End of Chapter Exercises

Exercises 1 – 12 are conceptual questions that are designed to see if you have understood the main concepts of the chapter.

1. While on an airplane, you take a drink from your water bottle, and then screw the cap tightly back on the bottle. After landing, you notice that the bottle is a funny shape, as if someone is deforming it by squeezing it. Explain what has happened.

2. A common lecture demonstration involves placing a gob of shaving cream in a bell jar, which is a device that can be sealed off from the atmosphere. Much of the air is then pumped out of the bell jar. What do you expect to happen when this is done? Why?

3. As shown in Figure 14.15, a sealed cylinder of ideal gas is divided into two parts by a piston that can move left and right without friction. There is ideal gas in both parts, but the parts are isolated from one another by the piston. The piston is in its equilibrium position. The volume occupied by the gas on the left side is larger than that occupied by the gas on the right side. On which side is the gas pressure higher? Explain your answer.

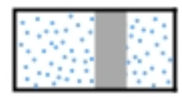

Figure 14.15: A sealed cylinder that is divided into two parts by a piston that is free to move left or right without friction. For Exercises 3 and 4.

4. Return to the situation described in Exercise 3 and shown in Figure 14.15. Initially, the temperature of the gas on the right side is larger that that of the gas on the left side. As time goes by, the two sides approach the same equilibrium temperature, as the temperature gradually decreases on the right side and gradually increases on the left side. Describe what happens to the piston as the system progresses toward equilibrium.

5. As shown in Figure 14.16, a sealed cylinder of ideal gas is divided into two parts by a piston that can move up and down without friction. There is ideal gas in both parts, but the gas from one part is isolated from that in the other part by the piston. The piston, which has a weight of 50.0 N, is shown in its equilibrium position. The volume occupied by the gas in the lower part is larger than that occupied by the gas in the upper part. On which side is the gas pressure higher? Explain your answer.

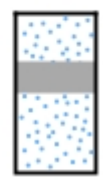

Figure 14.16: A sealed cylinder divided into two parts by a piston that is free to slide up and down without friction, for Exercise 5.

6. Three identical cylinders are sealed with identical pistons that are free to slide up and down the cylinder without friction. Each cylinder contains ideal gas, and the temperature is the same in each case, but the volumes occupied by the gases differ. In each cylinder the piston is above the gas, and the top of each piston is exposed to the atmosphere. As shown in Figure 14.17, the volume occupied by the gas is largest in case 1 and smallest in case 3. Rank the cylinders in terms of (a) the pressure of the gas, and (b) the number of moles of gas inside the cylinder.

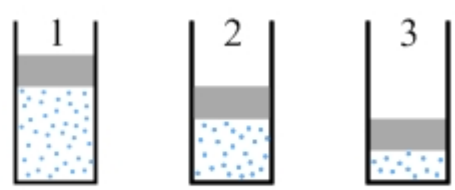

Figure 14.17: Three cylinders containing different volumes of gas at the same temperature, for Exercise 6.

7. Three identical cylinders are sealed with identical pistons that are free to slide up and down the cylinder without friction, as shown in Figure 14.18. Each cylinder contains ideal gas, and the gas occupies the same volume in each case, but the temperatures differ. In each cylinder the piston is above the gas, and the top of each piston is exposed to the atmosphere. In cylinders 1, 2, and 3 the temperatures are 0°C, 50°C, and 100°C, respectively. Rank the cylinders in terms of (a) the pressure of the gas, and (b) the number of moles of gas inside the cylinder.

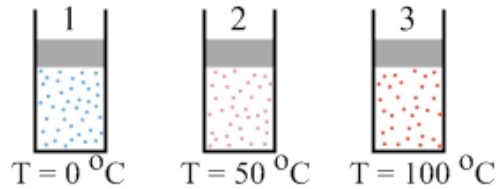

Figure 14.18: Three cylinders containing equal volumes of gas at different temperatures, for Exercise 7.

8. Is it possible for the total kinetic energy of the atoms in one container of ideal gas to be the same as the total kinetic energy of the atoms in a second container of ideal gas, but for their temperatures to be different? If so, describe how you could achieve this.

