PHYSICS 2
Section I
40 Questions
Time—90 minutes

Note: To simplify calculations, you may use $g = 10 \text{ m/s}^2$ in all problems.

Directions: Each of the questions or incomplete statements below is followed by four suggested answers or completions. Select the one that is best in each case and then fill in the corresponding circle on the answer sheet.

1. Three objects—*X*, *Y*, and *Z*—are each given an excess electric charge. The objects are then brought near each other in pairs but do not touch. It is found that *X* and *Y* attract each other, *Y* and *Z* repel, and *X* and *Z* attract. Which of the following is a correct conclusion about the signs of the charges that can be drawn from these observations?

   (A) *X* and *Y* have charges of the same sign, and *Z* has a charge of the opposite sign.
   (B) *X* and *Z* have charges of the same sign, and *Y* has a charge of the opposite sign.
   (C) *Y* and *Z* have charges of the same sign, and *X* has a charge of the opposite sign.
   (D) *X*, *Y*, and *Z* all have charges of the same sign.

2. Each of the figures below shows the path of a charged particle moving in the plane of the page in a magnetic field that is perpendicular to the page. If the mass, speed, and charge of the particles are the same, in which case does the field have the greatest magnitude?

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   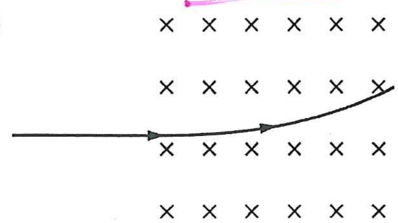

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   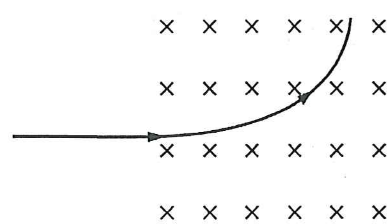

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   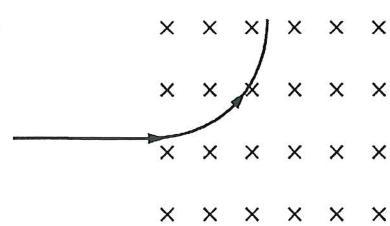

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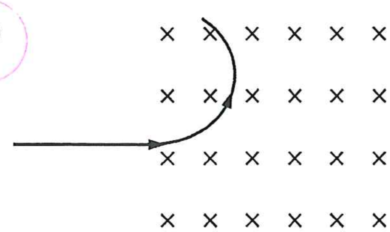
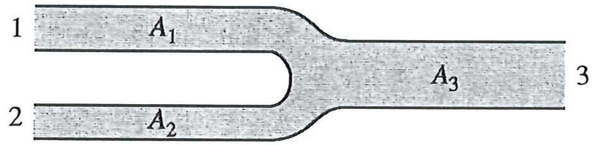
   



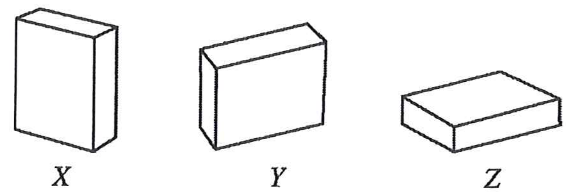
3. The figure above shows pipe 1 of cross-sectional area A_1 and pipe 2 of cross-sectional area A_2, which merge into pipe 3 of cross-sectional area A_3. The water in pipes 1 and 2 flows with speeds v_1 and v_2, respectively. What is the speed of the water in pipe 3 ?

(A) $\dfrac{A_1 v_1 + A_2 v_2}{A_3}$

(B) $\dfrac{A_1 v_1 - A_2 v_2}{A_3}$

(C) $\dfrac{(A_1 + A_2)(v_1 + v_2)}{A_3}$

(D) $A_3\left(\dfrac{v_1}{A_1} + \dfrac{v_2}{A_2}\right)$



4. A hollow rectangular box is filled with a liquid and can be placed in any of the three orientations shown above. In which orientation will the fluid pressure at the bottom of the box be greatest, and why?

(A) Orientation X, because pressure at the bottom of a fluid is greater when the vertical height of the fluid is greater
(B) Orientation Y, because pressure at the bottom of a fluid is greater when the width times the height of the fluid is greater
(C) Orientation Z, because pressure at the bottom of a fluid is greater when the area of the bottom surface is greater
(D) All three orientations have the same pressure, because the weight of the fluid is the same in each case.

5. An engineer has four wires made of the same material and wants to determine the material's resistivity. The engineer measures the length L and cross-sectional area A of each wire. The engineer then applies a potential difference V across each wire and measures the resulting current I. To estimate the resistivity of the material using only the slope of a graph of the data, which of the following should be graphed as a function of L/A ?

(A) V
(B) I
(C) V/I
(D) I/V

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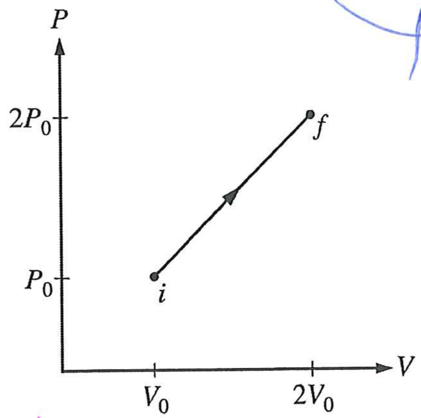
6. An ideal gas is taken from initial state i at pressure P_0 and volume V_0 to final state f at pressure $2P_0$ and volume $2V_0$. The figures below represent four possible processes by which the gas can be taken from state i to state f. For which process is the work done by the gas greatest?

(A)



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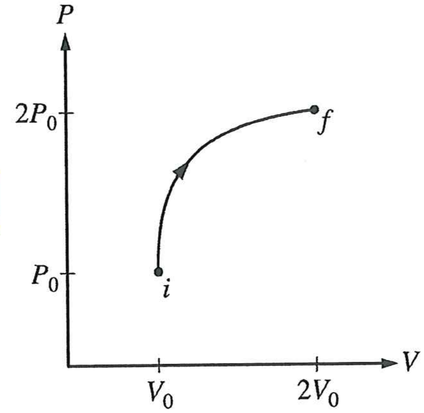

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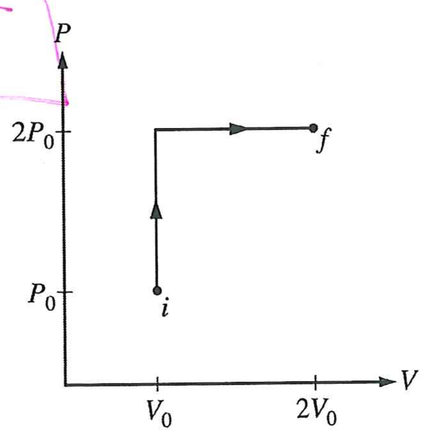

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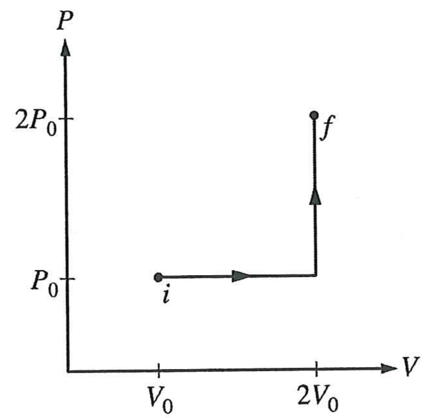

