The following list of formulae may be found useful :

Equation of state for an ideal gas	$pV = nRT$
Kinetic theory equation	$pV = \frac{1}{3}Nm\overline{c^2}$
Molecular kinetic energy	$E_k = \frac{3RT}{2N_A}$

Use the following data wherever necessary :

Molar gas constant	$R = 8.31\ \text{J K}^{-1}\ \text{mol}^{-1}$
Avogadro constant	$N_A = 6.02 \times 10^{23}\ \text{mol}^{-1}$

Part A : HKCE examination questions

1. **< HKCE 1986 Paper II - 19 >**

When observed through a microscope, smoke particles in a smoke cell are seen to be in continuous random motion. This is mainly due to
A. the motion of air molecules.
B. air currents.
C. the motion of atoms in the smoke particles.
D. heat radiation from the illuminating lamp of the smoke cell.

2. **< HKCE 1986 Paper II - 18 >**

When a constant mass of gas is compressed inside a vessel at constant temperature, the pressure of the gas increases. This is because
(1) the average distance between gas molecules decreases.
(2) the frequency of the gas molecules hitting the wall of the container increases.
(3) the average speed of the gas molecules increases.
A. (1) only
B. (2) only
C. (3) only
D. (1) & (2) only

3. **< HKCE 1988 Paper II - 9 >**

The pressure exerted by a gas in a container would increase if
(1) the average speed of the gas molecules were increased.
(2) the number of gas molecules were increased.
(3) the volume of the container were increased.
A. (1) only
B. (3) only
C. (1) & (2) only
D. (2) & (3) only

4. **< HKCE 1989 Paper II - 20 >**

When a constant mass of gas is heated at constant volume inside a vessel, the pressure of the gas increases. The main reasons include that
(1) the average speed of the gas molecules increases.
(2) the frequency of the gas molecules hitting the wall of the vessel increases.
(3) the average spacing between the gas molecules increases.
A. (1) only
B. (3) only
C. (1) & (2) only
D. (2) & (3) only

5. **< HKCE 1990 Paper II - 18 >**

Some gas is sealed inside a container of fixed volume. If the gas is heated, which of the following statements is/are true ?
(1) The pressure of the gas increases.
(2) The kinetic energy of the gas molecules increases.
(3) The density of the gas increases.
A. (2) only
B. (3) only
C. (1) & (2) only
D. (1) & (3) only

6. **< HKCE 1991 Paper II - 19 >**

Which of the following statements concerning the Brownian motion of smoke particles in air is/are correct ?
(1) The Brownian motion is caused by collision between smoke particles.
(2) The air molecules are moving randomly in all directions.
(3) The mass of air molecules is almost the same as that of smoke particles.
A. (1) only
B. (2) only
C. (1) & (3) only
D. (2) & (3) only

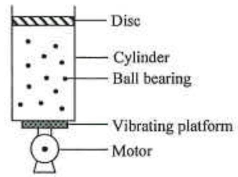
7. **< HKCE 1991 Paper II - 16 >**

Which of the following can increase the average kinetic energy of the molecules of a fixed mass of gas ?
(1) Heating the gas at constant volume
(2) Increasing the volume of the gas at constant pressure
(3) Reducing the volume of the gas at constant temperature
A. (1) only
B. (3) only
C. (1) & (2) only
D. (1), (2) & (3)

8. **< HKCE 1992 Paper II - 18 >**

If the volume of a fixed mass of gas is reduced at constant temperature, the pressure of the gas increases. Which of the following correctly account(s) for the increase in pressure ?
(1) The gas molecules hit the container wall more frequently.
(2) The average spacing between the gas molecules increases.
(3) The average speed of the gas molecules increases.
A. (1) only
B. (3) only
C. (1) & (2) only
D. (2) & (3) only

9. **< HKCE 1993 Paper II - 20 >**



The diagram shows a mechanical model of a gas. Which of the following processes can be used to demonstrate the variation of the pressure with the volume of a fixed mass of gas under constant temperature ?
A. Varying the weight of the disc.
B. Varying the power of the motor.
C. Varying the size of the ball bearings in the cylinder.
D. Varying the number of ball bearings in the cylinder.

10. **< HKCE 1993 Paper II - 17 >**

Energy is supplied to a fixed mass of gas which is kept at a constant volume. Which of the following statements is INCORRECT ?
A. The average speed of the gas molecules increases.
B. The average spacing between the gas molecules increases.
C. The gas molecules hit the container wall more frequently.
D. The temperature of the gas increases.

11. < HKCE 1995 Paper II - 23 >

A fixed mass of gas is heated at a constant pressure. Which of the following statements is/are correct ?

(1) The average speed of the gas molecules increases.
(2) The average spacing between the gas molecules increases.
(3) The number of gas molecules remains unchanged.

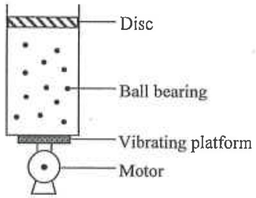
A. (3) only
B. (1) & (2) only
C. (1) & (3) only
D. (1), (2) & (3)

12. < HKCE 1996 Paper II - 23 >

Which of the following descriptions concerning the gas molecules is correct when a fixed mass of gas is compressed and also heated at the same time ?

	Average spacing between the gas molecules	Average speed of the gas molecule
A.	remains unchanged	increases
B.	decreases	increases
C.	decreases	decreases
D.	decreases	remains unchanged

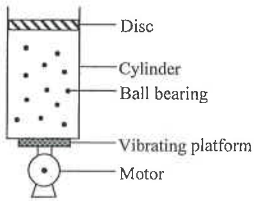
13. < HKCE 1997 Paper II - 21 >



The diagram shows a mechanical model of a gas. The weight of the disc and the power of the motor can give a measure of two different properties of the gas. What are these two properties ?

	Weight of the disc	Power of the motor
A.	Pressure	Volume
B.	Pressure	Temperature
C.	Volume	Temperature
D.	Temperature	Pressure

14. < HKCE 1998 Paper II - 24 >



The diagram shows a mechanical model of a gas. The ball bearings are set into motion by a motor-driven vibrating platform. Which of the following statements is/are correct if the operating voltage of the motor is increased ?

(1) The disc rises to a higher level.
(2) The average speed of the ball bearings increases.
(3) The average spacing between the ball bearings increases.

A. (2) only
B. (3) only
C. (1) & (2) only
D. (1), (2) & (3)

15. < HKCE 1998 Paper II - 23 >

Which of the following can increase the average kinetic energy of the molecules of a fixed mass of gas ?

(1) increasing the volume of the gas at constant pressure
(2) increasing the pressure of the gas at constant volume
(3) increasing the pressure of the gas at constant temperature

A. (1) only
B. (3) only
C. (1) & (2) only
D. (2) & (3) only

16. < HKCE 1999 Paper II - 19 >

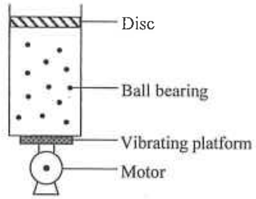


Figure (a)

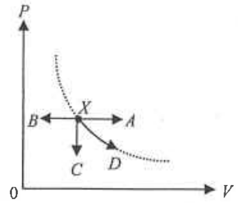


Figure (b)

Figure (a) shows a mechanical model of a gas and Figure (b) shows the P-V relation of a fixed mass of ideal gas at a certain temperature. If the operating voltage of the motor in the model is increased, which of the following denotes a corresponding transition in the P-V graph (point X represents the initial state of the gas) ?

