A LEVEL PHYSICS

WORKED SOLUTIONS

6.2. Thermal Physics MCQ

1. A solar panel transfers energy at a rate of 1.2 kW to liquid passing through it. The liquid has a specific heat capacity of 4.0 kJ kg^{-1} K^{-1}.

When the liquid flows through the solar panel, its temperature increases by 3.0 K.

The flow rate of the liquid is

A 0.10 kg s^{-1}.

B 1.1 kg s^{-1}.

C 10 kg s^{-1}.

D 100 kg s^{-1}.

m/t

$P = \frac{Q}{t} = \frac{mc\Delta\theta}{t}$

$\frac{m}{t} = \frac{P}{c\Delta\theta} = \frac{1200}{4000 \times 3.0} = 0.10$

(Total 1 mark)

2. A gas occupies a volume V. Its particles have a root mean square speed (c_{rms}) of u. The gas is compressed at constant temperature to a volume $0.5V$.

What is the root mean square speed of the gas particles after compression?

A $\frac{u}{2}$

B u

C $2u$

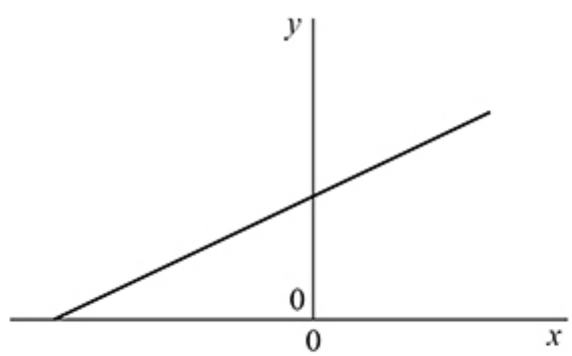
D $4u$

$\frac{1}{2}m(c_{rms})^2 = \frac{3}{2}kT$ $c_{rms}^2 \propto T$

T constant $\therefore$ c_{rms} constant

(Total 1 mark)

3. A fixed mass of gas is heated at constant volume. The graph is drawn for this process.



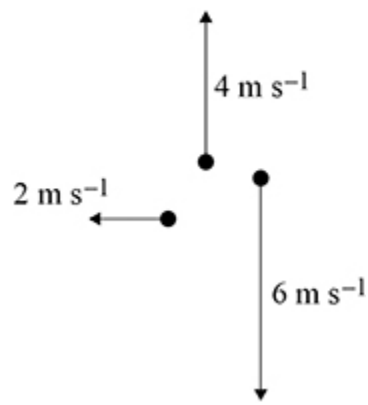
What do x and y represent?

	x	y	
A	pressure in Pa	temperature in °C	○
B	temperature in °C	pressure in Pa	●
C	pressure in Pa	temperature in K	○
D	temperature in K	pressure in Pa	○

$p \propto T$
Pressure can't be negative : on y-axis
Kelvin can't be negative : °C on x-axis

(Total 1 mark)

4. Three particles are travelling in the same plane with velocities as shown in the vector diagram.



What is the root mean square speed of the particles?

A 4.3 m s^{-1} ●

B 7.5 m s^{-1} ○

C 19 m s^{-1} ○

D 56 m s^{-1} ○

root, square, mean

$$\sqrt{\frac{2^2+4^2+6^2}{3}}$$

$$= \sqrt{\frac{56}{3}} = 4.32 \text{ m s}^{-1}$$

(Total 1 mark)

5. An ideal gas is contained in a cubical box of side length a. The gas has N molecules each of mass m.

$\therefore V = a^3$

What is the pressure exerted by the gas on the walls of the box?

A $\frac{mNa^3}{2} \times c_{rms}^2$

B $\frac{mNa^2}{2} \times c_{rms}^2$

C $\frac{mN}{3a^2} \times c_{rms}^2$

D $\frac{mN}{3a^3} \times c_{rms}^2$

$pV = \frac{1}{3} Nm (c_{rms})^2$

$p = \frac{Nm}{3V} \cdot c_{rms}^2$

$p = \frac{Nm}{3a^3} \cdot c_{rms}^2$

(Total 1 mark)

6. Which statement is true about an experiment where Brownian motion is demonstrated using smoke particles in air?

A The experiment makes it possible to see the motion of air molecules.

B The motion is caused by the collisions of smoke particles with each other.

C The motion is caused by collisions between air molecules and smoke particles.

D The motion occurs because air is a mixture of gases and the molecules have different masses.

(Total 1 mark)

7. Which is **not** an assumption about gas particles in the kinetic theory model for a gas?

A They collide elastically with the container walls.

B They have negligible size compared to the distance between the container walls.

C They travel between the container walls in negligibly short times.