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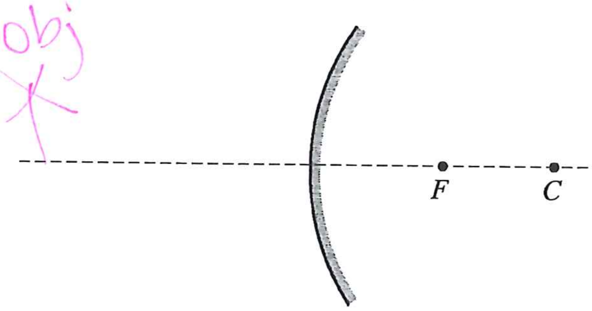
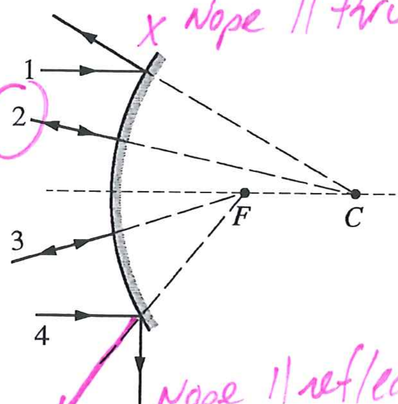
Questions 7-8 refer to the following material.



The figure above shows a convex mirror, its focal point F, and its center of curvature C.

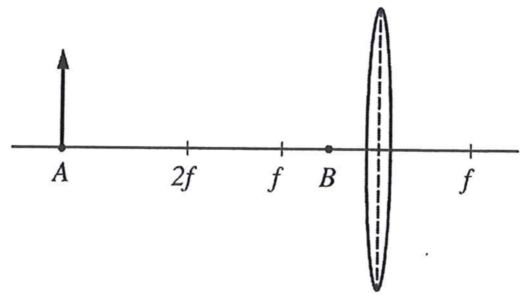


7. Which of the rays shown above is correct for this mirror?

   (A) 1
   (B) 2
   (C) 3
   (D) 4

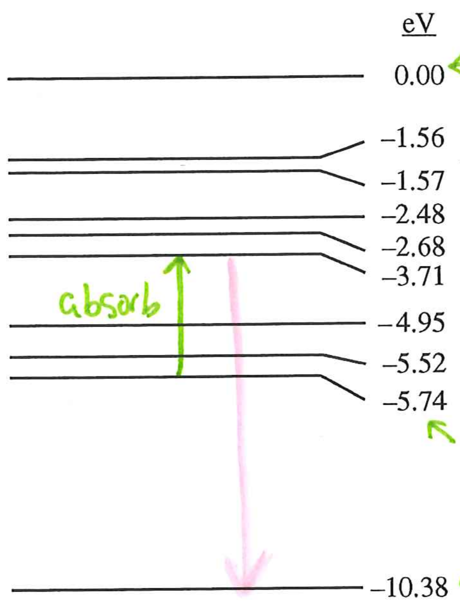
8. An object is located 2 m to the left of the mirror. If point C is 30 cm from the mirror, what is the approximate location of the object's image?

   (A) 26 cm to the right of the mirror
   (B) 14 cm to the right of the mirror
   (C) 16 cm to the left of the mirror
   (D) 35 cm to the left of the mirror



9. In the figure above, an object is moved from position A to position B. How does the image formed by the lens change during the move?

   (A) From real, reduced, and inverted to virtual, reduced, and upright
   (B) From real, reduced, and inverted to virtual, enlarged, and upright
   (C) From virtual, enlarged, and upright to real, reduced, and inverted
   (D) From virtual, enlarged, and inverted to real, enlarged, and inverted



10. The figure above shows energy levels for a mercury atom. A photon with energy 2.03 eV is incident on a mercury atom that is in its first excited state. The atom absorbs the photon and subsequently makes a transition to its ground state. Which of the following correctly describes the process the atom goes through?

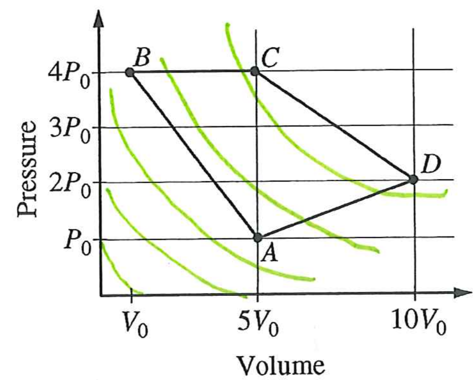
(A) It starts at −10.38 eV, transitions to −3.71 eV, and ends at −5.74 eV.
(B) It starts at −5.74 eV, transitions to −3.71 eV, and ends at −5.74 eV.
(C) It starts at −5.74 eV, transitions to −3.71 eV, and ends at −10.38 eV.
(D) It starts at −10.38 eV, transitions to −8.35 eV, and returns to −10.38 eV.

11. The following equation represents positron-electron annihilation, in which a positron and an electron become two photons.

$$e^{+} + e^{-} \rightarrow \gamma_1 + \gamma_2$$

Which of the following correctly explains a reason why the interaction is possible?

(A) The photons have no charge, so total charge is conserved.
(B) Two particles become two particles, so the number of particles is conserved.
(C) Each side of the equation has only one type of particle.
(D) Each particle has the same kinetic energy.



12. In a laboratory experiment, students recorded the pressure and volume of a sample of ideal gas as its temperature was varied. Their results are represented in the figure above. Which of the following ranks the internal energy U of the gas at the labeled points from greatest to least?

(A) $(U_B = U_C) > U_D > U_A$
(B) $(U_C = U_D) > U_B > U_A$
(C) $(U_C = U_D) > U_A > U_B$
(D) $U_D > (U_C = U_A) > U_B$

13. A 20 kΩ resistor is connected in series with an initially uncharged 100 μF capacitor and a 5 V battery. What is the charge on the capacitor when the circuit has reached steady state?