A. $X \rightarrow A$
B. $X \rightarrow B$
C. $X \rightarrow C$
D. $X \rightarrow D$

17. < HKCE 2002 Paper II - 23 >

A column of gas is trapped inside a cylinder. The piston is now pushed slowly causing the gas to be compressed at a constant temperature. Which of the following statements about the gas molecules in the cylinder is/are correct ?

(1) The average speed of the gas molecules increases.
(2) Each gas molecule exerts a greater impact force on the walls of the cylinder in each collision.
(3) The gas molecules collide more frequently with the walls of the cylinder.

A. (1) only
B. (3) only
C. (1) & (2) only
D. (2) & (3) only

Part B : HKAL examination questions

18. < HKAL 1980 Paper I - 5 >

Two gases X and Y are maintained at the same temperature. The molecular mass of X is 9 times that of Y. What is the ratio of the r.m.s. speed of molecules of gas Y to that of molecules of gas X ?

A. 3
B. $3\sqrt{2}$
C. 9
D. 18

19. **< HKAL 1982 Paper I - 12 >**

An ideal gas inside a container of volume V has a pressure P. If the mass of the gas is M, what is the r.m.s. speed of its molecules ?

A. $\sqrt{\frac{PV}{3M}}$
B. $\sqrt{\frac{PV}{M}}$
C. $\sqrt{\frac{3PV}{M}}$
D. $\sqrt{PVM}$

20. **< HKAL 1983 Paper I - 32 >**

A cylinder containing an ideal gas is fitted with a piston maintained at a constant temperature. The piston is moved very slowly until the volume of the cylinder becomes halved. Which of the following quantities would be doubled ?

(1) The average speed of the gas molecules in the cylinder.
(2) The average momentum of the gas molecules in the cylinder.
(3) The average force exerted by the gas molecules on the piston.

A. (1) only
B. (3) only
C. (1) & (2) only
D. (2) & (3) only

21. **< HKAL 1984 Paper I - 11 >**

A fixed mass of gas at room temperature occupies a volume of V. The gas is heated and allowed to expand to a final volume of $2V$ with its pressure doubled. The average kinetic energy of the gas molecules is

A. halved.
B. unchanged.
C. doubled.
D. increased four times.

22. **< HKAL 1985 Paper I - 11 >**

A gas vessel of volume 1000 cm^3 contains 0.72 g of an ideal gas at a pressure of 100 kPa. What is the r.m.s. velocity of the gas molecules ?

A. 20 m s^{-1}
B. 110 m s^{-1}
C. 340 m s^{-1}
D. 650 m s^{-1}

23. **< HKAL 1986 Paper I - 16 >**

The density of a gas is 0.179 kg m^{-3} at the temperature of 0°C and pressure of 100 kPa. What would be the r.m.s. velocity of the gas molecules at a temperature of 91°C ?

A. 231 m s^{-1}.
B. 470 m s^{-1}.
C. 1290 m s^{-1}.
D. 1490 m s^{-1}.

24. **< HKAL 1988 Paper I - 18 >**

Which of the following is NOT an assumption of the kinetic model of ideal gases ?

A. Attractive forces between the gas molecules are negligible.
B. The duration of collision between gas molecule and the walls is negligible compared with the time between collisions.
C. The collisions of gas molecules with the walls of the container cause no change in the average kinetic energy of molecules.
D. The gas molecules suffer negligible change of momentum on collision with the walls of the container.

25. **< HKAL 1988 Paper I - 17 >**

An ideal gas is at an absolute temperature T. If m is the mass of a gas molecule, then the r.m.s. speed of the molecules is

A. $\sqrt{\frac{3RT}{m}}$
B. $\sqrt{\frac{RT}{mN_A}}$
C. $\sqrt{\frac{3RT}{mN_A}}$
D. $\sqrt{\frac{RTN_A}{m}}$

26. **< HKAL 1988 Paper I - 12 >**

Smoke particles in air are observed to have Brownian motion observed by microscope. The Brownian motion of the smoke particles is mainly caused by

A. the interaction between oxygen and the nitrogen molecules.
B. collisions between air molecules.
C. collisions between smoke particles.
D. collisions between air molecules and smoke particles.

27. **< HKAL 1988 Paper I - 15 >**

An ideal gas is contained in a cylinder. The piston is slowly pushed into the cylinder so that the temperature remains unchanged. Which of the following statements is NOT correct ?

A. The mass of the gas remains the same.
B. The pressure of the gas increases.
C. The number of the molecules per unit volume increases.
D. The average speed of gas molecules increases.

28. **< HKAL 1989 Paper I - 17 >**

Two identical vessels contain two different gases A and B, which are treated as ideal gases. If the ratio of their molar masses and absolute temperatures are 8 : 1 and 2 : 1 respectively, what is the ratio of their r.m.s. molecular speeds ?

A. 1 : 4
B. 1 : 2
C. 1 : 1
D. 2 : 1

29. **< HKAL 1990 Paper I - 13 >**

Container X contains hydrogen gas while container Y contains oxygen gas. If both of the hydrogen molecules in X and the oxygen molecules in Y have the same r.m.s. speed, which of the following deduction must be correct ?

A. The gas in X has a higher temperature than Y.
B. The gas in X has a higher pressure than Y.
C. The gas in X has a lower temperature than Y.
D. The gas in X has a lower pressure than Y.

30. **< HKAL 1991 Paper I - 10 >**

A container holds an ideal gas on the Earth. If the container is brought to the surface of the Moon with the same temperature and the same volume, which of the following properties of the gas molecules is/are the same ?

(1) The average momentum change when a molecule of the gas rebounds from a wall of the container
(2) The average kinetic energy of a molecule of the gas
(3) The weight of a molecule of the gas

A. (1) only
B. (3) only
C. (1) & (2) only
D. (2) & (3) only

31. < HKAL 1991 Paper I - 17 >

A fixed mass of ideal gas at room temperature and atmospheric pressure occupies a volume of $0.2\ m^3$. The gas is heated and allowed to expand to a final volume of $0.4\ m^3$ with its pressure doubled. The root mean square speed of the gas molecules is

A. reduced to one quarter of its original value.
B. halved.
C. unchanged.
D. doubled.

32. < HKAL 1991 Paper I - 19 >

Smoke particles in air inside a smoke cell are seen to undergo Brownian motion by viewing through microscope. Which of the following statements concerning Brownian motion is/are correct ?

(1) The motion is caused by collisions between air molecules and smoke particles.
(2) The experiment makes it possible to see the motion of the air molecules.
(3) The motion is irregular because air is a mixture of gases, and the molecules have different masses.

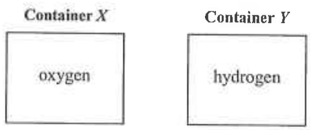
A. (1) only
B. (3) only
C. (1) & (2) only
D. (2) & (3) only

33. < HKAL 1992 Paper I - 14 >

The molar mass of oxygen gas and hydrogen gas are 32 g and 2 g respectively. What is the ratio of the r.m.s. speed of oxygen molecules to that of hydrogen molecules at room temperature ?

A. $\frac{1}{16}$
B. $\frac{1}{4}$
C. 1
D. 4

34. < HKAL 1993 Paper I - 18 >



Two identical gas vessels X and Y contain oxygen and hydrogen respectively. Both gases are at room temperature and atmospheric pressure. Which of the following statements is/are true concerning the two gases in both containers ?

(1) The number of gas molecules is the same.
(2) The r.m.s. speed of gas molecules is the same.
(3) The frequency of collision of gas molecules with the walls of container is the same.