9. Consider a sealed box of ideal gas that is separated into two parts of equal volume by a partition. All the gas molecules are in one half of the box and there is nothing at all in the other half of the box. The partition consists of two sliding doors, which can be opened quickly and automatically like the doors of an elevator. When the sliding doors open, allowing the molecules to expand into the other half of the box, do you expect either the pressure or the temperature to remain constant? Basing your argument on kinetic theory, state which of these parameters (pressure or temperature) you expect to stay constant, explain why, and explain what happens to the other parameter.

10. Two containers of ideal gas have the same volume, the same pressure, and have the same number of moles of gas, but the type of molecule in each container is different. To be specific, one container contains argon atoms while the other contains xenon atoms, which are both monatomic ideal gases. Which of the following are the same for the two containers and which are different? In cases where there is a difference, state how they differ. (a) Temperature, (b) average kinetic energy of the atoms, (c) total kinetic energy of the atoms, (d) rms speed of the atoms, (e) most probable speed of the atoms.

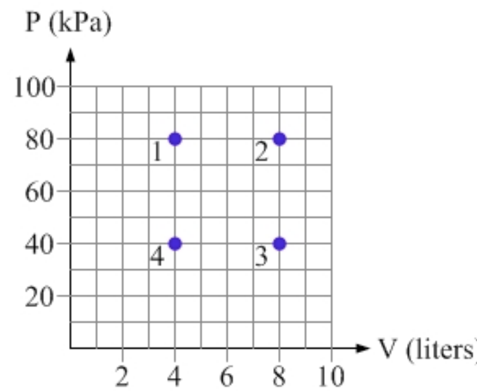

Figure 14.19: Four states are shown on the P-V diagram for a particular thermodynamic system. For Exercise 11.

11. Four states, labeled 1 through 4, of a particular thermodynamic system, are shown on the P-V diagram in Figure 14.19. The number of moles of gas in the system is constant. Rank the states based on their temperature, from largest to smallest.

12. Consider the P-V diagram in Figure 14.20. Find three other points on the diagram in which the system would have the same temperature as it has in state 1.

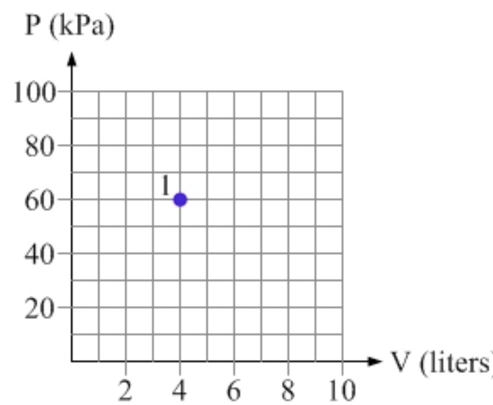

Figure 14.20: A P-V diagram for a particular thermodynamic system. For Exercise 12.

Exercises 13 – 16 deal with the ideal gas law.

13. A sample of monatomic ideal gas is kept in a container that keeps a constant volume while the temperature of the gas is raised from 10°C to 20°C. If the pressure of the gas is P at 10°C, what is the pressure at 20°C?

14. A particular cylindrical bucket has a height of 50 cm, while the radius of its circular cross-section is 15 cm. The bucket is empty, aside from containing air. The bucket is then inverted and, being careful not to lose any of the air trapped inside, lowered 20 m below the surface of a fresh-water lake. (a) If the temperature is the same at both points, what fraction of the bucket's volume is occupied by the air when the bucket is 20 m down? (b) Would the fraction be larger, smaller, or the same if the temperature drops from 25°C at the surface to 5.0°C 20 m below the surface? Why? (c) Calculate the fraction of the bucket's volume that is occupied by air when the bucket is 20 m down and the temperature changes as described in (b).

15. An empty metal can is initially open to the atmosphere at 20°C. The can is then sealed tightly, and heated to 100°C. While at 100°C, the lid of the can is loosened, opening the can to the atmosphere, and then the can is sealed tightly again. When the can cools to 20°C again, what is the pressure inside?