(A) 5×10^4 C
(B) 2.5×10^{-1} C
(C) 2.5×10^{-4} C
(D) 5×10^{-4} C

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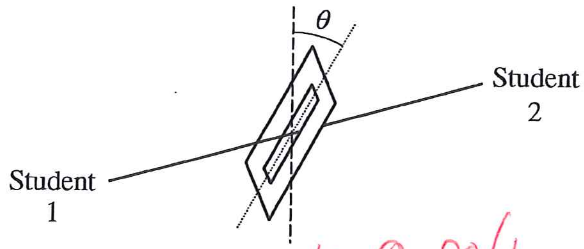
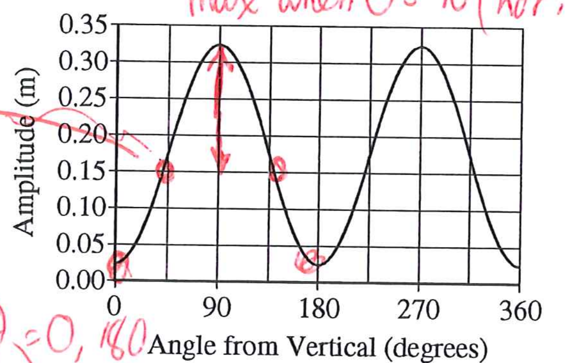




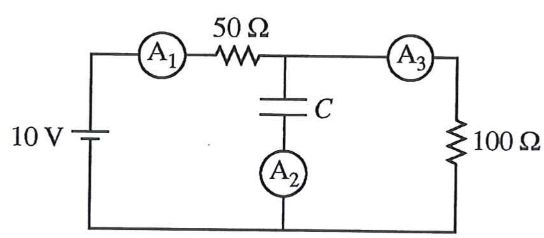
14. Student 1 and student 2 pull on opposite ends of a horizontal string that passes through a long, thin slit in a piece of cardboard, as shown in the top figure above. The plane of the cardboard is kept vertical, and the slit can be rotated so its angle θ relative to the dashed vertical line changes. Student 1 shakes the string, creating a transverse periodic wave of constant amplitude. At his end of the string, student 2 measures the amplitude of the wave that comes through the slit as a function of the angle of the slit relative to vertical. Student 2's data is shown in the graph. In what direction is student 1 shaking the string?

(A) Horizontally
(B) Vertically
(C) At 45° to vertical
(D) Toward and away from the slit

15. A particle with charge Q and mass M has instantaneous speed u_1 when it is at a position where the electric potential is V_1. At a later time, the particle has moved a distance R away to a position where the electric potential is V_2. Which of the following equations can be used to find the speed u_2 of the particle at the new position?

(A) $\frac{1}{2}M\left(u_2^2 - u_1^2\right) = Q(V_1 - V_2)$
(B) $\frac{1}{2}M(u_2 - u_1)^2 = Q(V_1 - V_2)$
(C) $\frac{1}{2}Mu_2^2 = QV_1$
(D) $\frac{1}{2}Mu_2^2 = \frac{1}{4\pi\varepsilon_0}\frac{Q^2}{R}$

Questions 16-18 refer to the following material.



The figure above shows a 10 V battery connected in a circuit with two resistors, a parallel-plate capacitor of capacitance C, and three ammeters. The circuit has been connected for a long time.

16. Let I_i be the current in ammeter A_i. Which of the following correctly ranks the currents in the three ammeters?

(A) $(I_1 = I_3) > I_2$
(B) $I_1 > (I_3 = I_2)$
(C) $I_1 > I_3 > I_2$
(D) $I_3 > (I_1 = I_2)$

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17. Which of the following is correct about the voltage V_C across the capacitor?

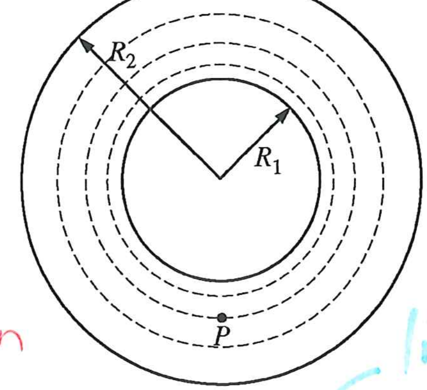
(A) $V_C = 0$
(B) $0 < V_C < 10$ V
(C) $V_C = 10$ V
(D) $V_C > 10$ V

18. Assume the capacitance C of the capacitor is known. The gap between the capacitor's plates is now filled with an unknown insulating material, and the circuit is again left connected for a long time. Measuring which of the following provides enough information to determine the unknown material's dielectric constant κ?

(A) The potential difference across the capacitor and the current in each branch of the circuit
(B) The potential difference across the capacitor and the charge on one of its plates
(C) The potential difference across the capacitor and the charge on the dielectric material
(D) The separation between the capacitor plates and the area of the plates

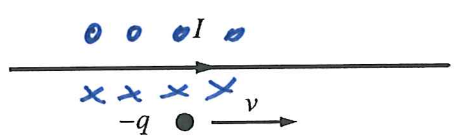
19. An ideal gas with molecules of mass m is contained in a cube with sides of area A. The average vertical component of the velocity of the gas molecules is v, and N molecules hit the side of the cube in a time Δt. What is the pressure exerted by the gas on the bottom of the cube?

(A) $mv/A\Delta t$
(B) $2mv/A\Delta t$
(C) $Nmv/A\Delta t$
(D) $2Nmv/A\Delta t$



20. The figure above represents two charged, concentric conducting shells with radii R_1 and R_2. The space between the shells is filled with air. The dashed lines represent equipotentials. The electric field just outside the inner shell has magnitude E_1, and the electric field just inside the outer shell has magnitude E_2. Which of the following statements is true of the magnitude E of the electric field at point P?

(A) $E = 0$
(B) $E_1 > E > E_2$
(C) $E = E_1$
(D) $E_1 < E < E_2$



21. An object with charge $-q$ is in motion near a wire that has a current I to the right. At the instant shown in the figure above, the object is traveling to the right with speed v. Both the wire and the motion of the object are in the plane of the page. Which of the following statements is true about the force on the object due to the current I at the instant shown?

(A) The force is directed toward the top of the page.
(B) The force is directed toward the bottom of the page.
(C) The force is directed toward the right.
(D) There is no force on the object due to the current.

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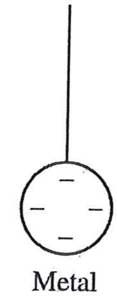
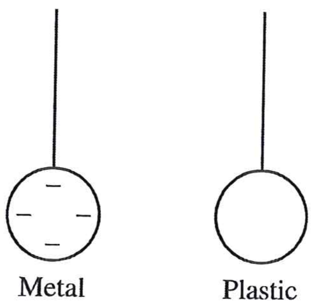
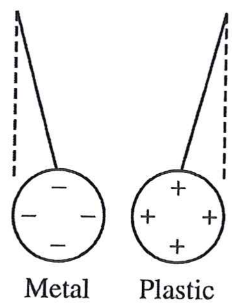


22. A metal sphere with a small negative charge hangs vertically from a light thread, as shown in the figure above. The metal sphere is then brought near but does not touch an uncharged plastic sphere of the same size that is also hanging vertically on a light thread. Which of the following best shows the two spheres after they have reached equilibrium?

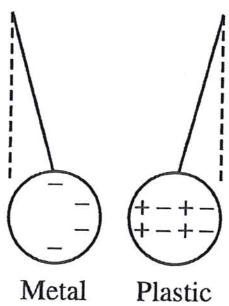
(A)



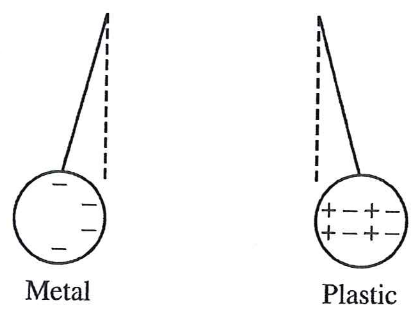
(B)



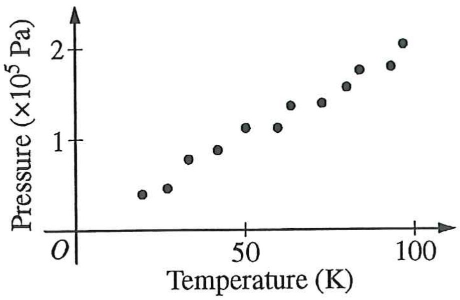
(C)



(D)



INDUCES charge on plastic, + attract to neg. meta



23. A sample of gas is in a container of fixed volume. The pressure of the gas is measured as its absolute temperature is increased. A graph of pressure measurements as a function of temperature is shown above. According to the ideal gas law, which of the following will be true if the container volume is reduced to half the original value and the experiment is repeated?