A. (1) only
B. (3) only
C. (1) & (2) only
D. (2) & (3) only

35. < HKAL 1995 Paper IIA 21 >

The r.m.s. speed of the molecules of a certain gas is $341\ m\ s^{-1}$ at 25°C. Find the molar mass of this gas.

A. 21.8 g
B. 33.8 g
C. 42.6 g
D. 63.9 g

36. < HKAL 1997 Paper IIA - 35 >

Two identical vessels contain two different ideal gases A and B. If the ratio of their absolute temperatures and the ratio of their root-mean-square speed of the molecules are respectively 2 : 1 and 3 : 1, what is the ratio of their molar mass ?

A. 2 : 3
B. 2 : 9
C. 1 : 6
D. 9 : 2

37. < HKAL 2000 Paper IIA - 39 >

Which of the following statements concerning a real gas are correct ?

(1) The collisions between gas molecules and the walls of a container are not perfectly elastic.
(2) The size of the gas molecules cannot be neglected.
(3) Intermolecular attraction forces between gas molecules cannot be neglected.

A. (1) & (2) only
B. (1) & (3) only
C. (2) & (3) only
D. (1), (2) & (3)

38. < HKAL 2001 Paper IIA - 32 >

Which of the following is NOT a basic assumption of the kinetic theory of an ideal gas ?

A. All gas molecules are in random motion.
B. All gas molecules move with the same speed at a certain temperature.
C. All gas molecules are point particles that have no physical size.
D. All collisions between gas molecules and the walls of the container are perfectly elastic.

39. < HKAL 2002 Paper IIA - 40 >

The r.m.s. speed of the molecules in a fixed mass of an ideal gas is c at 80°C. If the temperature is increased to 160°C, what would be the r.m.s. speed of the gas molecules ?

A. 2 c.
B. 1.4 c.
C. 1.2 c.
D. 1.1 c.

40. < HKAL 2005 Paper IIA - 20 >

Two gas vessels contain hydrogen and oxygen gas respectively. They have the same temperature and pressure. If both gases are assumed to be ideal, which of the following physical quantities must be the same for the two gases ?

A. The r.m.s. speed of the gas molecules
B. The volume of the gas
C. The mass per unit volume of the gas
D. The number of gas molecules per unit volume

41. < HKAL 2006 Paper IIA - 22 >

The following is the kinetic equation for ideal gas :

$$P = \frac{1}{3}\frac{N\,m}{V}\overline{c^2}.$$

In the above equation, the product $N\,m$ represent

A. the total mass of the gas.
B. the mass of one mole of the gas.
C. the number of molecules in unit volume of the gas.
D. the number of molecules in one mole of the gas.

42. < HKAL 2008 Paper IIA - 23 >

An ideal gas is contained in a gas vessel at a certain temperature. The gas is heated until its pressure reaches 1.2 times its initial value. Calculate the percentage increase in the average kinetic energy of the gas molecules.

A. 10%
B. 20%
C. 44%
D. It cannot be determined since the number of moles of gas molecules is not known.

43. < HKAL 2011 Paper IIA - 41 >

Which of the following is NOT an essential assumption of the kinetic model of ideal gas ?
A. The number of molecules in the container is large.
B. The volume occupied by the molecules is negligible compared with the container's volume.
C. There is no collision between the molecules.
D. There are no intermolecular forces of attraction between two molecules at any separation.

44. < HKAL 2011 Paper IIA - 42 >

Two different ideal gases are contained in two identical vessels. Both vessels are at the same temperature. Which of the following physical quantities about the two gases in their vessels must be the same ?
(1) the pressure of the gas
(2) the number of molecules per unit volume
(3) the average kinetic energy of molecules
A. (1) only
B. (3) only
C. (1) & (2) only
D. (2) & (3) only

45. < HKAL 2012 Paper IIA - 36 >

Two vessels X and Y contain equal mass of an ideal gas. The pressure of the gas in X is equal to that in Y, while the temperature of the gas in X is higher than that in Y. Which of the following statements is/are correct ?
(1) The average separation of the gas molecules in X is greater than that in Y.
(2) Every gas molecule in X has greater kinetic energy than that in Y.
(3) The collision frequency of the molecules on each wall of the vessel in X is greater than that in Y.
A. (1) only
B. (2) only
C. (1) & (3) only
D. (2) & (3) only

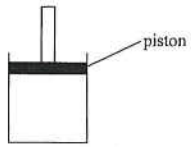
Part C : HKDSE examination questions

46. < HKDSE Sample Paper IA - 4 >

Two vessels contain hydrogen and oxygen gas respectively. Both gases have the same pressure and temperature and are assumed to be ideal. Which of the following physical quantities must be the same for the two gases ?
A. The volume of the gas
B. The mass per unit volume of the gas
C. The r.m.s. speed of the gas molecules
D. The number of gas molecules per unit volume

47. < HKDSE Practice Paper IA - 5 >

A fixed mass of an ideal gas is contained in a cylinder fitted with a frictionless piston as shown in the figure. If the gas is cooled under constant pressure,

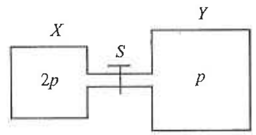


(1) the average separation of the gas molecules will decrease.
(2) the r.m.s. speed of the gas molecules will decrease.
(3) the number of collisions per second of the gas molecules on the piston will decrease.
A. (1) & (2) only
B. (1) & (3) only
C. (2) & (3) only
D. (1), (2) & (3)

48. < HKDSE 2013 Paper IA - 3 >

In which of the following situations would the r.m.s. speed of the molecules of a fixed mass of an ideal gas increase ?
(1) The gas is heated under constant volume.
(2) The gas expands under constant pressure.
(3) The gas is compressed under constant temperature.
A. (1) only
B. (3) only
C. (1) & (2) only
D. (2) & (3) only

49. < HKDSE 2013 Paper IA - 4 >



Vessel X of volume V and vessel Y of volume $2V$ are connected by a short narrow tube as shown. Initially, tap S is closed and the same kind of ideal gas at the same temperature is contained in X and Y at pressure $2p$ and p respectively. The tap S is then opened and equilibrium state is finally reached with the temperature unchanged. Which statement is **INCORRECT** ?
A. Before S is opened, both vessels contain the same number of gas molecules.
B. Before S is opened, the average kinetic energy of the gas molecules in both vessels is the same.
C. When S is opened, a net flow of gas from X to Y occurs.
D. When equilibrium is reached, the gas pressure becomes $\frac{3}{2}p$.

50. < HKDSE 2016 Paper IA - 3 >

When an ideal gas is heated from 25°C to 50°C, the average kinetic energy of the gas molecules will
A. double.
B. increase by 41%.
C. increase by 8.4%.
D. increase by 4.1%.

51.<HKDSE 2020 Paper IA-3>

HKEAA's Marking Scheme is prepared for the markers' reference. It should not be regarded as a set of model answers. Students and teachers who are not involved in the marking process are advised to interpret the Marking Scheme with care.

M.C. Answers

1. A	11. D	21. D	31. D	41. A	51.A
2. B	12. B	22. D	32. A	42. B	
3. C	13. B	23. D	33. B	43. C	
4. C	14. D	24. D	34. A	44. B	
5. C	15. C	25. C	35. D	45. A	
6. B	16. A	26. D	36. B	46. D	
7. C	17. B	27. D	37. C	47. A	
8. A	18. A	28. B	38. B	48. C	
9. A	19. C	29. C	39. D	49. D	
10. B	20. B	30. C	40. D	50. C	

M.C. Solution

1. A

The motion of air molecules causes the hitting of air molecules onto the large smoke particles, thus the smoke particles perform zig-zag motion.
This is called Brownian motion.