16. In 1992, a Danish study concluded that a standard toy balloon, made from latex and filled with helium, could rise to 10000 m (where the pressure is about 1/3 of that at sea level) in the atmosphere before bursting. In the study, a number of balloons were filled with helium, and then placed in a chamber maintained at –20°C. The pressure was gradually reduced until the balloons exploded, and then the researchers determined the height above sea level corresponding to that pressure. Assuming the balloons were filled with helium at +20°C and about atmospheric pressure, determine the ratio of the balloon's volume when it exploded to its volume when it was filled.

Questions 17 – 19 deal with calculating the rms average.

17. Consider the set of numbers –3, –2, –1, 1, 3, 5. (a) What is the average of this set of numbers? (b) What is the rms average of this set of numbers?

18. Is it possible for a set of four numbers to have an average of zero but an rms average that is non-zero? If so, come up with a set of four numbers for which this is true.

19. (a) Is it possible for the average of a set of four numbers to be equal to the rms average of those numbers? If so, find a set of four numbers for which this is true. (b) Is it possible for the average of a set of four numbers to be larger than the rms average of those numbers? If so, find a set of four numbers for which this is true.

Questions 20 – 25 are a sequence of ranking tasks that relate to cylinders that are sealed by pistons that are free to slide without friction. In all cases, the piston is at its equilibrium position.

20. Three identical cylinders are sealed with pistons that are free to slide up and down the cylinder without friction, but the masses of the pistons differ. As shown in Figure 14.21, Piston 1 has the largest mass, while piston 2 has the smallest mass. Each cylinder contains ideal gas at the same temperature and occupying the same volume. In each cylinder, the piston is above the gas, and the top of each piston is exposed to the atmosphere. Rank the cylinders in terms of (a) the pressure of the gas, and (b) the number of moles of gas inside the cylinder.

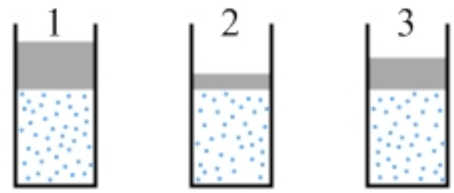

Figure 14.21: Three cylinders containing the same volume of gas at the same temperature, but the pistons have different mass. For Exercise 20.

21. As in Exercise 20, three identical cylinders are sealed with pistons that are free to slide up and down the cylinder without friction, but the masses of the pistons differ. As shown in Figure 14.22, piston 1 has the largest mass, while piston 2 has the smallest mass. The gas in each cylinder occupies the same volume, but in cylinders 1, 2, and 3 the temperatures are 0°C, 50°C, and 100°C, respectively. In each cylinder the piston is above the gas, and the top of each piston is exposed to the atmosphere. Is it possible to rank the cylinders, from largest to smallest, in terms of the pressure of the gas based on the information given here? If so, state the ranking, and compare the ranking to that in the previous exercise, explaining either why you expect the rankings to be the same or why you expect the rankings to differ. If it is not possible to rank the cylinders based on their pressures, clearly explain why not.

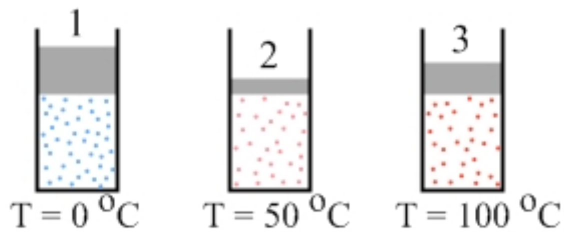

Figure 14.22: Three cylinders containing the same volume of gas at different temperatures, and with pistons of different mass. For Exercise 21.

22. Three identical cylinders are sealed with identical pistons that are free to slide up and down the cylinder without friction. Each cylinder contains ideal gas, and the gas occupies the same volume in each case, but the temperatures differ. As shown in Figure 14.23, each cylinder is inverted so the piston is below the gas, and the bottom of each piston is exposed to the atmosphere. In cylinders 1, 2, and 3 the temperatures are 0°C, 50°C, and 100°C, respectively. Rank the cylinders, from largest to smallest, in terms of (a) the pressure of the gas (b) the number of moles of gas inside the cylinder.

