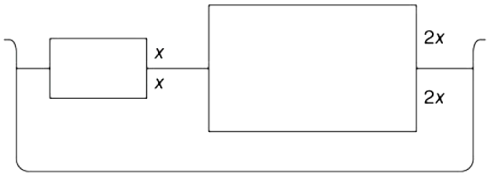
AP PHYSICS 2: FLUID MECHANICS & THERMODYNAMICS

19 & 20

Directions: Each of the questions or incomplete statements below is followed by five suggested answers or completions. Select the one that is best in each case and place the letter of your choice in the corresponding box on the student answer sheet.

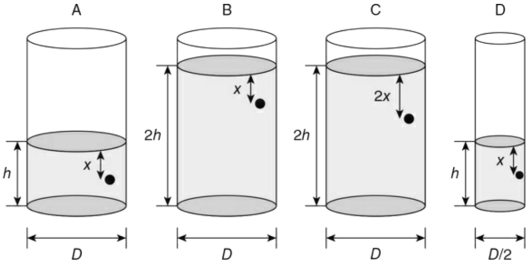
Note: To simplify calculations, you may use $g = 10\,\text{m/s}^2$ in all problems.

1. Two blocks of different sizes and masses float in a tray of water. Each block is half submerged, as shown in the figure. Water has a density of $1000\,\text{kg/m}^3$. What can be concluded about the densities of the two blocks?



(A) The two blocks have different densities, both of which are less than $1000\,\text{kg/m}^3$.
(B) The two blocks have the same density of $500\,\text{kg/m}^3$.
(C) The two blocks have the same density, but the density cannot be determined with the information given.
(D) The larger block has a greater density than the smaller block, but the densities of the blocks cannot be determined with the information given.

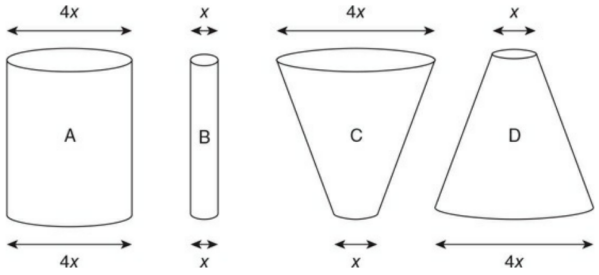
2. The figure shows four cylinders of various diameters filled to different heights with water. A hole in the side of each cylinder is plugged by a cork. All cylinders are open at the top. The corks are removed. Which of the following is the correct ranking of the velocity of the water (v) as it exits each cylinder?



(A) $v_A > v_D > v_C > v_B$
(B) $v_A = v_D > v_C > v_B$
(C) $v_B > v_C > v_A = v_D$
(D) $v_C > v_A = v_B = v_D$

Questions 3 and 4

Four differently shaped sealed containers are completely filled with alcohol, as shown in the figure. Containers A and B are cylindrical. Containers C and D are truncated conical shapes. The top and bottom diameters of the containers are shown.



3. Which of the following is the correct ranking of the pressure (P) at the bottom of the containers?

(A) $P_A = P_B = P_C = P_D$
(B) $P_A = P_D > P_C = P_B$
(C) $P_A > P_D > P_C > P_B$
(D) $P_D > P_A > P_C > P_B$

4. The force on the bottom of container A due to the fluid inside the container is F. What is the force on the bottom of container B due to the fluid inside?

(A) F
(B) $F/4$
(C) $F/8$
(D) $F/16$

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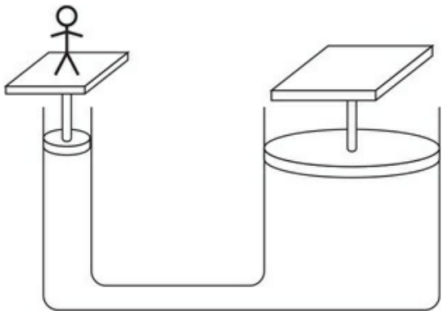
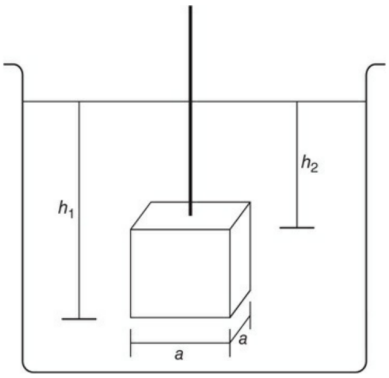
5. Two cylinders filled with a fluid are connected by a pipe so that fluid can pass between the cylinders, as shown in the figure. The cylinder on the right has 4 times the diameter of the cylinder on the left. Both cylinders are fitted with a movable piston and a platform on top. A person stands on the left platform. Which of the following lists the correct number of people that need to stand on the right platform so neither platform moves. Assume that the platform and piston have negligible mass and that all the people have the same mass.