2. B

× (1) Although the average distance between gas molecules is decreased due to the decrease of volume, it cannot explain why the pressure is increased.

✓ (2) When volume of container is decreased, distance between two walls is decreased, thus the gas molecules bombard the walls more frequently, therefore pressure is increased.

× (3) Since there is no change in temperature, thus the speed of molecules remains unchanged.

3. C

✓ (1) If the average speed of gas molecules is increased, the bombardment with the walls of container would become more violently and more frequently, thus pressure is increased.

✓ (2) If the number of gas molecules is increased, the bombardment with the walls of container would become more frequently, thus pressure is increased.

× (3) If the volume is increased, the bombardment with the walls of container would become less frequently, thus pressure is decreased.

4. C

✓ (1) When temperature is increased, the kinetic energy and the average speed of gas molecules must increase.

✓ (2) When the average speed of gas molecules increases, the molecules hit the wall more frequently.

× (3) Since the volume is constant, average spacing of gas molecules remains unchanged.

5. C

✓ (1) When the gas is heated, average speed of gas molecules must increase. Gas molecules hit the walls of container more violently and more frequently. Thus pressure increases.

✓ (2) When a gas is heated, its temperature must increase, thus its kinetic energy is increased.

× (3) Since the volume is fixed, its density must also be unchanged.

6. B

× (1) Smoke particles undergo Brownian motion as air molecules bombard the smoke particles but not the collision between smoke particles themselves.

✓ (2) Air molecules move randomly to give collision with smoke particles and causes Brownian motion

× (3) The mass of smoke particles is much larger than the mass of each air molecule.

7. C

✓ (1) When a gas is heated, its temperature must increase, thus the kinetic energy must increase.

✓ (2) At constant pressure, the volume of gas can be increased by increasing the temperature only.

× (3) If temperature is constant, the kinetic energy of molecules must be constant.

8. A

✓ (1) When the volume is decreased, distance between two walls of container is decreased, thus the gas molecules hit the walls more frequently, therefore pressure is increased.

× (2) The average spacing should be decreased when volume is decreased.

× (3) The average speed should be unchanged when temperature is constant.

9. A

✓ A. Varying the weight of disc means varying the pressure of gas.

× B. Varying the power of the motor means varying the temperature.

× C. Varying the size of ball bearings means varying the mass of the gas molecules.

× D. Varying the number of ball bearings means varying the number of gas molecules.

10. B

✓ A. When energy is supplied to a gas, its temperature must increase, thus the kinetic energy of gas molecules must increase, thus the average speed is increased.

× B. Since the gas is kept at constant volume, the average spacing does not change.

✓ C. Since the average speed is increased, the gas molecules hit the wall more frequently and more violently.

✓ D. When energy is supplied, its temperature must increase.

11. D

✓ (1) Under heating, the temperature of the gas must increase, and thus the average speed is increased.

✓ (2) When heating under constant pressure, the volume of container must increase, thus the average spacing of molecules must also increase.

✓ (3) For a fixed mass of gas, the number of gas molecules must also be unchanged.

12. B

① When a gas is compressed, its volume is decreased, thus the average spacing is decreased.

② When a gas is heated, its kinetic energy increases, thus the kinetic energy of the gas molecules increases.

13. B

Weight of the disc : simulates the pressure of the gas

Power of the motor : simulates the temperature of the gas

14. D

✓ (1) When the operating voltage is increased, the average speed of ball bearings is increased. The ball bearing thus hit the disc more violently to increase the volume.

✓ (2) When the operating voltage is increased, the average speed of ball bearings is increased.

✓ (3) When the volume is increased, the average spacing between ball bearings is increased.

15. C

✓ (1) At constant pressure, the volume of a gas can be increased by increasing the temperature only.

✓ (2) At constant volume, the pressure of a gas can be increased by increasing the temperature only.

× (3) At constant temperature, the kinetic energy of gas molecules must remain unchanged.

16. A

When the operating voltage of the motor is increased, it simulates the increase of temperature.

Since the disc remains unchanged, it represents no change of pressure.

As temperature is increased but pressure is unchanged, the volume must increase.

Thus the change should be from X to A.

17. B

× (1) The average speed of the gas molecules does not change as the temperature is constant.

× (2) Since the average speed is unchanged, the impact force of each molecule is unchanged.

✓ (3) As the volume decreases, the distance between the piston and the walls of container decreases, the gas molecules will collide more frequently with the walls of the container.

18. A

For same temperature, molecules have the same kinetic energy E_K.

$E_K = \frac{1}{2}mc^2 \therefore c \propto \frac{1}{\sqrt{m}}$ $\therefore \frac{c_Y}{c_X} = \sqrt{\frac{m_X}{m_Y}} = \sqrt{\frac{9}{1}} = 3$

19. C

As $PV = \frac{1}{3}Nmc^2$ $\therefore PV = \frac{1}{3}Mc^2$

$\therefore c = \sqrt{\frac{3PV}{M}}$

20. B

× (1) As T kept constant $\therefore$ r.m.s. speed c is no change $\therefore$ average speed is no change

× (2) average speed : no change $\Rightarrow$ average momentum : no change (By $p = mc$)

✓ (3) $V \to \frac{1}{2}V \Rightarrow P \to 2P$ (By PV = constant) $\Rightarrow F \to 2F$ (By $F = PA$)

21. D

$PV = nRT$

As $P \to 2P$ and $V \to 2V$ $\therefore T \to 4T$

Since average kinetic energy : $E_K \propto T$ $\therefore E_K$ increases 4 times

22. D

$PV = \frac{1}{3}Nmc^2 = \frac{1}{3}Mc^2$ (M is the mass of the gas)

$\therefore (100\times10^3)(1000\times10^{-6}) = \frac{1}{3}(0.72\times10^{-3})c^2$ $\therefore c = 650 \text{ m s}^{-1}$

23. D

At 0°C, $PV = \frac{1}{3}Nmc^2$ $\therefore P = \frac{1}{3}\rho c^2$

$\therefore (1\times10^5) = \frac{1}{3}(0.179)c^2$ $\therefore c = 1290 \text{ m s}^{-1}$

At 91°C, $c = \sqrt{\frac{3RT}{M_m}}$ $\therefore c \propto \sqrt{T}$ $\therefore \frac{c_1}{c_2} = \sqrt{\frac{T_1}{T_2}}$

$\therefore \frac{1290}{c_2} = \sqrt{\frac{0+273}{91+273}}$ $\therefore c_2 = 1490 \text{ m s}^{-1}$

24. D

Perfectly elastic collision $\Rightarrow$ change of momentum $= mc - (-mc) = 2mc$

$\therefore$ Momentum of molecules must change during collision $\therefore$ D is incorrect.

25. C

$PV = \frac{1}{3}Nmc^2$ and $PV = nRT$ $\therefore nRT = \frac{1}{3}Nmc^2$

$\therefore \frac{N}{N_A}RT = \frac{1}{3}Nmc^2$ $\therefore c = \sqrt{\frac{3RT}{mN_A}}$

26. D

Smoke particles perform Brownian motion is due to the collision between air molecules and smoke particles.

27. D

✓ A. The mass of the gas inside the cylinder must be unchanged since the gas is enclosed by the cylinder.

✓ B. By Boyle's Law, the decrease of volume gives the increase of pressure.

✓ C. As the volume decreases, more gas molecules is contained in a unit volume, thus the number of the molecules per unit volume increases.