    (A) The graph will still show a linear relationship that extrapolates to the origin, but with a smaller slope.
    (B) The graph will still show a linear relationship that extrapolates to the origin, but with a larger slope.
    (C) The graph will still show a linear relationship, but it will not extrapolate to the origin.
    (D) The graph will not show a linear relationship, but it will still extrapolate to the origin.

24. Two containers, each holding a different gas, are brought into thermal contact. The gas atoms in container *X* have twice the mass and half the average speed of the gas atoms in container *Y*. Which of the following best describes the energy transfer by thermal conduction, if any, between the two containers?

    (A) There is a net energy transfer from container *X* to container *Y*.
    (B) There is a net energy transfer from container *Y* to container *X*.
    (C) There is no net energy transfer between the containers, because no atoms move between them.
    (D) There is no net energy transfer between the containers, because energy is transferred at approximately equal rates in each direction.

25. A group of students wants to determine the internal resistance of a battery. They connect the battery to a variable resistor. The students measure the potential difference across the battery as a function of the current through the battery as they vary the resistance. Which of the following analyses of the data could be used to determine the internal resistance of the battery?

    (A) Divide the potential difference across the battery by the current through it for each data point. The average of these calculations gives the internal resistance of the battery.
    (B) Graph the potential difference across the battery as a function of the current through it. Extrapolate to find the y-intercept and divide this by the average of the current measurements to find the internal resistance of the battery.
    (C) Find the best-fit straight line for a graph of potential difference across the battery as a function of the current through it. The absolute value of the slope represents the internal resistance of the battery.
    (D) This data cannot be analyzed to give the internal resistance of the battery, because the potential difference across the battery does not depend on the current.

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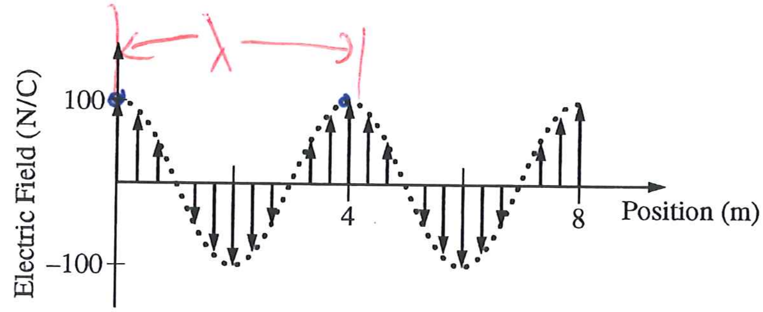


26. The figure above represents the electric field E as a function of position x due to a particular radio wave at time $t = 0$ s. Which of the following equations correctly describes the electric field?

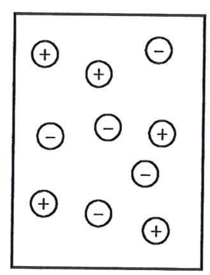
(A) $E = (100\ \text{N/C})\ \cos\left(\dfrac{\pi x}{1\ \text{m}}\right)$

(B) $E = (100\ \text{N/C})\ \cos\left(\dfrac{\pi x}{2\ \text{m}}\right)$

(C) $E = (100\ \text{N/C})\ \cos\left(\dfrac{\pi x}{4\ \text{m}}\right)$

(D) $E = (100\ \text{N/C})\ \sin\left(\dfrac{\pi x}{4\ \text{m}}\right)$

Questions 27-28 refer to the following material.



A very hot gas composed of equal numbers of positive and negative ions is in a closed, thermally insulated container and is in thermal equilibrium at temperature T_0. The figure above represents the initial distribution of the ions. A strong uniform electric field directed toward the bottom of the page is now created in and around the container, and the gas is allowed to reach a new thermal equilibrium at temperature T_1.

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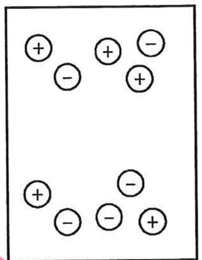
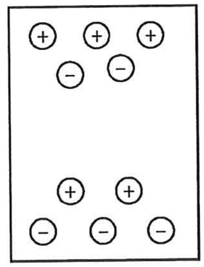
27. Which of the following best represents a possible distribution of the ions at temperature T_1 ?

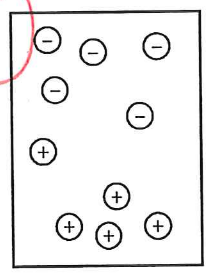
(A)



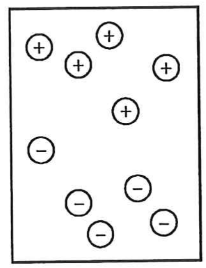
(B)



(C)



(D)



28. The electric field is now turned off, and the gas is allowed to reach a final equilibrium temperature T_2. How does T_2 compare to T_1, and why?

(A) T_2 is less, because the electric potential energy added by the field to separate the ions is gone once the field is turned off.

(B) T_2 is less, because pairs of positive and negative ions bond to become molecules once the field is turned off, and energy is required to create the bonds.

(C) T_2 is greater, because work is done on the ions in the process of turning off the field.

(D) T_2 is greater, because the electric potential energy of the separated ions is converted to kinetic energy as they mix and collide.

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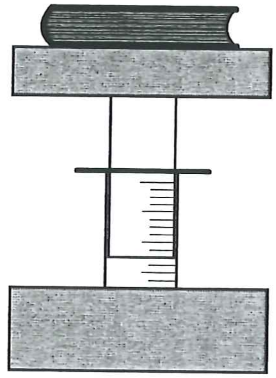
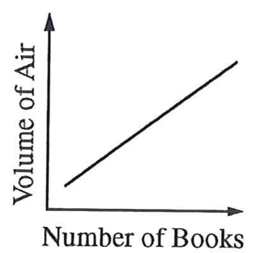
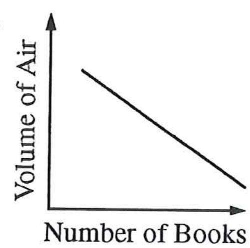
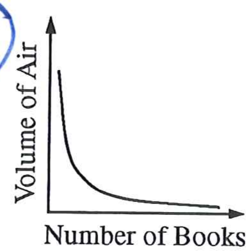
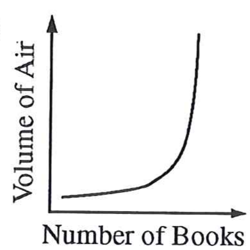


29. Students in a lab are given the plunger-syringe system represented above, which contains air at room temperature. The students take their physics textbooks and place them on top of the plunger one at a time. Each time a book is added, they allow the system to come to room temperature and then record the volume of the air in the syringe. Assume that air may be treated as an ideal gas. Which of the following best represents the expected graph of the volume of the air as a function of the number of books?