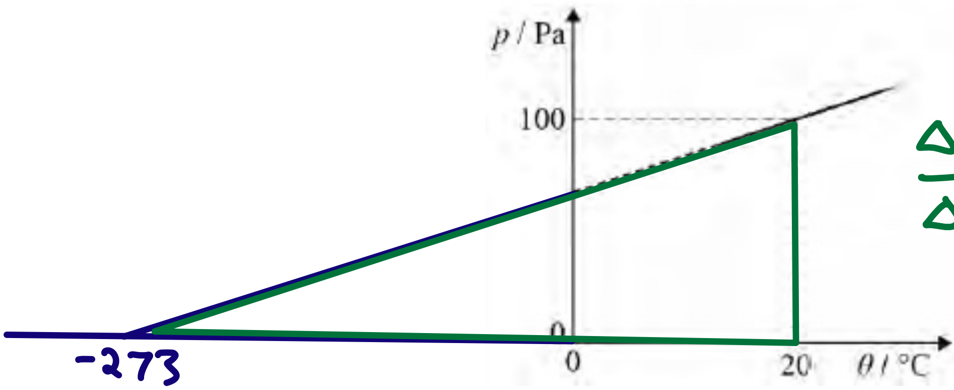
D They collide with the container walls in negligibly short times.

Time between collisions is not negligible

(Total 1 mark)

8. The graph shows the variation of pressure p with temperature θ for a fixed mass of an ideal gas at constant volume.

What is the gradient of the graph?



$\frac{\Delta y}{\Delta x} = \frac{100-0}{20-(-)273}$

$= 0.341$

A 0.341 ■

B 0.395 ○

C 2.93 ○

D 5.00 ○

(Total 1 mark)

9. Two flasks **X** and **Y** are filled with an ideal gas and are connected by a tube of negligible volume compared to that of the flasks. The volume of **X** is twice the volume of **Y**.
X is held at a temperature of 150 K and **Y** is held at a temperature of 300 K

What is the ratio $\frac{\text{mass of gas in X}}{\text{mass of gas in Y}}$?

$pV = NkT$

$\frac{V}{T} = \frac{Nk}{p}$ $\frac{V}{T} \propto N$

A 0.125 ○

B 0.25 ○

C 4 ■

D 8 ○

(Total 1 mark)

$V_X = 2V_Y$

$2T_X = T_Y$

$\frac{V_X}{T_X} = \frac{2V_Y}{\frac{1}{2}T_Y} = \frac{4V_Y}{T_Y}$

$\therefore N_X = 4N_Y$

and $M_X = 4M_Y$

10. The average mass of an air molecule is 4.8×10^{-26} kg

What is the mean square speed of an air molecule at 750 K?

A 3.3×10^5 m^2 s^{-2} ☐

B 4.3×10^5 m^2 s^{-2} ☐

C 6.5×10^5 m^2 s^{-2} ☒

D 8.7×10^5 m^2 s^{-2} ☐

$\frac{1}{2}m(c_{rms})^2 = \frac{3}{2}kT$

$c_{rms}^2 = \frac{3kT}{m} = \frac{3 \times 1.38 \times 10^{-23} \times 750}{4.8 \times 10^{-26}}$

$= 6.47 \times 10^5 \text{ m}^2 \text{s}^{-2}$

(Total 1 mark)

11. A transparent illuminated box contains small smoke particles and air.
The smoke particles are observed to move randomly when viewed through a microscope.

What is the cause of this observation of Brownian motion?

A Smoke particles gaining kinetic energy by the absorption of light. ☐

B Collisions between smoke particles and air molecules. ☒

C Smoke particles moving in convection currents caused by the air being heated by the light. ☐

D The smoke particles moving randomly due to their temperature. ☐

(similar to Q6)

(Total 1 mark)

12. A continuous stream of water falls through a vertical distance of 100 m.
Assume no thermal energy is transferred to the surroundings.
The specific heat capacity of water is 4200 J kg^{-1} K^{-1}.

What is the temperature difference of the water between the top and bottom of the waterfall?

A 0.023 K ☐

B 0.23 K ☒

C 2.3 K ☐

D 4.3 K ☐

$\Delta E_p = Q$

$mg\Delta h = mc\Delta\theta$

$\Delta\theta = \frac{g\Delta h}{c} = \frac{9.81 \times 100}{4200}$

$= 0.234$ K

(Total 1 mark)

13. A student measures the power of a microwave oven. He places 200 g of water at 23 °C into the microwave and heats it on full power for 1 minute. When he removes it, the temperature of the water is 79 °C.

The specific heat capacity of water is 4200 J kg^{-1} K^{-1}.

What is the average rate at which thermal energy is gained by the water?

A 780 W ■

B 840 W ○

C 1.1 kW ○

D 4.6 kW ○

$\Delta Q = mc\Delta\theta$

$P = \frac{\Delta Q}{\Delta t} = \frac{mc\Delta\theta}{\Delta t} =$

$P = \frac{0.200 \times 4200 \times (79-23)}{60} = 784$

(Total 1 mark)

14. Which of the following is **not** used as valid assumption when deriving the equation $P = \frac{1}{3} Nm (c_{rms})^2$ in the simple kinetic theory of gases?