× D. As the temperature is unchanged, the average speed should also be unchanged.

28. B

$$c = \sqrt{\frac{3RT}{M_m}} \propto \sqrt{\frac{T}{M_m}}$$

$$\therefore \frac{c_A}{c_B} = \sqrt{\frac{T_A}{T_B}} \cdot \sqrt{\frac{M_B}{M_A}} = \sqrt{\frac{2}{1}} \cdot \sqrt{\frac{1}{8}} = \frac{1}{2}$$

29. C

By $c = \sqrt{\frac{3RT}{M_m}}$ $\therefore$ for same $c \Rightarrow M_m \propto T$

$$\therefore M_{H_2} < M_{O_2} \Rightarrow M_X < M_Y \Rightarrow T_X < T_Y$$

30. C

✓ (1) At the moon, the mass of molecule remains unchanged, thus the momentum change should be the same.

✓ (2) At the moon, the mass of molecule remains unchanged, thus the kinetic energy should be the same.

× (3) At the moon, the gravity g is smaller, thus the weight mg would be smaller and not the same.

31. D

$PV = \frac{1}{3} N m c^2$ $\therefore PV = \frac{1}{3} M c^2$ $\therefore c = \sqrt{\frac{3PV}{M}} \propto \sqrt{PV}$

$\therefore \frac{c'}{c} = \sqrt{\frac{P'}{P} \cdot \frac{V'}{V}} = \sqrt{(2) \times \left(\frac{0.4}{0.2}\right)} = 2$ $\therefore c' = 2c$.

32. A

✓ (1) When thousands of air molecules collide with a smoke particle, the random resultant force makes the smoke particles move in zig-zag path, and this is the Brownian motion

× (2) Air molecules are invisible even under microscope.

× (3) The irregular motion of smoke particles is due to the collisions of air molecules on the smoke particles ; the irregular motion would still occur even for the same type of gas or for mixture.

33. B

$$c = \sqrt{\frac{3RT}{M_m}} \propto \frac{1}{\sqrt{M_m}}$$

$$\therefore \frac{c_{O_2}}{c_{H_2}} = \sqrt{\frac{M_{H_2}}{M_{O_2}}} = \sqrt{\frac{2}{32}} = \frac{1}{4}$$

34. A

✓ (1) Same $V, T, P \Rightarrow$ same n and same N (by $PV = nRT$)

× (2) Different molar mass $M_m \Rightarrow$ different c (by $c = \sqrt{\frac{3RT}{M_m}}$)

× (3) Different $c \Rightarrow$ different frequency f (for same volume V and same number N)

35. D

$$c = \sqrt{\frac{3RT}{M_m}}$$

$$\therefore (341) = \sqrt{\frac{3(8.31)(25+273)}{M_m}}$$

$\therefore M_m = 0.0639 \text{ kg} = 63.9 \text{ g}$

36. B

As $c = \sqrt{\frac{3RT}{M_m}}$

$$\therefore M_m = \frac{3RT}{c^2} \propto \frac{T}{c^2}$$

$$\therefore \frac{M_A}{M_B} = \frac{T_A}{T_B} \cdot \left(\frac{c_B}{c_A}\right)^2 = \left(\frac{2}{1}\right)\left(\frac{1}{3}\right)^2 = \frac{2}{9}$$

37. C

× (1) Otherwise, the molecules stop moving after a certain time period.

✓ (2) Gas molecules of real gas have size that is not negligible.

✓ (3) Intermolecular attraction forces of real gas are significant.

38. B

× A. Molecules of ideal gas are assumed to move in random motion.

✓ B. Speed of molecules should have a distribution, with an average value of speed.

× C. Molecules of ideal gas are assumed to have no volume.

× D. Molecules of ideal gas are assumed to have perfectly elastic collision.

39. D

As $c \propto \sqrt{T}$

$\therefore \frac{c_2}{c_1} = \sqrt{\frac{T_2}{T_1}}$

$\therefore \frac{c_2}{(c)} = \sqrt{\frac{160+273}{80+273}} = 1.1$ $\therefore c_2 = 1.1\,c$

40. D

By $PV = nRT$

Since P and T are the same, the ratio $\frac{n}{V}$ is the same for the two gases.

As the number of gas molecules N is proportional to the number of mole n,

they have the same number per volume $\frac{N}{V}$.

41. A

N represents the total number of molecules ; m represents the mass of each molecule.

Nm thus represents the total mass of all the gas molecules.

42. B

As the volume is unchanged in a closed vessel, $P \propto T$.
When pressure reaches 1.2 times, the absolute temperature also reaches 1.2 times.
As the average kinetic energy is proportional to the absolute temperature, i.e. $KE \propto T$.
When the absolute temperature reaches 1.2 times, the average kinetic energy of the gas molecules also reaches 1.2 times.
Thus the percentage increase is 20%.

43. C

✓ A. Large number of molecules in the container is assumed.

✓ B. Ideal gas molecules have negligible size.

× C. Molecules may collide with each when they move.

✓ D. Ideal gas molecules do not have intermolecular forces.

44. B

× (1) Since the two vessels are identical, their volumes are the same.
Since the two vessels are in thermal equilibrium, their temperatures are the same.
However, their pressure and number of mole may not be the same.

× (2) Since the number of mole may not be the same, the number of molecules may also not be the same.

✓ (3) Since their temperatures are the same, their average molecular kinetic energy must be the same.

45. A

✓ (1) As they have equal mass, their number of mole n must be the same.
By $PV = nRT$, as their pressures P are the same, since X has higher temperature,
the volume of vessel X is greater, thus the molecules in X has greater average separation.

× (2) Although the average kinetic energy of gas molecules in X is greater,
but still there are some gas molecules in X that may have kinetic energy less than that of Y,
as the molecules have a range of speed or range of kinetic energy.

× (3) Since the temperature of X is higher, the average speed of gas molecules in X is greater.
Thus, the gas molecules in X hit the wall more vigorously with greater momentum.
To have the same pressure, the collision of gas molecules in X must be less frequently.
Thus the collision frequency in X should be smaller than that in Y.

46. D

By $PV = nRT$

$\therefore \frac{n}{V} = \frac{P}{RT}$

Since P and T are the same, the ratio $\frac{n}{V}$ is the same for the two gases.

As the number of gas molecules N is proportional to the number of mole n,

they have the same number of gas molecules per unit volume $\frac{N}{V}$.

47. A

✓ (1) Under constant pressure, as temperature decreases, volume decreases.
Thus the average separation will decrease as it depends on the volume of the gas.

✓ (2) As the gas is cooled, the temperature decreases, thus KE decreases and r.m.s. speed decreases.

× (3) As the r.m.s. speed decreases, the gas molecules hit the walls less violently.
Thus the gas molecules must hit the walls more frequently so that the pressure is the same.
Therefore, the number of collisions per second of the gas molecules should increase.

48. C

✓ (1) As the gas is heated, its temperature must increase, thus r.m.s. speed would increase.

✓ (2) At constant pressure, the gas expands only when temperature increases, thus r.m.s. speed must increase.

× (3) Under constant temperature, average kinetic energy and r.m.s. speed remain unchanged.

49. D

✓ A. By $PV = nRT$, for X: $(2p)(V) = nRT$ and for Y: $(p)(2V) = nRT$
the number of mole n in both vessels are the same, thus they contain the same number of molecules.

✓ B. Since average kinetic energy depends on temperature only, same temperature has same average KE.

✓ C. Since pressure of X is greater, there is a net flow of gas from X to Y.

