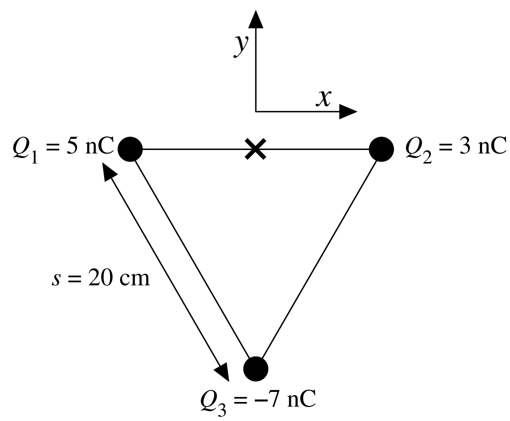
20. As shown three charges are arranged in an equilateral triangle with side 20 cm; we seek the electric field vector at the spot marked X (i.e., the midpoint of the horizontal segment).

    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).



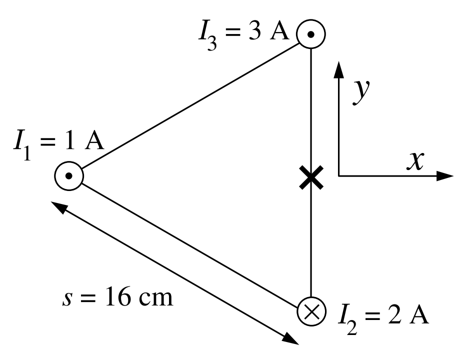
21. As shown below three long wires are arranged in an equilateral triangle with side $s = 16$ cm.. The currents I_1 and I_3 come directly out of this page; I_2 goes into the page. We seek the magnetic field vector at the spot marked X (i.e., the midpoint of the vertical segment).

    A. Directly on the diagram, draw (approximately) and label the magnetic field vector (including direction) at X due to each of the three currents. Label the magnetic field due to I_1: $\mathbf{B}_1$, etc.

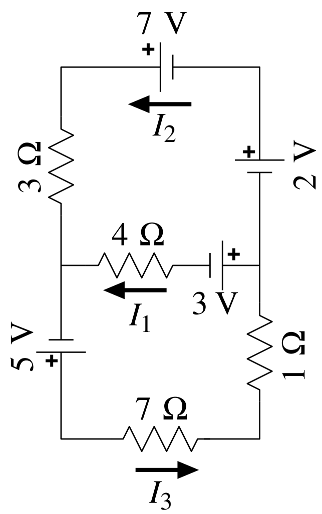
    B. Draw and label: $\mathbf{B}_{net}$ the arrow that represents sum of these three magnetic field vectors. Label an angle that describes the direction of this net magnetic field vector.

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

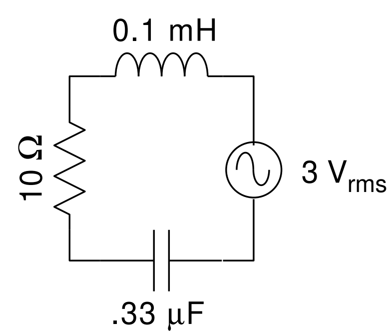
    D. Calculate the numerical value of the angle you labeled in part (B).



22. 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.)



23. Consider the below right LRC circuit, driven by a generator at a frequency of $f = 25$ kHz

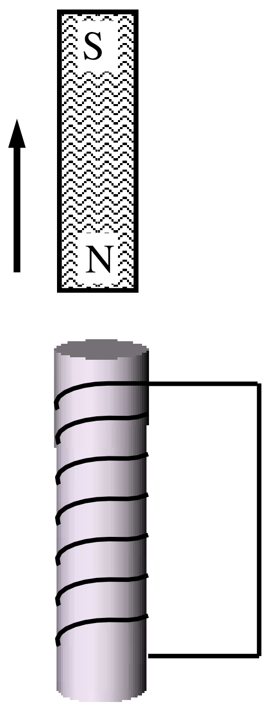


A. What is the inductive reactance (X_L)? What is the capacitive reactance (X_C)? What is the circuit impedance (Z)?

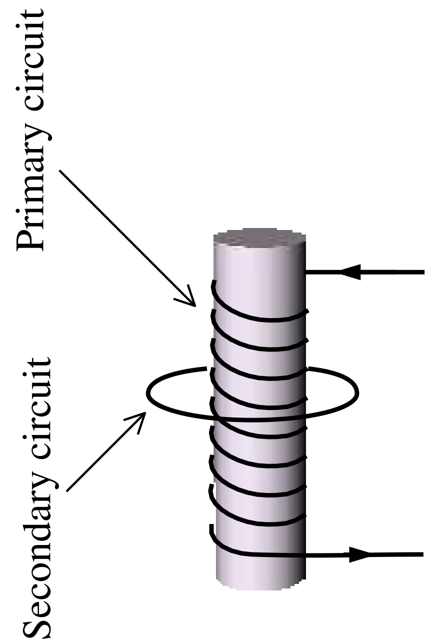
B. What rms current flows through the circuit?

C. What is the rms voltage across the inductor (V_L)? Across the capacitor (V_C)? Across the resistor (V_R)?

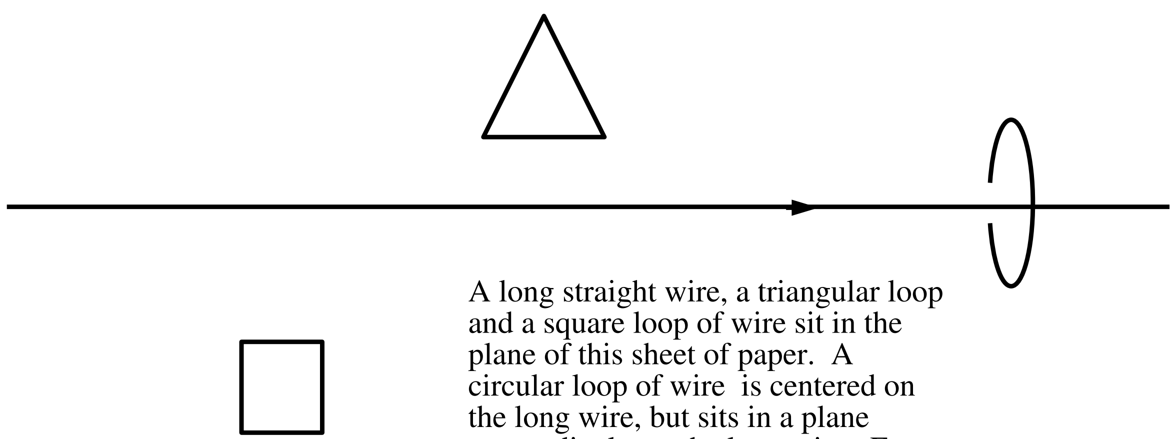
24. The below diagrams show three separate situations. For each case, add an arrow directly on a wire showing the direction of the induced current in that wire; if there is no induced current write “zero”. (Note that the bottom case of the long straight wire has three secondary circuits and hence three separate answers are required.)



The north pole of a bar magnet is moving away from the solenoid



The current shown flowing through the primary circuit is increasing



A long straight wire, a triangular loop and a square loop of wire sit in the plane of this sheet of paper. A circular loop of wire is centered on the long wire, but sits in a plane perpendicular to the long wire. For several minutes there has been a current flowing to the right; that current is now decreasing.