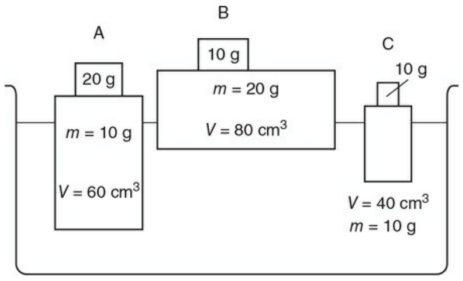
(A) 16 people
(B) 4 people
(C) 1 person
(D) It is impossible to balance the system because you need 1/16 of a person on the right side.

6. A mass (m) is suspended in a fluid of density (ρ) by a string, as shown in the figure below. The tension in the string is T. Which of the following is an appropriate equation for the buoyancy force? Select two answers.



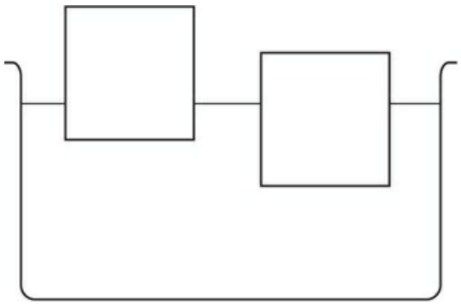
(A) $F_b = mg$
(B) $F_b = mg - T$
(C) $F_c = a_2 \rho g h_1$
(D) $F_d = a\rho g(h - h_2)$

7. Three wooden blocks of different masses and sizes float in a container of water, as shown in the figure. Each of the masses has a weight on top. Which of the following correctly ranks the buoyancy force on the wooden blocks?



(A) $A > B = C$
(B) $A = B > C$
(C) $B > A = C$
(D) $B > A > C$

8. Two blocks of the same dimensions are floating in a container of water, as shown in the figure. Which of the following is a correct statement about the two blocks?



(A) The net force on both blocks is the same.
(B) The buoyancy force exerted on both blocks is the same.
(C) The density of both blocks is the same.
(D) The pressure exerted on the bottom of each block is the same.

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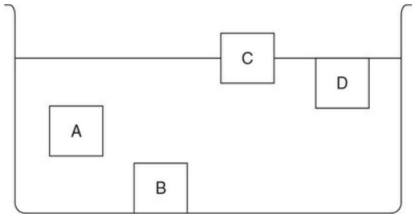
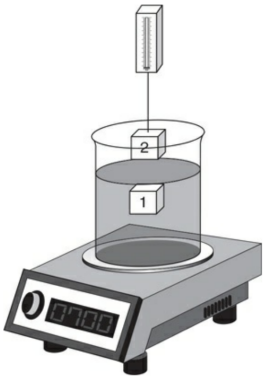
9. The figure shows four cubes of the same volume at rest in a container of water. Cube C is partially submerged. Cubes A, B, and D are fully submerged, with B resting on the bottom of the container. Which of the following correctly ranks the densities (ρ) of the cubes? Assume the water to be incompressible.



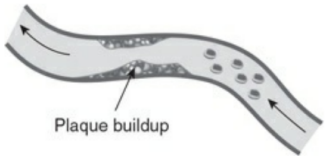
(A) $\rho_C > \rho_D > \rho_A > \rho_B$
(B) $\rho_B > \rho_A > \rho_D > \rho_C$
(C) $\rho_B > \rho_A = \rho_D > \rho_C$
(D) $\rho_B > \rho_A = \rho_D = \rho_C$

10. A beaker of water sits on a balance. A metal block with a mass of 70 g is held suspended in the water by a spring scale in position 1, as shown in the figure. In this position, the reading on the balance is 1260 g, and the spring scale reads 120 g. When the block is lifted from the water to position 2, what are the readings on the balance and spring scale?



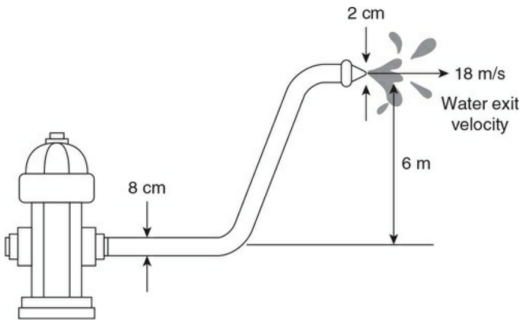
	Balance reading	Spring scale reading
(A)	1190 g	120 g
(B)	1190 g	190 g
(C)	1260 g	120 g
(D)	1330 g	120 g

11. Blood cells pass through an artery that has a buildup of plaque along both walls, as shown in the figure. Which of the following correctly describes the behavior of the blood cells as they move from the right side of the figure through the area of plaque? Assume the blood cells can change volume.



(A) The blood cells increase in speed and expand in volume.
(B) The blood cells increase in speed and decrease in volume.
(C) The blood cells decrease in speed and expand in volume.
(D) The blood cells decrease in speed and decrease in volume.

12. Firefighters use a hose with a 2 cm exit nozzle connected to a hydrant with an 8 cm diameter opening to attack a fire on the second floor of a building 6 m above the hydrant, as shown in the figure. What pressure must be supplied at the hydrant to produce an exit velocity of 15 m/s? (Assume the density of water is 1000 kg/m^3, and the exit pressure is 1×10^5 Pa.)