× D. At equilibrium, $(2p)(V) + (p)(2V) = p'(V + 2V)$ $\therefore p' = \frac{4}{3}p$.

50. C

By $E_K = \frac{3}{2} \cdot \frac{R}{N_A} \cdot T$ $\quad \therefore E_K \propto T$

$\therefore \frac{E_2}{E_1} = \frac{T_2}{T_1} = \frac{(50+273)}{(25+273)} = 1.084 = 108.4\%$

$\therefore$ Kinetic energy increases by 8.4%.

The following list of formulae may be found useful :

Equation of state for an ideal gas	$pV = nRT$
Kinetic theory equation	$pV = \frac{1}{3} N m \overline{c^2}$
Molecular kinetic energy	$E_k = \frac{3RT}{2N_A}$

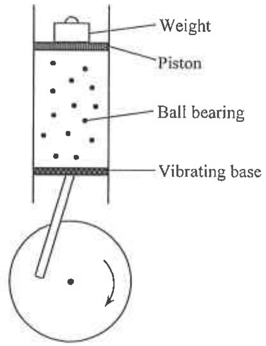
Use the following data wherever necessary :

Molar gas constant	$R = 8.31 \text{ J K}^{-1} \text{ mol}^{-1}$
Avogadro constant	$N_A = 6.02 \times 10^{23} \text{ mol}^{-1}$

Part A : HKCE examination questions

1. **< HKCE 1979 Paper I - 4 >**

(a) The below figure shows a mechanical model for the kinetic theory of a gas.



As the ball bearings are in motion, the mean separation between the piston and the base is h.

(i) State how the value of h may be affected by increasing the frequency of vibration of the base. (1 mark)

____

(ii) State how the value of h may be affected by adding weights to the piston. (1 mark)

____

(iii) State how the value of h may be affected by reducing the number of ball bearings. (1 mark)

____

(b) Explain in terms of the kinetic theory of matter, why at constant volume, the increase in the temperature of a gas causes an increase of its pressure. (3 marks)

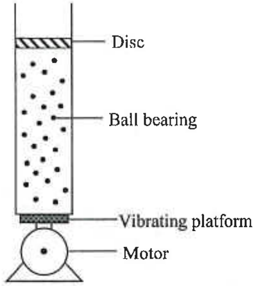
____

____

____

2. < HKCE 1988 Paper I - 4 >

The below figure shows a mechanical model of a gas. A large number of ball bearings are set in motion by a vibrating platform. The ball bearings represent gas molecules.



(a) Which property of the gas would be represented in this model by (2 marks)

(i) the weight of the disc; and

(ii) the voltage of the d.c. supply ?

(b) For a fixed amount of gas, when temperature is kept constant, its pressure increases as the volume decreases.

(i) Describe how this behaviour of gas can be demonstrated using the model. (2 marks)

(ii) Describe the change in the average speed of the ball bearings and the frequency of bombardment on the walls in this demonstration. (4 marks)

(c) In a real situation, gas molecules could keep on moving by themselves without an external energy supply but in this model energy has to be supplied to the ball bearings continuously by the vibrating platform. Briefly explain this difference. (3 marks)

(d) A large polystyrene ball is now placed into the cylinder. Briefly describe and explain the motion of the polystyrene ball. (3 marks)

3. < HKCE 1989 Paper I - 4 >

Based on the kinetic theory of gases, explain briefly why the pressure increases as the temperature does. (3 marks)

4. < HKCE 1990 Paper I - 4 >

Describe the arrangement and motion of the molecules of the substance in the (4 marks)

(i) solid state, and

(ii) liquid state.

5. < HKCE 1994 Paper I - 4 >

Explain, in terms of the kinetic theory of gases, the increase in the pressure of the gas when the volume decreases at a constant temperature. (3 marks)

6. < HKCE 1999 Paper I - 9 >

Based on the kinetic theory, explain why the pressure of a gas increases with temperature at a constant volume. (3 marks)

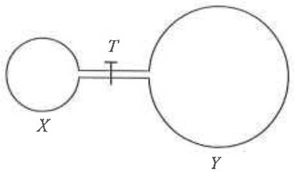
7. < HKCE 2001 Paper I - 2 >

Based on the kinetic theory, explain why the gas pressure inside a metal can increases with temperature at a constant volume. (3 marks)

Part B : HKAL examination questions

8. **< HKAL 2001 Paper I - 10 >**

Two containers X and Y with volumes 100 cm^3 and 500 cm^3 respectively are connected by a tube of negligible volume as shown in the figure below. Container X contains an ideal gas at a pressure of 12×10^5 Pa while there is a vacuum in container Y. The temperature of the two containers is maintained at 0°C by two separate water baths with melting ice. The tap T for controlling gas flow is closed initially



Given that the mass of one molecule of the ideal gas is 4.52×10^{-26} kg.

(a) Calculate the number of moles of gas in the container X. (2 marks)

(b) Calculate the root-mean-square speed of the gas molecules in X. (2 marks)

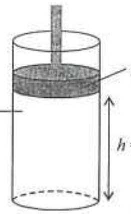
(c) Now the tap is open and the gas in X flows to Y. Finally, equilibrium state is achieved.

(i) What is the root-mean-square speed of the gas molecules in Y ? (1 mark)

(ii) What is the common pressure in the two vessels ? (2 marks)

(iii) What is the number of mole of gas in the vessel Y ? (2 marks)

9. **< HKAL 2006 Paper I - 5 >**



In the above Figure, an ideal gas is contained in a cylinder fitted with a piston which can move smoothly. The gas has a volume of 300 cm^3 at an atmospheric pressure of 100 kPa and a temperature of 300 K. The piston is at a height of 20 cm from the bottom of the cylinder. Given that the molar mass of the ideal gas is 4 g mol^{-1}.

(a) (i) Find the number of moles of the ideal gas in the cylinder. (2 marks)

(ii) Calculate the r.m.s. speed of the gas molecules. (2 marks)

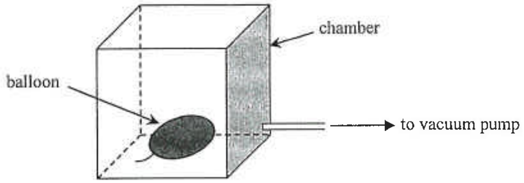
(b) The ideal gas in the cylinder is now heated to a temperature of 90°C while keeping the pressure at 100 kPa.

(i) Find the equilibrium position of the piston, i.e. its height from the bottom of the cylinder. (2 marks)

(ii) If the piston is pushed slowly back to the original position by keeping constant temperature, calculate the new pressure of the gas. (2 marks)

Part C : HKDSE examination questions

10. **< HKDSE Sample Paper IB - 1 >**

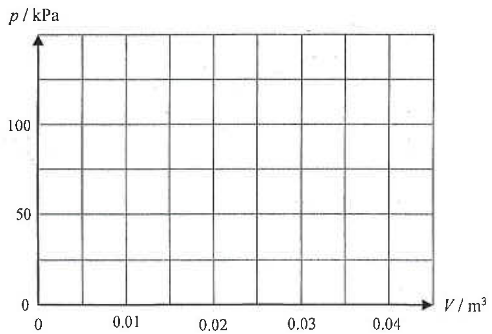


A balloon containing 0.01 m^3 of gas at a pressure of 100 kPa is placed inside a chamber. Air is slowly pumped out from the chamber while the temperature remains unchanged.