(A)


(B)


(C)


(D)


$PV = nRT$, $V = \frac{nRT}{P}$

$P = \frac{F}{A} = \frac{n mg}{A}$ (mg const, A const)

$V = \frac{(nRT)\text{const}}{n\left(\frac{mg}{A}\right)\text{const}}$

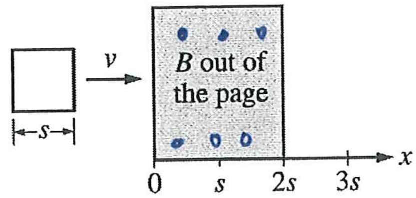
$V \propto \frac{1}{n}$

30. A hydrogen atom is isolated in a vacuum chamber. The electron is now separated from the proton and moved to a distance 1 cm away. Let F_G be the magnitude of the gravitational force between the proton and electron, and let F_E be the magnitude of the electric force between the proton and electron. How does the ratio F_G/F_E change as the particles are separated?

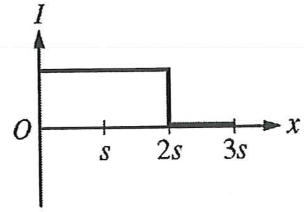
(A) F_G/F_E does not change; it is the same nonzero value for all separations.
(B) F_G/F_E becomes larger as the particles are moved apart.
(C) F_G/F_E becomes smaller as the particles are moved apart.
(D) F_G/F_E cannot be evaluated; it is undefined for all separations.

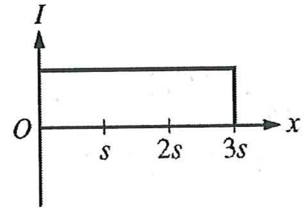
31. When the average speed of the molecules in a certain sample of gas is v, the absolute temperature of the gas is T. If the average speed of the molecules is doubled to $2v$, what is the new absolute temperature?

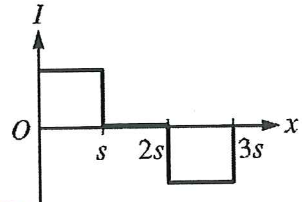
(A) $4T$
(B) $2T$
(C) T
(D) $\sqrt{2}T$

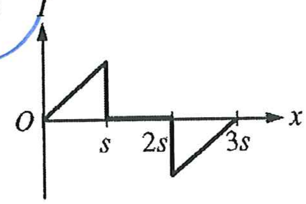


32. The gray rectangle in the figure above represents a region of uniform magnetic field directed out of the page. A square loop of wire of side s is in the plane of the page and is pulled at constant speed v through the field. Which of the following could show the current I in the loop as a function of the position of the right edge of the loop?

(A)


(B)


(C)


(D)


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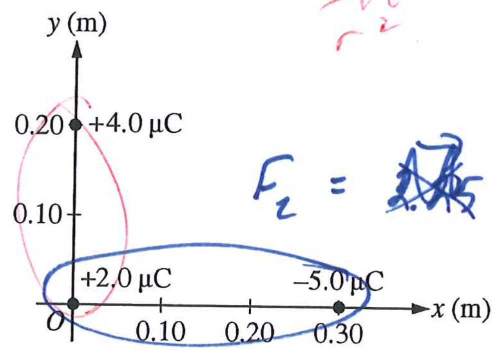
33. The mass of a proton is 1.673×10^{-27} kg, and the mass of a neutron is 1.675×10^{-27} kg. A proton and neutron combine to form a deuteron, releasing 3.520×10^{-13} J. What is the mass of the deuteron?

(A) 3.344×10^{-27} kg
(B) 3.348×10^{-27} kg
(C) 3.352×10^{-27} kg
(D) 3.911×10^{-30} kg



34. The figure above shows the locations and charges of three objects. The magnitude of the electric force exerted on the object located at the origin is most nearly

(A) 0.47 N
(B) 0.80 N
(C) 2.1 N
(D) 2.8 N

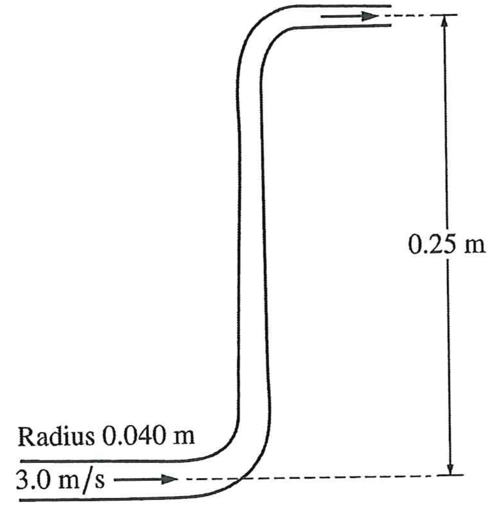
GO ON TO THE NEXT PAGE.

$$^{214}_{83}\text{Bi} \rightarrow \text{X} + \beta^{+}$$

35. In the decay represented above, what is the nucleon number of particle X?

(A) 82
(B) 83
(C) 213
(D) 214

#n + #p = nucleon #



36. Water of density $1000\ \text{kg/m}^3$ flows at a speed of $3.0\ \text{m/s}$ through a section of pipe of radius $0.040\ \text{m}$. The pipe bends upward to $0.25\ \text{m}$ above its original height and tapers to a radius of $0.020\ \text{m}$, as shown in the figure above. If the water pressure is $1.50 \times 10^5\ \text{Pa}$ in the lower part of the pipe, the water pressure in the upper part of the pipe is most nearly

(A) 0.80×10^5 Pa
(B) 1.48×10^5 Pa
(C) 1.53×10^5 Pa
(D) 2.29×10^5 Pa

Bernoulli 2nd

Continuity 1st

$P_1 + \rho g h_1 + \frac{1}{2}\rho v_1^2 = P_2 + \rho g h_2 + \frac{1}{2}\rho v_2^2$

$A_1 v_1 = A_2 v_2$

$1.5\times10^2 + 0 + \frac{1}{2}(1000)3^2 = P_2 + (1000 \times 9.8 \times .25) + \frac{1}{2}(1000)12^2$

$\pi\left(\frac{.04}{2}\right)^2 3 = \pi\left(\frac{.02}{2}\right)^2 V_2$

$150 + 4.5 - 2.45 - 72 = P_2(1000)$

$\frac{(.04)^2\, 3}{(.02)^2} = V_2 = 12\ \frac{m}{s}$

$.8\times10^5$ Pa

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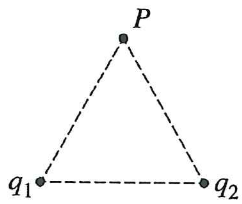
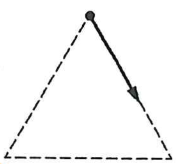
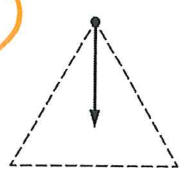
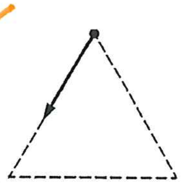
Directions: For each of the questions or incomplete statements below, two of the suggested answers will be correct. For each of these questions, you must select both correct choices to earn credit. No partial credit will be earned if only one correct choice is selected. Select the two that are best in each case and then fill in the corresponding circles that begin with number 131 on page 3 of the answer sheet.