(A) 1.7×10^5 Pa
(B) 2.0×10^5 Pa
(C) 2.6×10^5 Pa
(D) 3.2×10^5 Pa

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13. A 1 cm diameter pipe leads to a showerhead with twenty 1 mm diameter exit holes. The velocity of the water in the pipe is v. What is the velocity of the water exiting the holes?

(A) $0.05v$
(B) $0.5v$
(C) $5v$
(D) $100v$

14. Air is made up primarily of nitrogen and oxygen. In an enclosed room with a constant temperature, which of the following statements is correct concerning the nitrogen and oxygen gases?

(A) The nitrogen gas molecules have a higher average kinetic energy than the oxygen gas molecules.
(B) The nitrogen gas molecules have the same average kinetic energy as the oxygen gas molecules.
(C) The nitrogen gas molecules have a lower average kinetic energy than the oxygen gas molecules.
(D) More information is necessary to compare the average kinetic energies of the two gases.

15. Air is made up primarily of nitrogen and oxygen. In an enclosed room with a constant temperature, which of the following statements is correct concerning the nitrogen and oxygen gases?

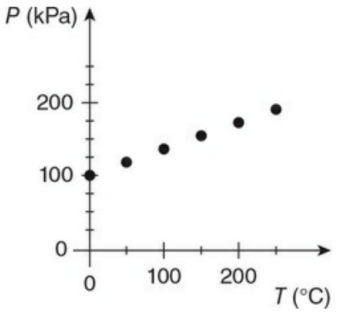
(A) The nitrogen gas molecules have a higher velocity than the oxygen gas molecules.
(B) The nitrogen gas molecules have the same velocity as the oxygen gas molecules.
(C) The nitrogen gas molecules have a lower velocity than the oxygen gas molecules.
(D) It is impossible to compare the velocity of the two gases without knowing the temperature of the air and the percentage of nitrogen and oxygen in the room.

16. In an experiment, a gas is confined in a cylinder with a movable piston. Force is applied to the piston to increase the pressure and change the volume of the gas. Each time the gas is compressed, it is allowed to return to a room temperature of 20 °C. The data gathered from the experiment is shown in the table. What should be plotted on the vertical and horizontal axes so the slope of the graph can be used to determine the number of moles of gas in the cylinder?

Pressure 10^5 Pa	**Volume** 10^{-3} m^3
1.0	25
1.5	17
1.8	14
2.2	11
2.6	9.6
3.3	7.6

(A) P and V_2
(B) P and V
(C) P and $(V)12$
(D) P and $1/V$

17. In an experiment, a sealed container with a volume of 100 ml is filled with hydrogen gas. The container is heated to a variety of temperatures, and the pressure is measured. The data from the experiment is plotted in the figure. Which of the following methods can be used to determine additional information regarding the gas? Select two answers.



(A) The slope can be used to calculate the number of atoms in the gas.
(B) The area under the graph can be used to calculate the work done by the gas.
(C) The vertical axis can be used to calculate the force the gas exerts on the container.
(D) The x-intercept can be used to estimate the value of absolute zero.

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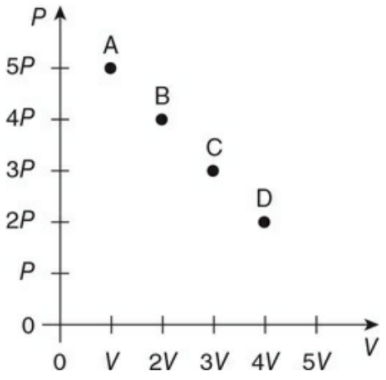
18. Two identical rooms are connected by an open door. The temperature in one room is greater than the temperature in the other. Which room contains the most gas molecules?

(A) The warmer room.
(B) The colder room.
(C) The number of gas molecules will be the same in both rooms.
(D) It is impossible to determine without more information.

19. On a hiking trip in the mountains, where the air temperature is cool and has a lower concentration of oxygen, you seal an empty water bottle. You return to your home near sea level where the air temperature is warm and has a higher concentration of oxygen. You notice that the sealed bottle appears partially crushed. Which of the following would contribute to the decrease in volume of the bottle?

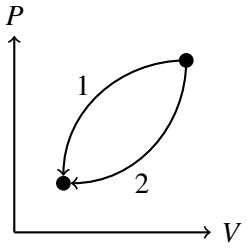
(A) The change in temperature
(B) The change in atmospheric pressure
(C) The change in oxygen concentration
(D) The change in temperature, pressure, and oxygen concentration

20. The figure shows the pressure and volume of a gas at four different states. Which of the following correctly ranks the temperature of the gas at the different states?