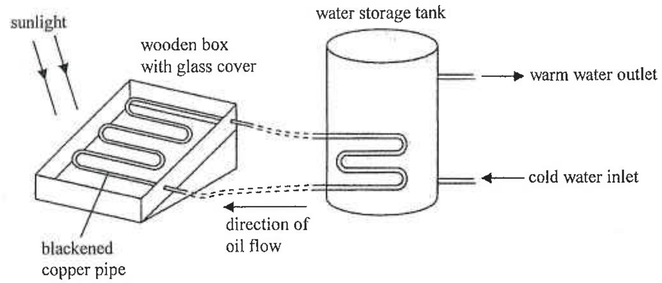
(a) Explain, in terms of molecular motion, how the gas inside the balloon exerts a pressure on its inner surface. (2 marks)

(b) Find the final pressure inside the balloon when its volume is doubled. (2 marks)

(c) Sketch a graph to show the relationship between the pressure p inside the balloon and the volume V of the balloon. (2 marks)



11. **< HKDSE Practice Paper IB - 1 >**



The Figure above shows a solar water heating system. The heater is made from a glass-covered wooden box and the copper pipe inside is painted black. The heater is put on an inclined plane. Oil circulates between the heater and the water storage tank via the copper pipe.

(a) (i) Explain why the copper pipe inside the box is painted black. (1 mark)

(ii) Explain why the wooden box is covered by a sheet of glass. (1 mark)

(iii) Explain why the oil circulates in the system in the direction as indicated in the above Figure. (2 marks)

(b) When the oil flows through the pipe in the heater at a rate of 0.3 kg per minute, the temperature of the oil rises from 25°C to 37°C. Determine the power absorbed by the oil.

Given : specific heat capacity of oil = 2500 J kg^{-1} °C^{-1} (3 marks)

(c) If the wooden box is sealed and made air-tight, how would the air pressure inside change when temperature increases ? Explain briefly in terms of kinetic theory. No mathematical derivation is required. (3 marks)

12. **< HKDSE 2012 Paper IB - 2 >**

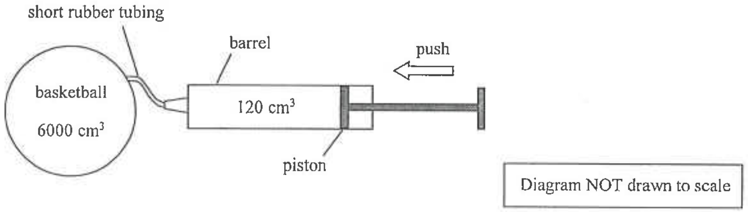
A gas bubble rises from the bottom of a lake to the water surface. Its radius increases from 0.8 cm to 1.0 cm.

(a) If the gas pressure in the bubble at the water surface is 1.01×10^5 Pa, find the gas pressure in the bubble when it is at the bottom of the lake. Assume that the temperature of the gas in the bubble remains constant. (2 marks)

(b) Use kinetic theory to explain the change in gas pressure in the bubble as its volume increases. (2 marks)

13. **< HKDSE 2014 Paper IB - 2 >**

The Figure below shows a basketball connected to an air pump via a short rubber tubing. By pushing the piston inward, the pump can compress 120 cm³ of air inside its barrel at atmospheric pressure and room temperature into the basketball for each stroke.



Initially the volume of air inside the basketball is 6000 cm³ and is at equilibrium with the atmospheric pressure 100 kPa. The basketball has to be pumped to a pressure of 156 kPa for an official match. Throughout the pumping process, the temperature of the basketball and the surrounding is assumed to be maintained at room temperature which is constant.

(a) (i) Show that 3360 cm³ of air, originally at atmospheric pressure, is required to be pumped into the basketball until its pressure is suitable for an official match. Assume that the volume of the basketball remains unchanged at 6000 cm³. (3 marks)

(ii) Hence estimate the minimum number of strokes needed to pump the basketball to the required pressure. (1 mark)

(b) Use kinetic theory of an ideal gas to explain the increase of pressure inside the basketball when air is pumped into it. (2 marks)

14. **< HKDSE 2017 Paper IB - 3 >**

The average kinetic energy of one monatomic gas molecule at temperature T is given by

$$E_K = \frac{3}{2}\left(\frac{R}{N_A}\right)T$$

where R is the universal gas constant and N_A is the Avogadro constant.

A monatomic gas is heated from 300 K to 350 K under fixed volume.

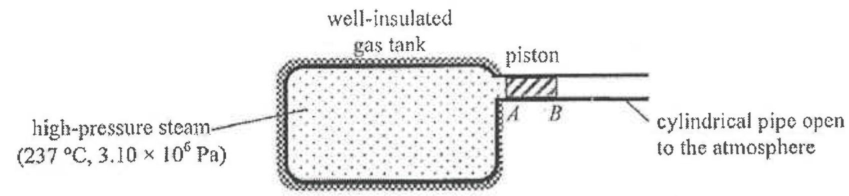
(a) Estimate the ratio of the root-mean-square speed ($c_{r.m.s.}$) of the gas molecules at the two temperatures $\left(\frac{c_{r.m.s.} \text{ at } 350\text{ K}}{c_{r.m.s.} \text{ at } 300\text{ K}}\right)$. (2 marks)

(b) Thus, using kinetic theory, explain why the gas pressure would increase. (2 marks)

15. < HKDSE 2020 Paper 1B -2>

Figure 2.1 shows a large gas tank connected with a cylindrical pipe open to the atmosphere. The pipe is fitted with a smooth piston AB. This well-insulated gas tank is filled with high-pressure steam at a temperature of 237 °C under a pressure of 3.10×10^6 Pa while the movable piston is held stationary by a force F_p.
Given: atmospheric pressure = 1.0×10^5 Pa

Figure 2.1

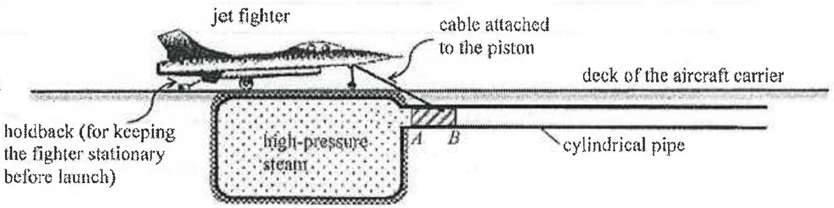


(a) (i) On Figure 2.1 indicate the force F_p. (1 mark)

*(ii) By considering the force acting on the piston due to the difference in pressure, find the value of F_p. The piston has a cross-sectional area of 0.67 m². (2 marks)

*(iii) Estimate the volume of the gas tank which contains 570 kg steam. You may treat the steam as an ideal gas. Given: mass of one mole of steam = 0.018 kg. (3 marks)

(b) This set-up can be used as a 'steam catapult' to launch jet fighters from an aircraft carrier. A jet fighter in position to be launched is connected to the piston via an inextensible cable as shown in Figure 2.2. When the holdback behind the jet fighter is released, the high-pressure steam in the gas tank expands and pushes the piston which in turn helps to accelerate the jet fighter.



ure 2.2

In a trial run of the catapult, a jet fighter (with its engine shut down) acquires a final speed of 54 m s^{-1} in 1.5 s after running a distance horizontally on the deck. The mass of the jet fighter is 2.6×10^4 kg.

(i) Find the work done by the net force on the jet fighter during launch. (2 marks)

(ii) Calculate the average acceleration of the jet fighter during launch.

