Thermal Properties of Materials

Mark Scheme 5

Level	International A Level
Subject	Physics
Exam Board	CIE
Topic	Thermal Properties of Materials
Sub Topic	
Paper Type	Theory
Booklet	Mark Scheme 5

Time Allowed: **90 minutes**

Score: **/75**

Percentage: **/100**

A*	A	B	C	D	E	U
>85%	'77.5%	70%	62.5%	57.5%	45%	<45%

1	**(a**	mass / volume (ratio idea essential)	B1	[1]
	(b) (i)	mass = $Ah\rho$	B1	[1]
	(ii)	pressure = force/area	B1	
		weight (of liquid)/force (on base) = $Ah\rho g$	B1	
		pressure = $h\rho g$	A0	[2]
	(c) (i)	ratio = 1600 or 1600:1	A1	[1]
	(ii)	ratio = $\sqrt[3]{1600}$	C1	
		= 11.7 (*allow 12*)	A1	[2]
	(d) **(i)**	<u>density</u> of solids and liquids are (about) equal	B1	[1]
	(ii)	strong forces: fixed volume	B1	
		rigid forces: retains shape / does not flow / little deformation	B1	[2]
		(allow 1 mark for fixed volume, fixed shape)		
2	**(a (i)**	*either* $\omega = 2\pi / T$ *or* $\omega = 2\pi f$ and $f = 1 / T$	C1	
		$\omega = 2\pi / 0.30$		
		$= 20.9\,\text{rad s}^{-1}$ (*accept 2 s.f.*)	A1	[2]
	(ii)	kinetic energy $= ½m\omega^2x_0^2$ *or* $v = \omega x_0$ and $½mv^2$	C1	
		$= ½ \times 0.130 \times 20.9^2 \times (1.5 \times 10^{-2})^2 = 6.4 \times 10^{-3}\,\text{J}$	A1	[2]
	(b) (i)	as magnet moves, flux is cut by <u>cup / aluminium</u> giving rise to induced e.m.f. (in cup)	B1	
		induced e.m.f. gives rise to currents and heating of the cup	B1	
		thermal energy derived from oscillations of magnet so amplitude decreases	B1	
		or		
		induced e.m.f. gives rise to currents which generate a magnetic field	(B1)	
		the magnetic field opposes the motion of the magnet so amplitude decreases	(B1)	[3]
	(ii)	*either* use of $½m\omega^2x_0^2$ and $x_0 = 0.75\,\text{cm}$ *or* x_0 is halved so ¼ energy to give new energy = 1.6 mJ	C1	
		either loss in energy = 6.4 – 1.6 *or* loss = ¾ × 6.4 giving loss = 4.8 mJ	A1	[2]
	(c)	$q = mc\Delta\theta$		
		$4.8 \times 10^{-3} = 6.2 \times 10^{-3} \times 910 \times \Delta\theta$	C1	
		$\Delta\theta = 8.5 \times 10^{-4}\,\text{K}$	A1	[2]

3	**(a)**	initially, $pV/T = (2.40 \times 10^5 \times 5.00 \times 10^{-4})/288 = 0.417$	M1	
		finally, $pV/T = (2.40 \times 10^5 \times 14.5 \times 10^{-4})/835 = 0.417$	M1	
		ideal gas because pV/T is constant	A1	[3]
		(*allow 2 marks for two determinations of V/T and then 1 mark for V/T* <u>*and*</u> *p constant, so ideal*)		
	(b) (i)	work done $= p\Delta V$		
		$= 2.40 \times 10^5 \times (14.5 - 5.00) \times 10^{-4}$	C1	
		= 228 J (*ignore sign, not 2 s.f.*)	A1	[2]
	(ii)	$\Delta U = q + w$ = 569 – 228		
		= 341 J	M1	
		increase	A1	[2]
4	**(a (i)**	*N*: (total) number of <u>molecules</u>	B1	[1]
	(ii)	$\langle c^2 \rangle$: mean square speed/velocity	B1	[1]
	(b)	$pV = \frac{1}{3}Nm\langle c^2 \rangle = NkT$		
		(mean) kinetic energy = $\frac{1}{2} m\langle c^2 \rangle$	C1	
		algebra clear leading to $\frac{1}{2} m\langle c^2 \rangle = (3/2)kT$	A1	[2]
	(c) (	*either* energy required $= (3/2) \times 1.38 \times 10^{-23} \times 1.0 \times 6.02 \times 10^{23}$	C1	
		= 12.5 J (*12J if 2 s.f.*)	A	[2]
		or energy $= (3/2) \times 8.31 \times 1.0$	(C1)	
		= 12.5 J	(A1)	
	(ii)	energy is needed to push back atmosphere/do work against atmosphere		
		so total energy required is greater	A1	[2]