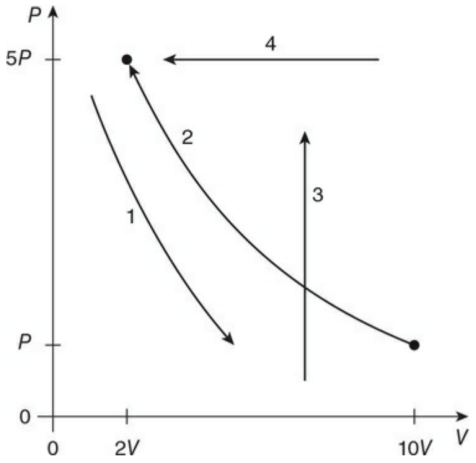
(A) $T_A > T_B > T_C > T_D$
(B) $T_B = T_C > T_A = T_D$
(C) $T_C > T_B = T_D > T_A$
(D) $T_D > T_C > T_B > T_A$

21. Which of the following is correct concerning the two processes shown in the figure?



(A) $\Delta U_1 = \Delta U_2$ and $W_1 = W_2$
(B) $\Delta U_1 = \Delta U_2$ and $W_1 > W_2$
(C) $\Delta U_1 > \Delta U_2$ and $W_1 = W_2$
(D) $\Delta U_1 > \Delta U_2$ and $W_1 \geq W_2$

22. The figure shows four samples of gas being taken through four different processes. Process 1 is adiabatic. In which process is heat being transferred to the gas sample from the environment?



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

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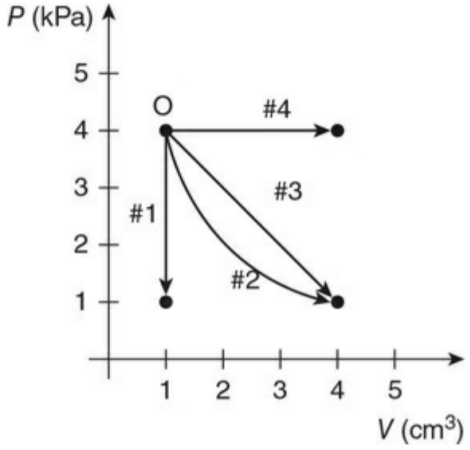
23. Two sealed cylinders holding different gases are placed one on top of the other so heat can flow between them. Cylinder A is filled with hydrogen. Cylinder B is filled with helium moving with an average speed that is half that of the hydrogen atoms. Helium atoms have four times the mass of hydrogen atoms. Which of the following best describes the transfer of heat between the two containers by conduction?

(A) Net heat flows from cylinder A to cylinder B, because heat flows from higher kinetic energy atoms to lower kinetic energy atoms.
(B) Net heat flows from cylinder B to cylinder A, because heat flows from higher kinetic energy atoms to lower kinetic energy atoms.
(C) There is no net heat transfer between the two cylinders, because both gases have the same average atomic kinetic energy.
(D) There is no net heat transfer between the two cylinders, because heat conduction requires the movement of atoms between the cylinder, and the cylinders are sealed.

Questions 24 and 25

A gas beginning at point O on the graph can be taken along four paths to different ending conditions.



24. Which of the following are the same for processes 2 and 3? *Select two answers.*

(A) Q
(B) ΔT
(C) ΔU
(D) W

25. Along which of the paths is the most thermal energy removed from the gas?

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

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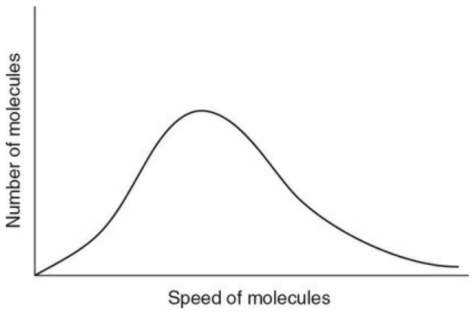
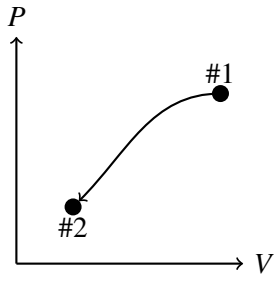
26. The graph shows the distribution of speeds for one mole of hydrogen at temperature T, pressure P, and volume V. How would the graph change if the sample was changed from one mole hydrogen to one mole of argon at the same temperature, pressure, and volume?



(A) The peak will shift to the left
(B) The peak will shift upward and to the left
(C) The peak will shift to the right
(D) The peak will shift downward and to the right

27. The graph shows the pressure and volume of a gas being taken from state #1 to state #2. Which of the following correctly indicates the sign of the work done by the gas, and the change in temperature of the gas?



	Work done	Δ Temperature
(A)	+	+
(B)	+	−
(C)	−	+
(D)	−	−

28. A fixed mass of oxygen (O_2, molecular mass 32 g/mol) is contained in a cylinder whose volume is 2.80 liters. The pressure is 148 atm when the temperature is 23 °C. Find the mass of oxygen in the cylinder.

(A) 20 g
(B) 80 g
(C) 140 g
(D) 280 g
(E) 546 g

29. A tire is filled with air at 15 °C to a gauge pressure of 2.2×10^5 Pa. If the tire reaches a temperature of 38 °C, what will the new gauge pressure be inside it?