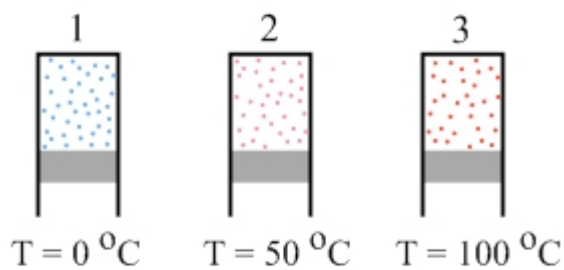

Figure 14.23: Three inverted cylinders containing the same volume of gas at different temperatures. For Exercise 22.

23. Three identical cylinders are sealed with pistons that are free to slide up and down the cylinder without friction, but the masses of the pistons differ. Piston 1 has the largest mass, while piston 2 has the smallest mass. Each cylinder contains ideal gas at the same temperature and occupying the same volume. As shown in Figure 14.24, each cylinder is inverted so the piston is below the gas, and the bottom of each piston is exposed to the atmosphere. Rank the cylinders, from largest to smallest, in terms of (a) the pressure of the gas, and (b) the number of moles of gas inside the cylinder.

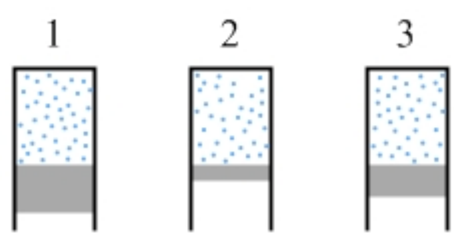

Figure 14.24: Three inverted cylinders containing the same volume of gas at equal temperatures, but having pistons of different mass. For Exercise 23.

24. Three identical cylinders are sealed with pistons that are free to slide up and down the cylinder without friction. Each cylinder contains ideal gas, and the gas occupies the same volume in each case and is at the same temperature. As shown in Figure 14.25, the pistons in cylinders 1 and 3 are identical but the piston in cylinder 1 is above the gas while cylinder 3 is inverted so the piston is below the gas. The piston in cylinder 2, which is above the gas, has more mass than the other two pistons. The top surfaces of the pistons in cylinders 1 and 2, and the bottom surface of the piston in cylinder 3, are exposed to the atmosphere. Rank the cylinders, from largest to smallest, in terms of (a) the pressure of the gas, and (b) the number of moles of gas inside the cylinder.

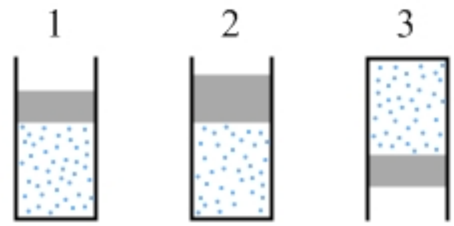

Figure 14.25: Three cylinders containing the same volume of gas at equal temperatures, but cylinder 3 is inverted while the piston in cylinder 2 has a larger mass than the other two pistons. For Exercise 24.

25. Three identical cylinders are sealed with pistons that are free to slide up and down the cylinder without friction. Each cylinder contains ideal gas. As shown in Figure 14.26, the volume occupied by the gas is different in each case, and the temperatures are also different. The pistons also have different masses. The piston in cylinder 1 has the smallest mass while the piston in cylinder 2 has the largest mass. In each cylinder the piston is above the gas, and the top of each piston is exposed to the atmosphere. Is it possible to rank the cylinders, from largest to smallest, in terms of the pressure of the gas? If so, provide the ranking. If not, explain why not.

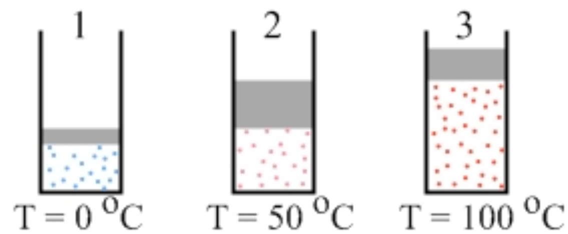

Figure 14.26: Three cylinders containing different volumes of gas at different temperatures, and with pistons of different mass. For Exercise 25.