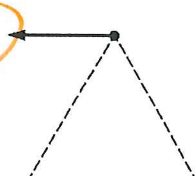


133. Two point charges, q_1 and q_2, of equal magnitude are at the vertices of an equilateral triangle, as shown above. The sign of each of the charges is unknown. A positive point charge is placed at vertex P and released from rest. Which of the following shows a possible direction of the initial acceleration of the positive point charge due to the net force exerted on it by q_1 and q_2? Select two answers.

(A) 

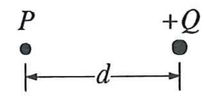
(B) 

(C) 

(D) 

131. For which of the following phenomena is an explanation that treats light as a wave most appropriate? Select two answers.

(A) Visible light shining on a metal must have a minimum frequency to cause electrons to be emitted.
(B) Visible light shining on a multislit grating causes an interference pattern.
(C) X-rays impart some of their momentum to an electron, causing the x-rays to be scattered.
(D) X-rays incident on a crystalline solid create a diffraction pattern.



132. An isolated point charge $+Q$ is located a distance d to the right of point P, as shown above. The point charge is then moved a distance less than d. Movement in which of the following directions will result in a change in the direction of the electric field at point P ? Select two answers.

(A) Toward the left
(B) Toward the right
(C) Toward the top of the page
(D) Toward the bottom of the page

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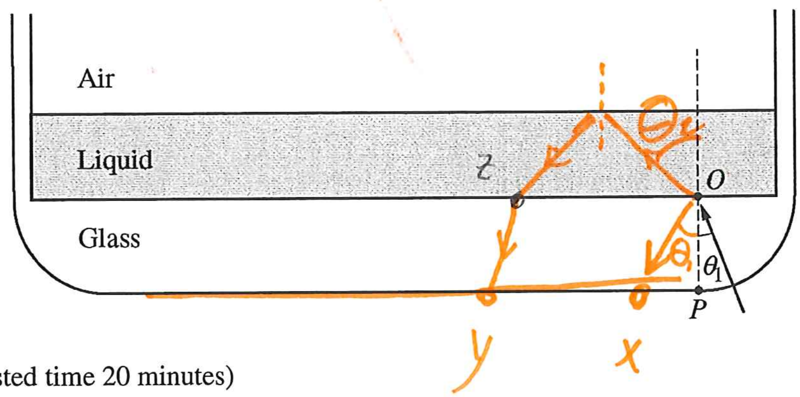
PHYSICS 2
Section II
4 Questions
Time—90 minutes

Directions: Questions 1 and 4 are short free-response questions that require about 20 minutes each to answer and are worth 10 points each. Questions 2 and 3 are long free-response questions that require about 25 minutes each to answer and are worth 12 points each. Show your work for each part in the space provided after that part.



1. (10 points - suggested time 20 minutes)

The figure above shows a cross section of a drinking glass (index of refraction 1.52) filled with a thin layer of liquid (index of refraction 1.33). The bottom corners of the glass are circular arcs, with the bottom right arc centered at point O. A monochromatic light source placed to the right of point P shines a beam aimed at point O at an angle of incidence θ. The flat bottom surface of the glass containing point P is frosted so that bright spots appear where light from the beam strikes the bottom surface and does not reflect. When $\theta = \theta_1$, two bright spots appear on the bottom surface of the glass. The spot closer to point P will be referred to as X; the spot farther from P will be referred to as Y. The location of spot X and that of spot Y both change as θ is increased.

(a) In a coherent paragraph-length answer, describe the processes involved in the formation of spots X and Y when $\theta = \theta_1$. Include an explanation of why spot Y is located farther from point P than spot X is and what factors affect the brightness of the spots.

X is formed when light reflects off the glass-~~water~~ liquid interface at angle θ_i and refracts at $\theta_2 > \theta_1$ as $n_l < n_{glass}$

Y is formed when light transmits thru the glass-water interface, some of which reflects off the liquid air interface ~~refl~~ refracting back at the liquid glass interface. As only some light transmits at each boundary there is measureably less brightness at Y

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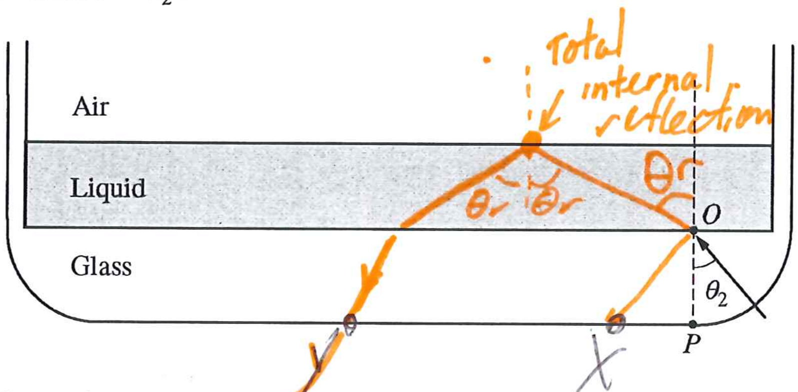
(b) When θ is increased to θ_2, one of the spots becomes brighter than it was before, due to total internal reflection.

i. On the figure below, draw a ray diagram that clearly and accurately shows the formation of spots X and Y when $\theta = \theta_2$.

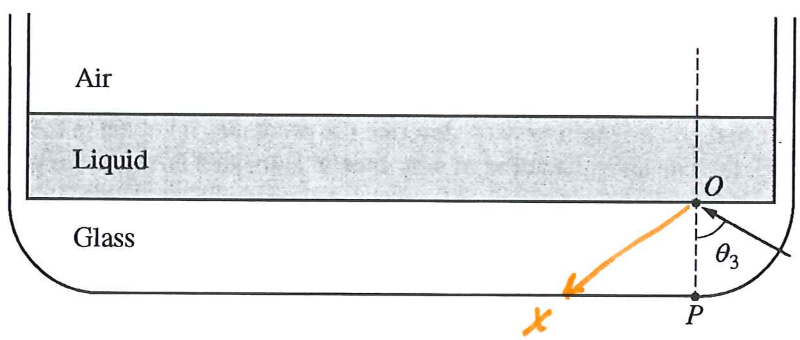


ii. Which spot, X or Y, becomes brighter than it was before due to total internal reflection? Explain your reasoning.

Y. Total internal reflection will occur at liquid-air interface due to $\theta_r > \theta_2$ and greater difference in n values ∴ Y has gain in brightness

(c) When θ is further increased to θ_3, one of the spots disappears entirely.

i. On the figure below, draw a ray diagram that clearly and accurately shows the formation of the remaining spot, X or Y, when $\theta = \theta_3$.



ii. Indicate which spot, X or Y, disappears. Explain your reasoning in terms of total internal reflection.