A The molecules suffer negligible change of momentum on collision with the walls of the container. ■

B Attractive forces between molecules are negligible. ○

C The duration of a collision is negligible compared with the time between collisions. ○

D The volume of the molecules is negligible compared with the volume of the gas. ○

(Total 1 mark)

$P = \frac{F}{A} \leftarrow F = \frac{\Delta p}{\Delta t} \leftarrow$ not negligible

15. A liquid flows continuously through a chamber that contains an electric heater. When the steady state is reached, the liquid leaving the chamber is at a higher temperature than the liquid entering the chamber. The difference in temperature is Δt.

Which of the following will increase Δt with no other change?

- **A** Increasing the volume flow rate of the liquid ☐ Decreases Δt
- **B** Changing the liquid to one with a lower specific heat capacity ■
- **C** Using a heating element with a higher resistance ☐ $R\uparrow$ $\Delta t\downarrow$
- **D** Changing the liquid to one that has a higher density ☐ Won't heat as quickly

(Total 1 mark)

16. What is the total internal energy of 2.4 mol of an ideal gas which has a temperature of 15 °C?

- **A** 6.0×10^{-21} J ☐
- **B** 1.4×10^{-20} J ☐
- **C** 4.5×10^{2} J ☐
- **D** 8.6×10^{3} J ■

1 molecule; no. moles

$U = \frac{3}{2}kT \times 2.4 \times N_A$

$U = 8613$ J

(Total 1 mark)

17. The composition of a carbon dioxide (CO_2) molecule is one atom of $^{12}_{6}C$ and two atoms of $^{16}_{8}O$.

What is the number of molecules of CO_2 in 2.2 kg of the gas?

- **A** 1.0×10^{22} ☐
- **B** 3.0×10^{22} ☐
- **C** 3.0×10^{25} ■
- **D** 4.7×10^{25} ☐

$M_r = 12 + (2 \times 16) = 44$g

$n = \frac{M}{M_r} = \frac{2.2}{0.044} = 50$ moles

$N = nN_A = 50 \times 6.02 \times 10^{23}$

$N = 3.01 \times 10^{25}$ molecules

(Total 1 mark)

18. Brownian motion

A makes it possible to see the motion of air molecules.

B is caused by the collisions of smoke particles.

C is caused by collisions between air molecules and smoke particles.

D occurs because air is a mixture of gases and the molecules have different masses.

(similar to Q6 and Q11)

(Total 1 mark)

19. A sample **P** of an ideal gas contains 1 mol at an absolute temperature T.

A second sample **Q** of an ideal gas contains $\frac{2}{3}$ mol at an absolute temperature $2T$.

The total molecular kinetic energy of **P** is E.

What is the total molecular kinetic energy of **Q**?

A $\frac{2}{3}E$

B $\frac{3}{4}E$

C $\frac{4}{3}E$

D $\frac{3}{2}E$

$$E_k \propto NT$$

$$\frac{E_{kP}}{E_{kQ}} = \frac{1 \times T}{\frac{2}{3} \times 2T} = \frac{3}{4}$$

$$E_{kQ} = \frac{4}{3} E_{kP}$$

(Total 1 mark)

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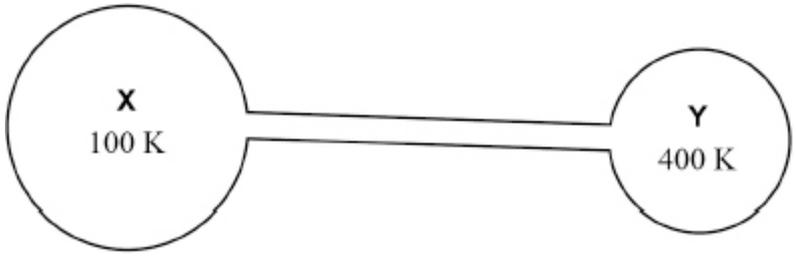
20. The diagram shows two flasks **X** and **Y** connected by a thin tube of negligible volume.



The flasks contain an ideal gas.

The volume of **X** is twice the volume of **Y**. When **X** is at a temperature of 100 K and **Y** is at a temperature of 400 K there is no net transfer of particles between the flasks.

X contains gas of mass m.

$P_X = P_Y \quad 4T_X = T_Y \quad V_X = 2V_Y$

What is the mass of gas in **Y**?

- **A** $\frac{m}{8}$ ●
- **B** $\frac{m}{2}$ ○
- **C** $2m$ ○
- **D** $8m$ ○

$$\frac{V_X}{T_X} = \frac{2V_Y}{\frac{1}{4}T_Y} = \frac{8V_Y}{T_Y}$$

$$\frac{V}{T} \propto N \propto m \qquad m_X = 8m_Y \qquad m_Y = \frac{m_X}{8}$$

(Total 1 mark)

21. When an ideal gas at a temperature of 27 °C is suddenly compressed to one quarter of its volume, the pressure increases by a factor of 7

What is the new temperature of the gas?

- **A** 15 °C ○
- **B** 47 °C ○
- **C** 171 °C ○
- **D** 252 °C ●

$$\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}$$

$$T_2 = T_1 \cdot \frac{P_2}{P_1} \cdot \frac{V_2}{V_1} = (273+27) \cdot 7 \cdot \frac{1}{4}$$

(Total 1 mark)

$T_2 = 525\ K$

$525 - 273 = 252°C$