(A) 2.4×10^2 Pa
(B) 3.4×10^3 Pa
(C) 2.4×10^5 Pa
(D) 6.0×10^7 Pa
(E) 8.0×10^9 Pa

30. A fixed mass of an ideal gas having a volume of 2500 cm^3 at 20 °C and absolute pressure of 65 atm expands until its volume is 4000 cm^3 and its absolute pressure is 45 atm. Find its new temperature.

(A) 20 °C
(B) 42.3 °C
(C) 51.6 °C
(D) 61.8 °C
(E) 80 °C

31. A fixed mass of an ideal gas is in a container with a constant volume. By what factor will the pressure change if the absolute temperature is tripled?

(A) 1/9
(B) 1/3
(C) 3
(D) 9

32. When using the ideal gas law, $PV = nRT$,

(A) P can be gauge pressure
(B) N can be in kilograms
(C) T can be in degrees Celsius
(D) none of the above

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33. For ideal gases, the ratio PV/T is

(A) equal to Avogadro's number
(B) equal to Boltzmann's constant
(C) independent of the number of molecules
(D) independent of the chemical nature of the molecules

34. The volume of an ideal gas at constant pressure is proportional to its

(A) Fahrenheit temperature
(B) Celsius temperature
(C) Absolute temperature
(D) Molar mass

35. If the pressure of gas is doubled and the temperature is constant, then the volume is what factor times the original?

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

36. What is the volume of one mole of ideal gas at 300 K and at standard atmospheric pressure?

(A) 23.21
(B) 24.11
(C) 24.61
(D) 25.71

37. An ideal gas in a container has a pressure of 2.50 atm and a volume of 1 m^3 at a temperature of 30 °C. How many moles of gas are in the container?

(A) 20 moles
(B) 45 moles
(C) 62 moles
(D) 83 moles
(E) 100 moles

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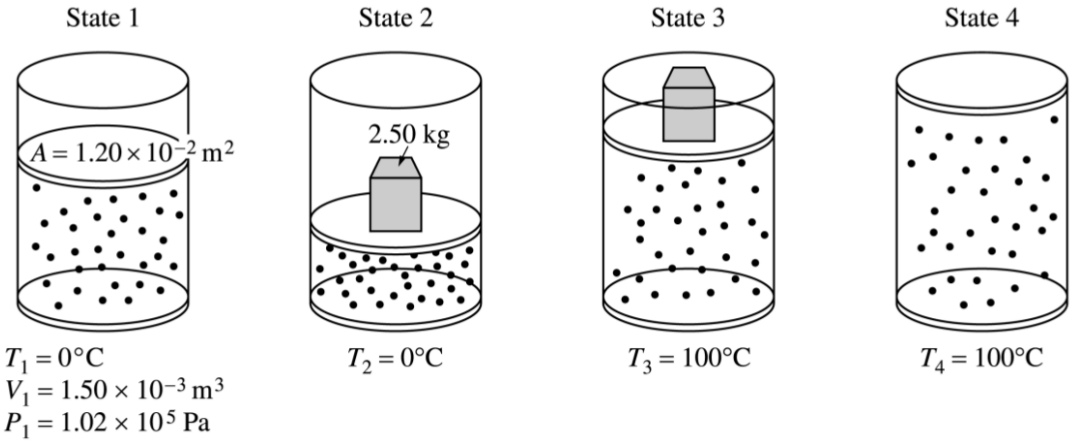
AP PHYSICS 2: Thermodynamics of Gases
SECTION II
5 Questions

Directions: Answer all questions. The suggested time is about 15 minutes for answering each of the questions. The parts within a question may not have equal weight. All final numerical answers should include appropriate units. Credit depends on the quality of your solutions and explanations, so you should show your work. Credit also depends on demonstrating that you know which physical principles would be appropriate to apply in a particular situation. Therefore, you should clearly indicate which part of a question your work is for.



Note: Figure not drawn to scale.

1. A cylinder is fitted with a freely moveable piston of area 1.20×10^{-2} m^2 and negligible mass. The cylinder below the piston is filled with a gas. At state 1, the gas has volume 1.50×10^{-3} m^3, pressure 1.02×10^5 Pa, and the cylinder is in contact with a water bath at a temperature of 0 °C. The gas is then taken through the following four-step process.

   - A 2.50 kg metal block is placed on top of the piston, compressing the gas to state 2, with the gas still at 0 °C.
   - The cylinder is then brought in contact with a boiling water bath, raising the gas temperature to 100 °C at state 3.
   - The metal block is removed and the gas expands to state 4 still at 100 °C.
   - Finally, the cylinder is again placed in contact with the water bath at 0 °C, returning the system to state 1.

   (a) Determine the pressure of the gas in state 2.

   (b) Determine the volume of the gas in state 2.

   (c) Indicate below whether the process from state 2 to state 3 is isothermal, isobaric, or adiabatic.