Y disappears. As θ_3 exceeds critical angle for glass-liquid no light enters liquid & path Y ceases to exist

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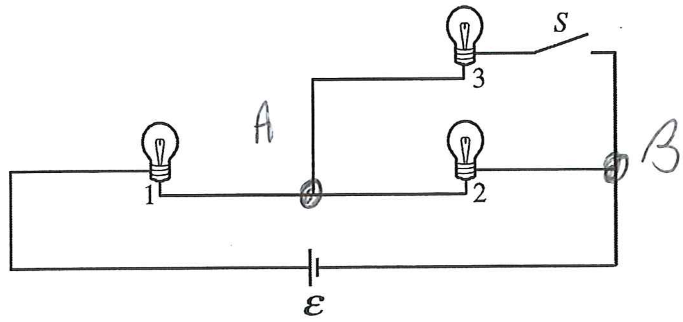
$V = IR$



2. (12 points, suggested time 25 minutes)

A battery of emf $\mathcal{E}$ and negligible internal resistance, three identical incandescent lightbulbs, and a switch S that is initially open are connected in the circuit shown above. The bulbs each have resistance R. Students make predictions about what happens to the brightness of the bulbs after the switch is closed.

(a) A student makes the following prediction about bulb 1: "Bulb 1 will decrease in brightness when the switch is closed."

i. Do you agree or disagree with the student's prediction about bulb 1 ? Qualitatively explain your reasoning.

NO #'s

Disagree. Closing switch drops R_{AB} as parallel path added. This ~~more~~ decreases R_{TOTAL} for circuit which increases I_{TOTAL} with constant $\mathcal{E}$. As total current goes thru 1 it gets brighter

ii. Before the switch is closed, the power expended by bulb 1 is P_1. Derive an expression for the power P_{new} expended by bulb 1 after the switch is closed in terms of P_1.

$I_{TOTAL\ OLD} = \frac{\mathcal{E}}{2R}$

$R_{AB} = \frac{R}{2}$ $\quad R_{TOTAL\ new} = \frac{3}{2}R$ $\quad I_{TOTAL\ New} = \frac{\mathcal{E}}{\frac{3}{2}R}$

$P_{new} = I_{new}^2 R$

$P_1 = I^2 R_1 = \left(\frac{\mathcal{E}}{2R}\right)^2 R = \frac{\mathcal{E}^2}{4R}$

$\frac{P_{new}}{P_1} = \frac{\mathcal{E}^2 / \frac{9}{4}R}{\frac{\mathcal{E}^2}{4R}} = \frac{\frac{1}{9/4}}{\frac{1}{4}}$

$\left(\frac{\mathcal{E}}{\frac{3}{2}R}\right)^2 R = \frac{\mathcal{E}^2}{\frac{9}{4}R}$

iii. How does the result of your derivation in part (a)ii relate to your explanation in part (a)i?

~~The power drop in bulb 1 as the power delivered by~~

Increased current in bulb 1 with constant R gives $P = I^2R$ and a ratio must show $P_{new} > 1 P_1$

$\frac{P_{new}}{P_1} = \frac{4}{9} \times \frac{4}{1} = \frac{16}{9}$

$P_{new} = \frac{16}{9} P_1$

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(b) A student makes the following prediction about bulb 2: "Bulb 2 will decrease in brightness after the switch is closed."

i. Do you agree or disagree with the student's prediction about bulb 2 ? Explain your reasoning in words.

Agree. As current in bulb 1 increased voltage there increases & with constant source V_{AB} decreases. Since $\frac{V_{AB}}{R_2} = I_2$ I_2 must ∴ decrease

ii. Justify your explanation with a calculation.

New: $V_1 = I_{TOT} R = \frac{\mathcal{E}}{\frac{3}{2}R} R = \frac{2\mathcal{E}}{3}$

$V_{AB} = \mathcal{E} - V_1 = \frac{1}{3}\mathcal{E}$

OLD: $V_1 = I_{TOT} R = \frac{\mathcal{E}}{2R} R = \frac{\mathcal{E}}{2}$

$V_{AB} = \mathcal{E} - V_1 = \frac{\mathcal{E}}{2}$

(c) While the switch is open, bulb 3 is replaced with an uncharged capacitor. The switch is then closed.

i. How does the brightness of bulb 1 compare to the brightness of bulb 2 immediately after the switch is closed? Justify your answer.

bulb 1 on, bulb 2 off. Capacitor has zero initial charge & all current follows its path with no current thru R_2

ii. How does the brightness of bulb 1 compare to the brightness of bulb 2 a long time after the switch is closed? Justify your answer.

Same. Once capacitor Voltage $V_c = \frac{Q_{max}}{C}$ no current flows thru capacitor & current in $R_2 = R_1$

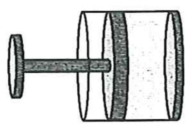
3. (12 points, suggested time 25 minutes)

Students are watching a science program about the North Pole. The narrator says that cold air sinking near the North Pole causes high air pressure. Based on the narrator's statement, a student makes the following claim: "Since cold air near the North Pole is at high pressure, temperature and pressure must be inversely related."

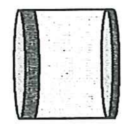
(a) Do you agree or disagree with the student's claim about the relationship between pressure and temperature? Justify your answer.

Disagree: Pressure = # of collisions per sec per unit area, Temp ∝ ave speed & faster molecules will have more collisions per sec ∴ higher P

After hearing the student's hypothesis, you want to design an experiment to investigate the relationship between temperature and pressure for a fixed amount of gas. The following equipment is available.



Cylinder with Movable Piston



Cylinder with Fixed Lid

No ↓

___ A cylinder with a movable piston, shown above on the left

✓ A cylinder with a fixed lid, shown above on the right ← Keep volume constant

Note: The two cylinders have gaskets through which measurement instruments can be inserted without gas escaping.

✓ A pressure sensor

✓ A basin that is large enough to hold either cylinder with a lot of extra room

✓ A source of hot water

✓ A source of mixed ice and water

___ A meterstick

✓ A thermometer

___ A stopwatch

(b) Put a check in the blank next to each of the items above that you would need for your investigation. Outline the experimental procedure you would use to gather the necessary data. Make sure the outline contains sufficient detail so that another student could follow your procedure.

- fill basin w/ cold water bath,
- insert thermometer & pressure sensor in fixed cylinder

~~record T & P~~

- allow cylinder to reach thermal equilib w/ ice bath
- record P & T in cylinder
- empty basin & fill with hot water
- record P & T in cylinder as time passes reaching thermal equilib
- Plot P vs T

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The table below shows data from a different experiment in which the volume, temperature, and pressure of a sample of gas are varied.