5 **(a)** e.g. moving in random (rapid) motion of molecules/atoms/particles
no intermolecular forces of attraction/repulsion
volume of molecules/atoms/particles negligible compared to volume of container
time of collision negligible to time between collisions
(1 each, max 2) B2 [2]

(b) (i) 1. number of (gas) molecules B1 [1]

2. mean square speed/velocity (of gas molecules) B1 [1]

(ii) either $pV = NkT$ *or* $pV = nRT$ and links n and k
and $\langle E_K \rangle = \frac{1}{2}m\langle c^2 \rangle$ M

clear algebra leading to $\langle E_K \rangle = \frac{3}{2}kT$ A1 [2]

(c) (i) sum of potential energy and kinetic energy of molecules/atoms/particles M1
reference to random (distribution) A1 [2]

(ii) no intermolecular forces so no potential energy B1
(change in) internal energy is (change in) kinetic energy and this is proportional to (change in) T B1 [2]

6 **(a (i)** no forces (of attraction or repulsion) between atoms / molecules / particles B1 [1]

(ii) sum of kinetic and potential energy of atoms / molecules M1
due to random motion A1 [2]

(iii) (random) kinetic energy increases with temperature M1
no potential energy
(so increase in temperature increases internal energy) A1 [2]

(b) (i) zero A1 [1]

(ii) work done $= p\Delta V$ C1
$= 4.0 \times 10^5 \times 6 \times 10^{-4}$
$= 240\,\text{J}$ (*ignore any sign)* A1 [2]

(iii)

change	work done / J	heating / J	increase in internal energy / J
P → Q	**+240**	–600	**–360**
Q → R	0	+720	**+720**
R → P	**–840**	+480	**–360**

(*correct signs essential*)
(*each horizontal line correct, 1 mark – max 3*) B3 [3]

7 **(a (i)** 1 deg C corresponds to (3840 – 190) / 100 Ω — C1
for resistance 2300 Ω, temperature is 100 × (2300 – 3840) / (190 – 3840)
temperature is 42 °C — A1 [2]

(ii) *either* 286 K ≡ 13 °C *or* 42 °C ≡ 315 K — B1
thermodynamic scale does not depend on the property of a substance — M1
so change in resistance (of thermistor) with temperature is non-linear — A1 [3]

(b) heat gained by ice in melting = $0.012 \times 3.3 \times 10^5$ J — C1
= 3960 J
heat lost by water = $0.095 \times 4.2 \times 10^3 \times (28 - \theta)$ — C1
$3960 + (0.012 \times 4.2 \times 10^3 \times \theta) = 0.095 \times 4.2 \times 10^3 \times (28 - \theta)$ — C1
θ = 16°C — A1 [4]
(answer 18°C – melted ice omitted – allow max 2 marks)
(use of (θ – T) then allow max 1 mark)

8 **(a** e.g. two objects of different masses at same temperature — (M1)
same material would have different amount of heat — (A1)
e.g. temperature shows direction of heat transfer — (M1)
from high to low regardless of objects — (A1)
e.g. when substance melts/boils — (M1)
heat input but no temperature change — (A1)
any two, M1 + A1 each, max 4 ..... [4]

(b) (i) energy losses (to the surroundings) M1
either increase as the temperature rises
or rise is zero when heat loss = heat input ..... A1 [2]

(ii) idea of input <u>power</u> = maximum <u>rate</u> of heat loss C1
power = $m \times c \times \Delta\theta / \Delta t$
$54 = 0.96 \times c \times 3.7 / 60$ C1
$c = 910$ J kg^{-1} K^{-1} ..... A1 [3]

[Total: 9]