Exercises 26 – 35 relate to cylinders that are sealed by pistons that are free to slide without friction.

26. In Exploration 14.4, we analyzed a cylinder filled with ideal gas that is sealed by a piston that is above the gas. The piston is a cylindrical object, with a weight of 20.0 N, that can slide up or down in the cylinder without friction. The inner radius of the cylinder, and the radius of the piston, is 10.0 cm. With the top of the piston exposed to the atmosphere, at a pressure of 101.3 kPa, we determined the pressure inside the cylinder. Now, very slowly, so that the gas inside the cylinder stays constant at the temperature of its surroundings, sand is poured onto the top of the piston. When 30.0 N of sand has been added to the piston, determine: (a) the pressure inside the cylinder, and (b) the ratio of the final volume occupied by the gas after the sand is added to the volume occupied by the gas before the sand is added.

27. A cylinder filled with ideal gas is sealed by a piston that is above the gas. The piston is a cylindrical object, with a weight of 10.0 N, that can slide up or down in the cylinder without friction. The inner radius of the cylinder, and the radius of the piston, is 10.0 cm. (a) If the top of the piston is exposed to the atmosphere, and the atmospheric pressure is 101.3 kPa, what is the pressure inside the cylinder? (b) What happens to the gas pressure, and the volume occupied by the gas, if the cylinder's temperature is gradually increased from 20°C to 60°C? Be as quantitative as possible.

28. Consider the cylinder in Exercise 27. If the cylinder is inverted, so the piston lies below the gas, what will happen to the piston? Will it remain in the cylinder, or will it fall out? Explain qualitatively what will happen, and explain why. Assume the piston is initially located about halfway down the cylinder.

29. Return to Exercise 28, but now analyze it quantitatively. Assuming the piston is in equilibrium below the gas, determine (a) the gas pressure, and (b) the ratio of the volume occupied by the gas when the piston is below the gas to the volume occupied by the gas when the piston is above the gas.

30. A cylinder filled with ideal gas is sealed by a piston that is above the gas. The piston is a cylindrical object, with a weight of 50.0 N, that can slide up or down in the cylinder without friction. The inner radius of the cylinder, and the radius of the piston, is 5.00 cm. The top of the piston is exposed to the atmosphere, and the atmospheric pressure is 101.3 kPa. The cylinder has a height of 30.0 cm, and, when the temperature of the gas is 20°C, the bottom of the piston is 15.0 cm above the bottom of the cylinder. Find the number of moles of ideal gas in the cylinder.

31. Return to the cylinder described in Exercise 30. When the temperature of the gas is raised from 20°C to 200°C, find the distance between the bottom of the cylinder and the bottom of the piston when the piston comes to its new equilibrium position.

32. Consider again the cylinder described in Exercise 30. What is the maximum temperature the ideal gas can have for the cylinder to remain sealed?

33. Consider again the cylinder described in Exercise 30. Now, the entire cylinder is sealed in a vacuum chamber and air is gradually pumped out of the chamber. Assume the temperature of the gas remains the same. (a) Describe qualitatively what, if anything, happens to the cylinder as the air is removed from the chamber. (b) What is the lowest pressure the chamber can have for the cylinder to remain sealed?

34. Consider again the cylinder described in Exercise 30. As the temperature of the gas is gradually raised from 20°C to 220°C you, wearing insulating gloves to prevent a nasty burn, push down on the top of the piston so that the piston remains in the same position at all times. How much downward force do you have to exert on the piston when the gas temperature is (a) 120°C? (b) 220°C?

35. Consider again the cylinder described in Exercise 30, except this time the piston is tied to a string that passes over a pulley system and is tied to a block that has a weight of 90.0 N, as shown in Figure 14.27. Both the block and the piston are in equilibrium. What is the pressure in the cylinder?

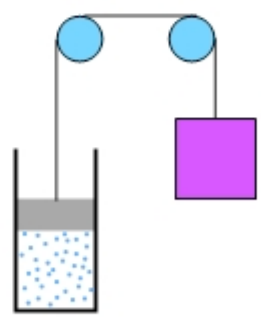

Figure 14.27: The 50.0 N piston is tied to a 90.0 N block by a string passing over a pulley system. The system is in static equilibrium. For Exercise 35.