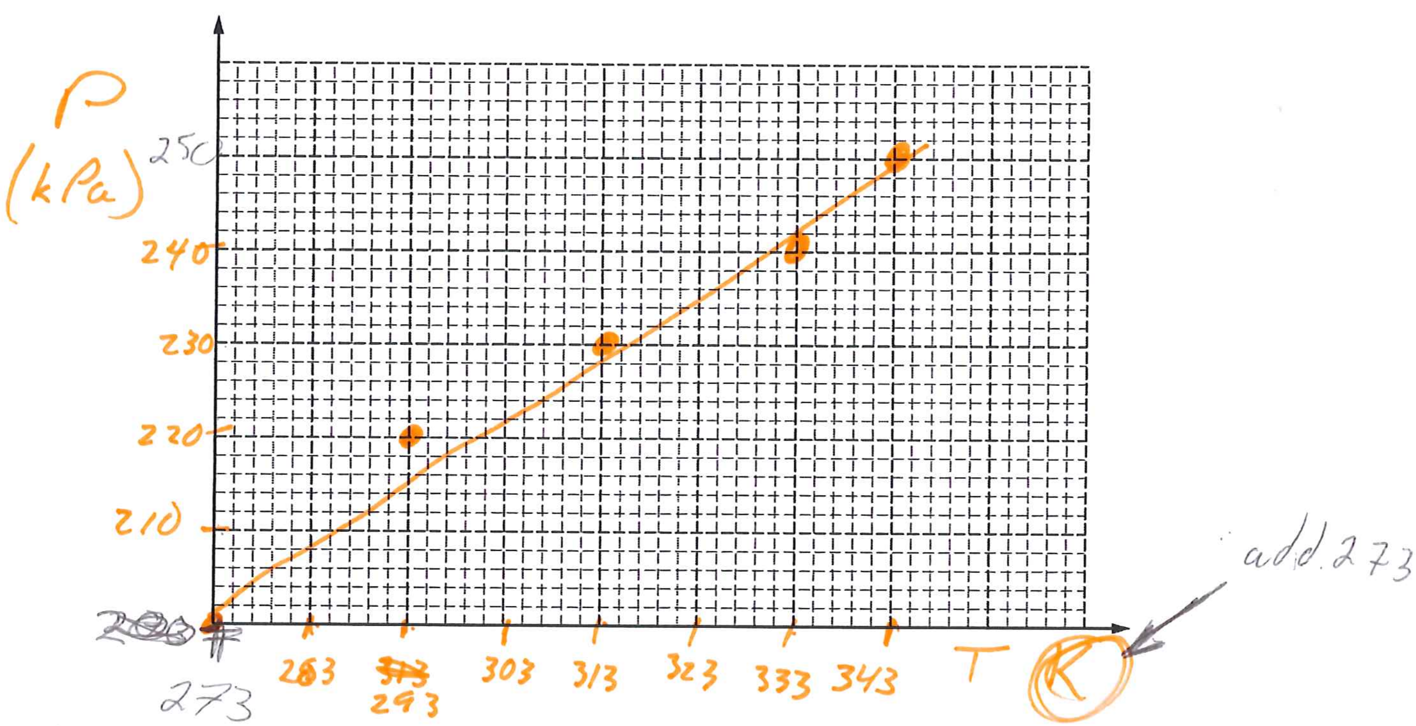
Trial Number	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Volume (cm^3)	10.0	5.0	4.0	3.0	5.0	4.0	10.0	5.0	3.0	4.0	5.0	10.0	3.0	5.0
Pressure (kPa)	100	200	250	330	220	270	110	230	380	290	240	120	420	250
Temperature (°C)	0	0	0	0	20	20	20	40	40	40	60	60	70	70

(c) What subset of the experimental trials would be most useful in creating a graph to determine the relationship between temperature and pressure for a fixed amount of gas? Explain why the trials you selected are most useful.

Keep V const

2, 5, 8, 11, 14 (largest set of const Volume)

(d) Plot the subset of data chosen in part (c) on the axes below. Be sure to label the axes appropriately. Draw a curve or line that best represents the relationship between the variables.



(e) What can be concluded from your curve or line about the relationship between temperature and pressure?

$P \propto T$

Pressure is linearly related to Temp AT CONSTANT V

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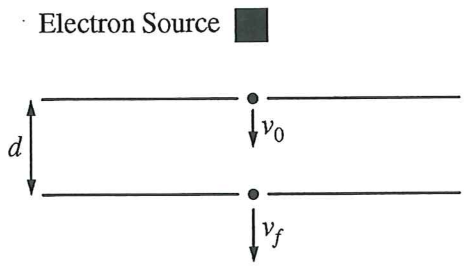


Note: Figure not drawn to scale.

4. (10 points - suggested time 20 minutes)

The apparatus shown in the figure above consists of two oppositely charged parallel conducting plates, each with area $A = 0.25\ \text{m}^2$, separated by a distance $d = 0.010\ \text{m}$. Each plate has a hole at its center through which electrons can pass. High velocity electrons produced by an electron source enter the top plate with speed $v_0 = 5.40 \times 10^6\ \text{m/s}$, take 1.49 ns to travel between the plates, and leave the bottom plate with speed $v_f = 8.02 \times 10^6\ \text{m/s}$. ← faster so bottom is positive

(a) Which of the plates, top or bottom, is negatively charged? Support your answer with a reference to the direction of the electric field between the plates.

Top is neg, increase in speed at bottom plate shows conversion of $E_p \rightarrow E_k$ ∴ Top neg & bottom Positive

(b) Calculate the magnitude of the electric field between the plates.

$E_p + E_k$ (Top) $= E_p + E_k$ bottom

$qV_{top} + \frac{1}{2}mv^2 = qV_b + \frac{1}{2}mv_b^2$

$\frac{1}{2}\, 9.11\times10^{-31}(5.4\times10^6)^2 = -1.6\times10^{-19}\, V_b + \frac{1}{2}\, 9.11\times10^{-31}(8.02\times10^6)^2$

$1.6\times10^{-19} = -1.6\times10^{-19}V + 2.93\times10^{-17}$

$1.6\times10^{-19}V = 2.91\times10^{-17}$

$V = 182V$

$\frac{V}{d} = \vec{E}$

$\vec{E} = \frac{182}{.01} = 1.82\times10^4\ \frac{V}{m}$

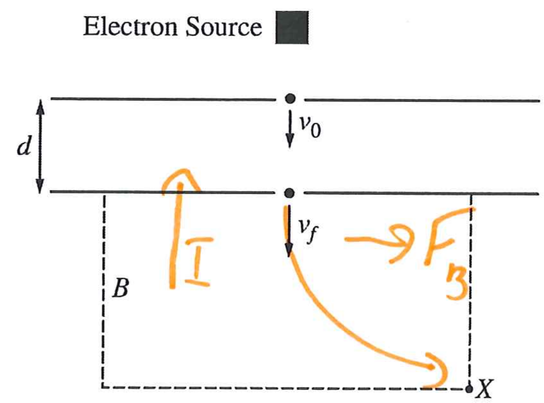
(c) Calculate the magnitude of the charge on each plate.

$Q = CV$

$Q = \frac{k\varepsilon_0 A}{d}V = \frac{8.85\times10^{-12}(.25)}{.01}V = 4.0\times10^{-12}C$

GO ON TO THE NEXT PAGE.

(d) The electrons leave the bottom plate and enter the region inside the dashed box shown below, which contains a uniform magnetic field of magnitude B that is perpendicular to the page. The electrons then leave the magnetic field at point X.



Note: Figure not drawn to scale.

i. On the figure above, sketch the path of the electrons from the bottom plate to point X. Explain why the path has the shape that you sketched.

Since B is uniform & ⊥ velocity F at right angle to both, as this changes V F also changes direction forming circular motion

ii. Indicate whether the magnetic field is directed into the page or out of the page. Briefly explain your choice.

out of page, using RHR, I is north, initial F is east