   ____ Isothermal ____ Isobaric ____ Adiabatic

   Explain your reasoning.

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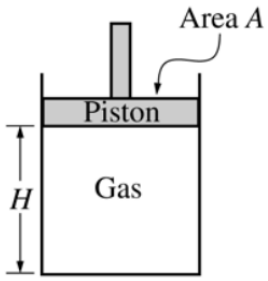
(d) Is the process from state 4 to state 1 isobaric?

____Yes ____ No

Explain your reasoning.

(e) Determine the volume of the gas in state 4.

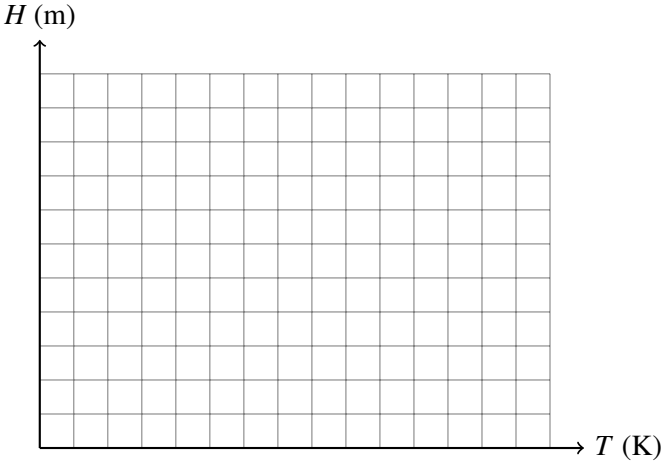


2. An experiment is performed to determine the number n of moles of an ideal gas in the cylinder shown above. The cylinder is fitted with a movable, frictionless piston of area A. The piston is in equilibrium and is supported by the pressure of the gas. The gas is heated while its pressure P remains constant. Measurements are made of the temperature T of the gas and the height H of the bottom of the piston above the base of the cylinder and are recorded in the table below. Assume that the thermal expansion of the apparatus can be ignored.

T (K)	H (m)
300	1.11
325	1.19
355	1.29
375	1.37
405	1.47

(a) Write a relationship between the quantities T and H, in terms of the given quantities and fundamental constants, that will allow you to determine n.

(b) Plot the data on the axes below so that you will be able to determine n from the relationship in part (a). Label the axes with appropriate numbers to show the scale.



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(c) Using your graph and the values $A = 0.027\,\text{m}^2$ and $P = 1.0\,\text{atmosphere}$, determine the experimental value of n.

3. An air bubble is released from the bottom of a swimming pool and ascends to the surface.

(a) In a clear, coherent, paragraph-length response, describe any changes in the bubble size and describe the motion of the bubble as it ascends to the surface. Explain the factors that affect the size of the bubble and the bubble's motion. Include a description of any forces acting on the bubble from the time it is at the bottom of the pool until it reaches the surface.

(b) Draw a diagram of all the forces acting on the bubble. Make sure the forces are in correct proportion.

(c) The bubble does not collapse under the pressure of the water. Explain how the behavior of the gas atoms keep the bubble from collapsing.

(d) The bubble has an initial volume of V_D , begins at a depth of D below the surface of the water, and reaches the surface where the pressure is P_S . The density of the water is r.

i. Derive an expression for the initial pressure (P_D) in the bubble in terms of the given quantities and known constants.

ii. Assume the air temperature in the bubble remains the same as it rises. Derive an expression for the volume (V_S) of the bubble when it reaches the surface.

(e) Now assume that the bubble rises quickly to the surface, and that there is negligible thermal energy transfer between the bubble andthe swimming pool. Base your answers on this assumption.

i. Sketch the process on the PV diagram. Indicate on the axis the initial and final pressures and volumes.

ii. How does the value P_S–V_S compare to the value P_D–V_D? Justify your answer.

(f) The bubble passes through higher temperature water as it nears the sun-warmed surface of the pool. Unexpectedly, this allows a sizable amount of thermal energy to transfer from the water to the bubble as it rises. How does this affect the final volume of the bubble? Justify your answer.

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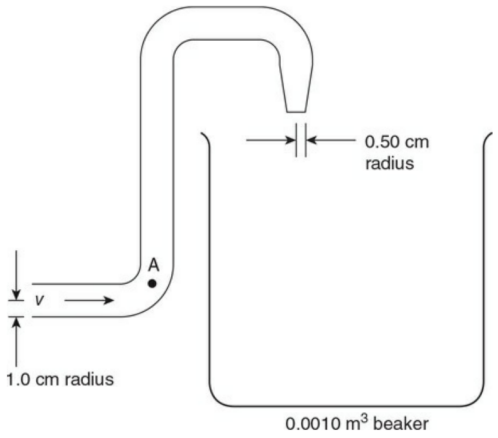
4. A 1.0 cm radius hose with a 0.50 cm radius exit nozzle is being used to fill a 1000 ml beaker with oil (1000 ml=0.0010 m^3). The velocity of the oil in the hose is $v = 0.40$ m/s as shown in the figure. The density of the oil is 960 kg/m^3, and the atmospheric pressure is 1.01×10^5 Pa.