General exercises and conceptual questions

36. Kids love to bounce around inside a moonwalk, which consists of a floor inflated with air and four walls made of elastic mesh. In a particular moonwalk, there are 8 children, each with a mass of 15 kg. Each wall of the moonwalk measures 3.0 m by 3.0 m and, on average, each child bounces off a wall once every 5.0 s. Assume that each child has a speed of 2.0 m/s when he or she hits a wall; that the child's velocity is directed perpendicular to the plane of the wall; and that the collision with the wall simply reverses the direction of the child's velocity. What is the average pressure experienced by a wall because of the children in the moonwalk?

37. A box of ideal gas contains two kinds of atoms, which have different masses. The atoms are in thermal equilibrium. You observe that the average speed of one of the kinds of atoms is 50% larger than the average speed of the other. What is the ratio of the masses of the atoms?

38. Equation 14.16 gives an expression for the root-mean-square speed of the Maxwell-Boltzmann distribution. Derive this equation by starting from Equation 14.14,
$$K_{av} = \frac{3}{2}kT \ .$$

39. You have two identical cylinders that are sealed with identical pistons that are free to slide up and down the cylinder without friction. Each cylinder contains ideal gas, and the gas occupies the same volume and is at the same temperature in each case. In each cylinder the piston is above the gas. Cylinder A contains argon gas (atomic mass = 40 g), while cylinder B contains xenon (atomic mass = 131 g). (a) In which cylinder is the pressure larger? Explain your answer. (b) In which cylinder is the number of moles of gas larger? Explain your answer.

40. You have two identical cylinders that are sealed with identical pistons that are free to slide up and down the cylinder without friction. Each cylinder contains the same number of moles of a diatomic ideal gas, and the gas is at the same temperature in each case. In each cylinder the piston is above the gas. Cylinder A contains oxygen gas (molecular mass = 32 g), while cylinder B contains nitrogen (molecular mass = 28 g). (a) In which cylinder is the pressure larger? Explain your answer. (b) In which cylinder is the volume occupied by the gas larger? Explain your answer.

41. As shown in Figure 14.28, a sealed cylinder of ideal gas is divided into two parts by a piston that can move up and down without friction. There is ideal gas in both parts, but the gas from one part is isolated from that in the other part by the piston. The volume occupied by the gas in the lower part is twice that occupied by the gas in the upper part, while the temperature is the same in both parts. The pressure in the lower part is 2000 Pa, and the weight of the piston is 50.0 N. The piston is in its equilibrium position. The cross-sectional area of the cylinder is 100 cm^2. Determine (a) the pressure in the upper part, and (b) the ratio of the number of moles of gas in the lower part to the number of moles in the upper part.

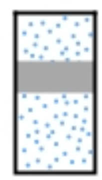

Figure 14.28: A sealed cylinder divided into two parts by a piston that is free to slide up and down without friction, for Exercise 41.

42. A cylinder sealed by a movable piston contains a certain number of molecules of air, which we can treat as an ideal gas. The pressure is initially 1 x 10^5 Pa in the cylinder, and the temperature is 20°C. Very slowly, so the temperature of the gas remains constant, you push on the piston so that the volume occupied by the gas changes from V, its original value, to $V/4$. Plot a graph of the pressure in the cylinder as a function of the volume occupied by the gas.

43. Return to the situation described in Exercise 42. If you carry out the compression very quickly, instead of slowly, the temperature of the gas can change significantly. (a) Would you expect the temperature in the cylinder to increase or decrease? (b) Thinking about the interaction between the piston and the individual gas molecules, come up with an explanation regarding why and how the average kinetic energy of the gas molecules changes.

44. On a hot summer day, you are sitting at a café drinking a carbonated beverage from a tall glass. As you watch bubbles rise from the bottom to the top of the glass you start thinking that they should be changing in volume as they rise. (a) Why, and in what way, would you expect the bubbles to change in volume as they rise? (b) Assuming the beverage has the same density as water, 1000 kg/m^3, estimate the ratio of the volume of a bubble at the surface to its volume at the bottom of the glass, 30 cm below the surface.