*(iii) State whether the acceleration of the jet fighter is increasing, decreasing or uniform during launch. Explain your answer. (3 marks)

Question Solution

1. (a) (i) h increases [1]

   (ii) h decreases [1]

   (iii) h decreases [1]

   (b) When temperature increases, the gas molecules have greater K.E. and move faster. [1]
   They bombard the container wall more violently [1]
   and more frequently. This causes an increase in pressure. [1]

2. (a) (i) Pressure [1]

   (ii) Temperature [1]

   (b) (i) Add weight on the disc to decrease the volume [2]

   (ii) No change in the average speed of ball bearings. [2]
   Frequency of bombardment on the walls increases [2]

   (c) In real situation, elastic collision between gas molecules and the wall occurs [1]
   and thus no energy is lost due to collision. [1]
   In this model, the collision is not elastic and kinetic energy is lost during collisions. [1]

   (d) The polystyrene ball moves with a zig-zag path (or Brownian motion) [1]
   since the polystyrene ball is being hit by the ball bearings [1]
   with a random resultant force. [1]

3. When the temperature of a fixed volume of gas is increased, the molecules move faster. [1]
   Thus they hit the container wall more frequently [1]
   and more vigorously. [1]
   This increases the pressure.

4. (i) Molecules are arranged in regular structure **OR** Molecules are closely packed [1]
   Molecules can only vibrate about their mean position. [1]

   (ii) Molecules are not arranged in regular structure **OR** Molecules are loosely packed [1]
   Molecules can move freely. [1]

5. If the volume of the gas is decreased at constant temperature,
   distance travelled by the gas molecules between two walls decreases. [1]
   Thus the molecules hit the container wall more frequently. [2]
   So the pressure of the gas increases.

6. As temperature increases, the speed of the gas molecules increases. [1]
   The gas molecules hit the wall of the container more violently and more frequently. [2]
   So pressure increases.

7. As temperature increases, the speed of the gas molecules increases. [1]
   The gas molecules hit the wall of the container more violently [1]
   and more frequently. So pressure increases. [1]

8. (a) $PV = nRT$

   $\therefore\ (12\times10^5)(100\times10^{-6}) = n(8.31)(0+273)$ [1]

   $\therefore\ n = 0.0529$ mol < accept answer without unit > [1]

   (b) $PV = \frac{1}{3}Nmc^2 = \frac{1}{3}(nN_A)mc^2$

   $\therefore\ (12\times10^5)(100\times10^{-6}) = \frac{1}{3}(0.0529\times6.02\times10^{23})(4.52\times10^{-26})c^2$ [1]

   $\therefore\ c = 500\ \text{m s}^{-1}$ [1]

   OR

   By $c = \sqrt{\dfrac{3RT}{M_m}} = \sqrt{\dfrac{3(8.31)(0+273)}{(4.52\times10^{-26})(6.02\times10^{23})}}$ [1]

   $\therefore\ c = 500\ \text{m s}^{-1}$ [1]

   (c) (i) As r.m.s. speed depends on temperature, and the temperature of gas in vessel Y is also at 0°C.

   $\therefore\ c = 500\ \text{m s}^{-1}$ [1]

   (ii) Boyle's Law :

   $P_1V_1 = P_2V_2$

   $\therefore\ (12\times10^5)(100) = P(100+500)$ [1]

   $\therefore\ P = 2\times10^5$ Pa [1]

   (iii) $PV = nRT$

   $\therefore\ (2\times10^5)(500\times10^{-6}) = n(8.31)(0+273)$ [1]

   $\therefore\ n = 0.0441$ mol [1]

9. (a) (i) $PV = nRT$

$\therefore\ (100 \times 10^3)(300 \times 10^{-6}) = n(8.31)(300)$ [1]

$\therefore\ n = 0.012$ mol [1]

(ii) $PV = \frac{1}{3}Nmc^2 = \frac{1}{3}Mc^2 = \frac{1}{3}nM_m c^2$

$\therefore\ (100 \times 10^3)(300 \times 10^{-6}) = \frac{1}{3}(0.012 \times 4 \times 10^{-3})\,c^2$ [1]

$\therefore\ c = 1370\ \text{m s}^{-1}$ [1]

(b) (i) $\dfrac{V_1}{T_1} = \dfrac{V_2}{T_2}$ [1]

$\therefore\ \dfrac{(20)}{(300)} = \dfrac{h}{(90+273)}$ $\therefore\ h = 24.2$ cm [1]

(ii) Since the process is slow, the temperature is constant.

$P_1V_1 = P_2V_2$ [1]

$\therefore\ (100)(24.2) = P_2(20)$ $\therefore\ P_2 = 121$ kPa [1]

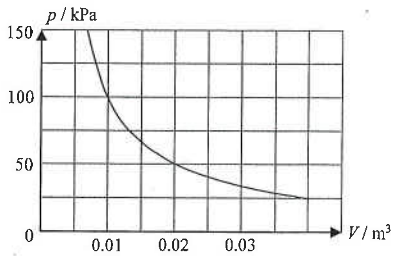
10. (a) The gas molecules collide with the surface of the balloon and rebound, [1]

it results in momentum change and thus gives pressure to the surface of the balloon. [1]

(b) $p_1V_1 = p_2V_2$ [1]

$(100)(0.01) = p_2(0.02)$ $\therefore\ p_2 = 50$ kPa [1]

(c)



< a curve > [1]

< the curve passing the 0.01 and 0.02 points > [1]

11. (a) (i) A black surface is a good absorber of radiation. [1]

(ii) A cover can reduce heat loss due to convection of air. [1]

OR

A cover can trap heat by greenhouse effect. [1]

(iii) The oil in the copper pipe inside the box is heated, becomes less dense and rises. [1]

The cooler and denser oil from the pipe in the storage tank will move downwards to replace the heated oil. [1]

11. (b) $Pt = mc\Delta T$ [1]

$P(60) = (0.3)(2500)(37 - 25)$ [1]

$P = 150$ W [1]

(c) The pressure increases when temperature increases. [1]

As temperature increases, the average speed of the gas molecules increases. [1]

The air molecules will then hit the wall of the box more violently and more frequently. [1]

12. (a) $P_1V_1 = P_2V_2$ [1]

$P_1[\frac{4}{3}\pi \times (0.8)^3] = (1.01 \times 10^5)[\frac{4}{3}\pi \times (1.0)^3]$

$P_1 = 1.97 \times 10^5$ Pa [1]

(b) Volume increases as the bubble rises but the average speed of the gas molecules remains unchanged, [1]

therefore the frequency of collision on the bubble's inner surface decreases, thus the gas pressure decreases. [1]

13. (a) (i) By Boyle's Law,

$P_1V_1 = P_2V_2$ [1]

$(100)(6000 + V_o) = (156)(6000)$ [1]

$\therefore\ V_o = 3360\ \text{cm}^3$ [1]

(ii) $N = \dfrac{3360}{120} = 28$ [1]

(b) As volume and temperature of the gas remain unchanged, [1]

the increase of pressure is due to the increase of number of air molecules hitting the wall per unit time. [1]

OR

As the number of air molecules increases, [1]

the frequency of collision of molecules with the walls increases, thus pressure increases. [1]

14. (a) $E_K = \dfrac{3}{2}\left(\dfrac{R}{N_A}\right)T = \dfrac{1}{2}mc^2$ $\therefore\ c \propto \sqrt{T}$ [1]

$\therefore\ \left(\dfrac{c_{r.m.s.}\text{ at } 350\text{ K}}{c_{r.m.s.}\text{ at } 300\text{ K}}\right) = \sqrt{\dfrac{350}{300}} = 1.08$ [1]

(b) As the temperature increases, the speed of the gas molecules increases. [1]

Gas molecules hit the walls of the container more violently and more frequently. [1]

Thus, the pressure increases.