(a) The nozzle attached to the end of the hose has a smaller radius than the hose. If the nozzle is removed from the hose, will the beaker be filled faster? Justify your answer with conservation laws.

(b) Calculate the exit velocity of the oil from the nozzle.

(c) How long will it take to fill the beaker?

(d) Point A is shown in the figure. How does the pressure in the fluid at point A compare to the pressure in the fluid at the exit nozzle? Justify your claim.

(e) The hose is now used to fill a 200 ml graduated cylinder with oil to the same height as the height of the oil in the 1000 ml beaker. Compare the net force from the oil on the bottom of the 200 ml cylinder and the 1000 ml. Explain your answer.

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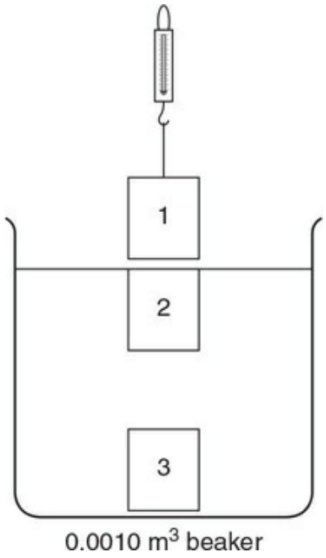
(f) A cube of lead with a side dimension of 5.0 cm is slowly lowered into the beaker of oil by a thin string attached to a spring scale at a constant rate, as shown in the figure. The density of lead is 11,300 kg/m^3.



i. What will be the spring scale reading in newtons when the lead has been submerged to location 2?

ii. Does the spring scale reading increase, decrease, or stay the same when the cube is lowered from location 2 to location 3? Justify your answer by referencing the pressure of the fluid on the lead cube.

iii. The lead cube is lowered from above the oils surface (location 1) to a spot just below the surface (location 2) until the cube is just above the bottom of the beaker (location 3). Describe any changes in pressure on the bottom of the beaker during this process. Explain your answer.

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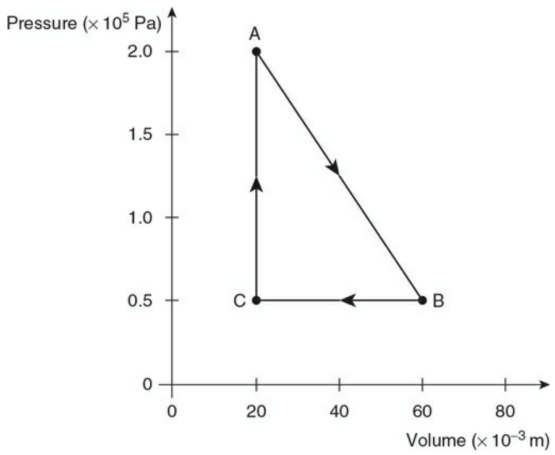
5. A mole of ideal gas is enclosed in a cylinder with a movable piston with a cross-sectional area of $1 \times 10^{-2}\ \text{m}^2$. The gas is taken through a thermodynamic process, as shown in the figure.



(a) Calculate the temperature of the gas at state A, and describe the microscopic property of the gas that is related to the temperature.

(b) Calculate the force of the gas on the piston at state A, and explain how the atoms of the gas exert this force on the piston.

(c) Predict qualitatively the change in the internal energy of the gas as it is taken from state B to state C. Justify your prediction.

(d) Is heat transferred to or from the gas as it is taken from state B to state C? Justify your answer.

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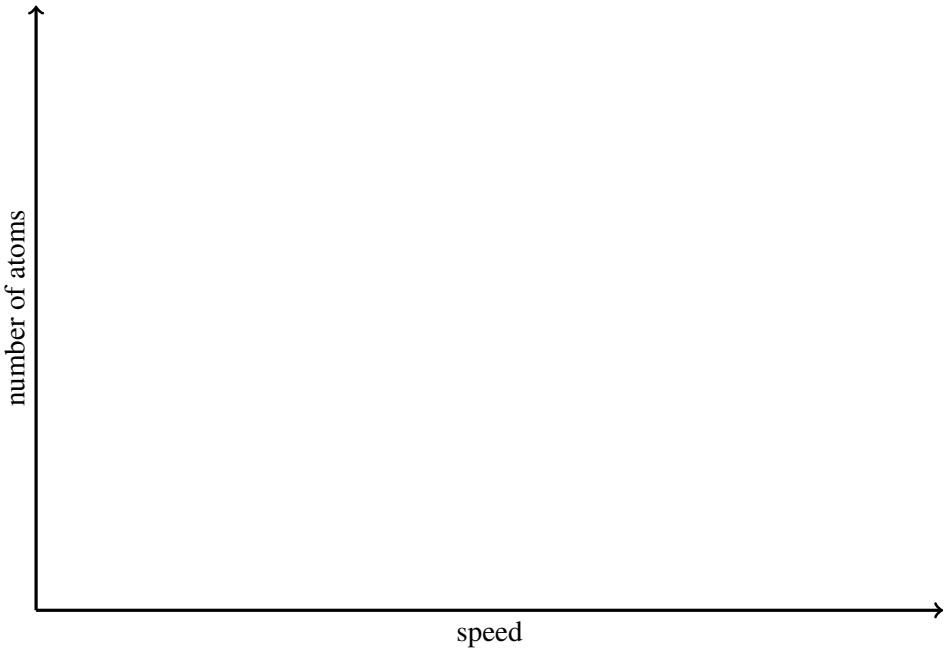
(e) Discuss any entropy changes in the gas as it is taken from state B to state C. Justify your answer.