45. A spherical copper container with a radius of 8.0 cm is sealed when the air inside is at atmospheric pressure, 101.3 kPa, and the temperature is 20°C. (a) How many moles of gas does the sphere contain? (b) Neglecting any change in volume in the copper sphere itself, plot a graph of the pressure in the container as a function of temperature over the range of –150°C to +150°C. (c) What is the slope of the graph equal to? State your answer in terms of variables as well as giving a numerical value.

46. Consider the set of pressures, volumes, and temperatures for a sealed container of ideal gas shown in Table 14.3. Complete the table, and then rank the four states, from largest to smallest, based on their (a) pressure, (b) volume, and (c) temperature.

State	Pressure	Volume	Temperature
A	P_i	V_i	T_i
B	$3P_i$	$2V_i$	
C	$\frac{1}{2}P_i$		$2T_i$
D		$3V_i$	$\frac{1}{2}T_i$

Table 14.3: A table showing the pressure, volume, and temperature of a sealed ideal gas in four different states, for Exercise 46.

47. You have a cubical box measuring 30 cm on each side. Sealed in this box is monatomic argon gas at a temperature of 20°C and at a pressure of 100 kPa. (a) Determine the number of moles of argon in the box. (b) Determine the number of atoms of argon in the box. For these argon atoms, determine the (c) most probable speed (d) average speed (e) rms speed.

48. Return to the box of argon gas described in Exercise 47. Let's make some simple calculations to work out approximately how many collisions each side of the box experiences every second, and to determine the average force exerted on one side of the box by a single colliding atom. (a) Using the given pressure and the area of one side of the box, determine the average force applied by the atoms to one side of the box. (b) Use the value of v_{rms} and the relationship $v_{rms}^2 = 3v_x^2$ to find the value of v_x. (c) Use Equation 14.5 to determine the time interval between successive collisions of one atom with one side of the box. (d) Determine how many collisions one atom makes with one side of the box every second. (e) Multiply by the number of atoms to determine the total number of collisions that one side of the box experiences every second. (f) Divide your answer from part (a) by your answer from part (e) to determine the average force associated with one collision.

49. A particular ideal gas system contains a fixed number of moles of ideal gas. The number of moles of gas is such that the product $nR = 0.300$ J/K. Values of the volume and temperature for particular states of the system are shown in Table 14.4. (a) Find the pressure for each of the states shown in the table. (b) Plot these points on a P-V diagram. (c) Describe a system that these states could correspond to, and explain how you could move the system from state 1 through the other states listed to state 5.

State	P (kPa)	V (liters)	T (K)
1		1.0	150
2		2.0	300
3		3.0	450
4		4.0	600
5		5.0	750

Table 14.4: Volume and temperature readings in five states of an ideal gas system, for Exercise 49.

50. A particular ideal gas system contains a fixed number of moles of ideal gas. The number of moles of gas is such that the product $nR = 0.100$ J/K. Values of the pressure and temperature for particular states of the system are shown in Table 14.5. (a) Find the volume for each of the states shown in the table. (b) Plot these points on a P-V diagram. (c) Describe a system that these states could correspond to, and explain how you could move the system from state 1 through the other states listed to state 5.

State	P (kPa)	V (liters)	T (K)
1	40		80
2	80		160
3	120		240
4	160		320
5	200		400

Table 14.5: Pressure and temperature readings in five states of an ideal gas system, for Exercise 50.

51. Four states, labeled 1 through 4, of a particular thermodynamic system, are shown on the P-V diagram in Figure 14.29. The number of moles of gas in the system is constant. (a) Rank the states based on their temperature, from largest to smallest. (b) If the number of moles of gas is chosen such that the product $nR = 10.0 \text{ J/K}$, find the absolute temperature of the system in the various states.