(f) Calculate the change in the total kinetic energy of the gas atoms as the gas is taken from state C to state A.

(g) On the axis provided, sketch and label the distribution of the speeds of the atoms in the gas for states A and B.

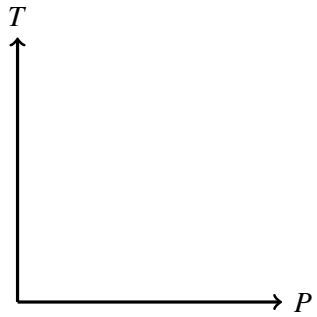


6. You wish to determine the relationship between gas pressure and temperature.

(a) List the items you would use to perform this investigation.

(b) Draw a simple picture of the lab setup, and outline the experimental procedure you would use to gather the necessary data. Indicate the measurements to be taken and how the measurement will be used to obtain the data needed. Make sure your outline contains sufficient detail so that another student could follow your procedure.

(c) On the axis, sketch the line or curve that you predict will represent the results of the data gathered in this experiment.



(d) Explain how you could use your results to estimate the value of absolute zero.

You are given the following set of data acquired in a gas laboratory experiment and asked to determine the relationship between pressures and volume for the gas.

Trial	Temperature (K)	Volume (ml)	Pressure (kPa)
1	270	500	8,979
2	270	1,000	4,490
3	270	2,000	2,245
4	270	5,000	898
5	300	1,000	4,988
6	300	2,000	2,494
7	300	5,000	998
8	320	1,000	5,321
9	320	5,000	1,064
10	350	500	11,640
11	350	5,000	1,164
12	370	500	12,305
13	370	2,000	3,076
14	370	3,000	1,230
15	370	6,000	769

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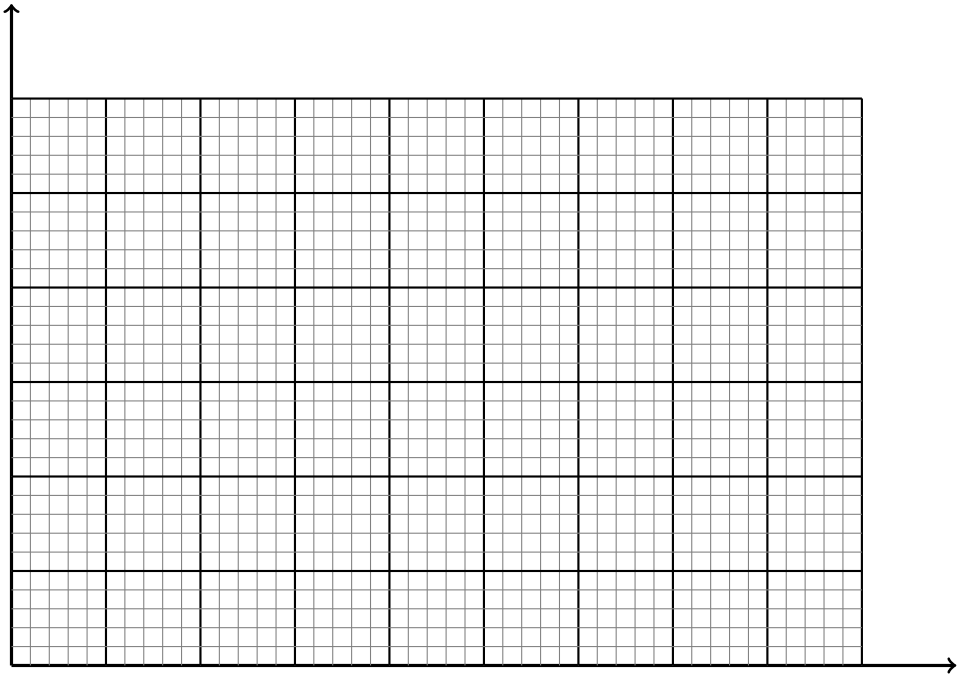
(e) Which subset of the data would be most useful in creating a graph to determine the relationship between gas pressure and volume? Explain why the trials you selected are the most useful.

(f) Plot the subset of data you chose on the graph, being sure to label the axes. Draw a line or curve that best represents the relationship between the variables.



(g) What can you conclude from your line or curve about the relationship between volume and pressure?

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