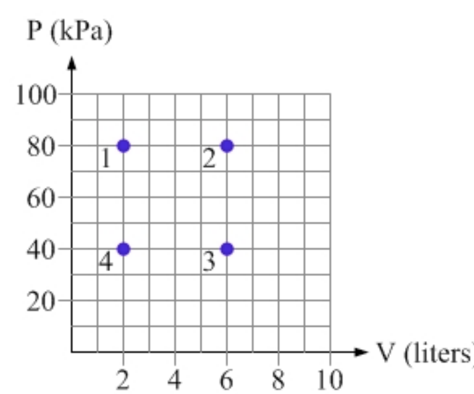

Figure 14.29: Four states are shown on the P-V diagram for a particular thermodynamic system. For Exercise 51.

52. Consider the situations represented by the two P-V diagrams shown in Figures 14.29 and 14.30. Let's say Figure 14.29 shows four different states of thermodynamic system A, and Figure 14.30 shows four different states of thermodynamic system B. The number of moles of ideal gas is constant in both systems, and the two systems happen to have the same temperature when each system is in its own state 2. Find the ratio of the absolute temperatures of the two systems when both systems are in (a) state 1, and (b) state 3. (c) Find the ratio of the number of moles of gas in system A to that in system B.

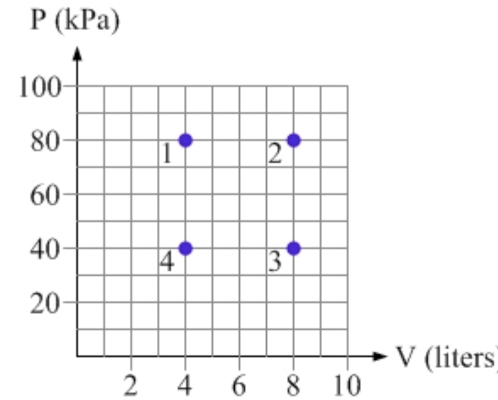

Figure 14.30: Four states are shown on the P-V diagram for a particular thermodynamic system. For Exercise 52.

53. You have two containers of the same volume. Both containers are full of ideal gas. The containers contain the same number of moles of gas, and their temperatures are identical. The internal energy of the gas in one container is 600 J, while in the other container it is only 360 J. How do the pressures compare?

54. Comment on each statement in the following conversation between two students, pertaining to the P-V diagram in Figure 14.31. In addition, state the correct answer to the question the students are trying to answer.

Valentina: This question wants to know by what factor the temperature of an ideal gas system increases when the system goes from state 1 to state 2, as shown in Figure 14.31. Let's see, the volume doubles, so does that mean the temperature doubles?

Brandon: I'm not sure. Don't we have to know how the system moves from state 1 to state 2? The diagram doesn't show us that at all.

Valentina: You might be right about that. Hmmm…also, I don't think my first answer can be right, because the pressure changes by a factor of 1.5. That, by itself, means the temperature goes up by 1.5, too.

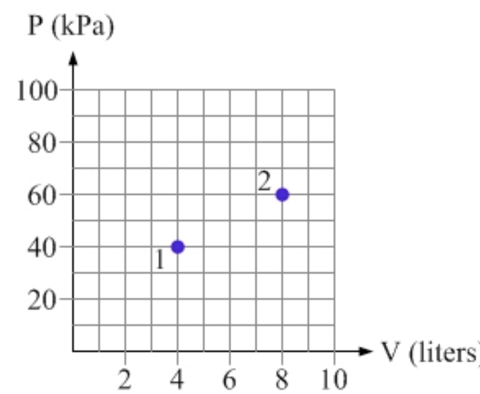

Figure 14.31: Two states are shown on the P-V diagram for a particular thermodynamic system. For Exercise 54.

55. This problem is adapted from a problem created by Todd Cooke and Joe Redish at the University of Maryland. A common earthworm requires about 1.0 micromoles of oxygen per gram of body mass per hour. This oxygen diffuses through the skin of the worm at a rate of about 0.25 micromoles per square centimeter of surface area. (a) We will first assume the worm is a cylinder 10 cm long and has a mass of 3.0 g, and we will neglect the area of the end-caps of the cylinder. Assuming just enough oxygen diffuses through the skin to satisfy the metabolic needs of the worm, what is the worm's radius? (b) If the radius doubles, how do you expect the mass and surface area of the worm to change? Would this thicker worm be able to take in enough oxygen to meet its needs?