2. Thermal Physics

2.2 Thermal properties and temperature

Paper 3 and 4

Answer Key

Paper 3

Q1.

Question	Answer	Marks
(a)(i)	evaporation	B1
(a)(ii)	any **three** from the following: at the surface more energetic molecules escape (from liquid) owtte (as they) overcome / break forces / bonds (between molecules) (liquid (molecules) →) gas / vapour (molecules)	B3

Q2.

Question	Answer	Marks
(a)(i)	conduction	B1
(a)(ii)	1 80 (°C)	B1
	2 170 (°C)	B1
	3 26 (minutes)	B1

Q3.

Question	Answer	Marks
(a)	high(er / est) energy molecules	B1
	(near the surface) escape (from surface)	B1
(b)	(temperature) decreases	B1
	AND any **two** from: higher energy molecules have escaped (leaving) lower energy particles behind (so) average energy of remaining molecules is lower	B2

Q4.

Question	Answer	Marks
(a)	0 AND 100 correctly labelled	M1
	36	A1
(b)(i)	Melting	B1
	Any one of: molecules gain energy molecule (begin to) break (some) bonds arrangement becomes irregular or arrangement changes	B1
(b)(ii)	boiling	B1
	Any one of: molecules break (all) bonds molecules move (more) freely molecules become widely separated or far apart	B1

Q5.

Question	Answer	Marks
4(a)(i)	expand or increase in size/volume increase in pressure decrease in density	B1
4(a)(ii)	any 3 from: density (of air) is less molecules move faster/have more (kinetic) energy more collisions (per second) collisions with surface OR balloon (owtte) more force (in collisions) molecules move (further) apart	B3

Paper 4

Q6.

Question	Answer	Marks
(a)	1 Any one method to transfer measurable amount of thermal energy for $\Delta\theta$: (a) to aluminium block (with electrical heater) (b) from aluminium block to known liquid (c) from known liquid to insulated aluminium (calorimeter) (d) to known liquid and aluminium (calorimeter)	**B1**
	2 Determination of energy transferred for $\Delta\theta$, to match workable method in 1: (a) Use of $E = Pt$ **OR** $E = IVt$ (b) Use of $E = mc\Delta\theta$ with s.h.c. of known liquid (c) Use of $E = mc\Delta\theta$ with s.h.c. of known liquid (d) Use of $E = Pt$ **OR** $E = IVt$ **AND** $E = mc\Delta\theta$ (with known s.h.c. of liquid)	**B1**
	3 Any one measurement from: • initial and final temperature / temperature change • time (of heating) • mass of aluminium	**B1**
	4 $c = E / m\Delta\theta$ **OR** $(c =) E / m\Delta\theta$	**B1**
(b)(i)	Any three from: 1 (net) transfer of energy from higher temperature to lower temperature **OR** (net) transfer of energy from water / to dish 2 (energy transfer) by conduction **OR** aluminium is a good conductor (of thermal energy) 3 temperature of water decreases **AND** temperature of dish increases 4 no (net) transfer of energy when temperature of dish = temperature of water	**B3**
(b)(ii)	(particles) gain energy in kinetic store (as temperature of aluminium increases)	**B1**
	(average) separation of (aluminium) particles increases **OR** (aluminium) particles move further apart owtte	**B1**
(b)(iii)	(water) molecules with more/enough energy escape from the surface	**A2**
	escape of more energetic molecules (from water) **OR** (molecules) leave from the surface	C1

Q7.

Question	Answer	Marks
(a)	boiling happens at a specific temperature **OR** evaporation happens at a range of temperatures **OR** evaporation happens at any temperature (below the boiling point)	**B1**
	evaporation happens at the surface of the water OR boiling happens throughout the water	**B1**
(b)	*any **four** from:* 1 (as the water is heated) the number of gas particles increases 2 (particles) gain internal / kinetic energy 3 (there are) more frequent collisions between particles and surface / wall / lid of the cooker 4 (each) collision (of particles) is harder / exerts more force (on cooker surface) **OR** greater change of momentum when particles collide (on cooker surface) 5 pressure ∝ (total) force (of collisions) **OR** pressure = force / area	**B4**

Q8.

Question	Answer	Marks
(a)	(evaporation:) (only) at the surface **OR** boiling: happens throughout the liquid	**B1**
	(evaporation:) takes place at any temperature **OR** boiling: takes place at a specific temperature / boiling point	**B1**
(b)(i)	113 (K)	**B1**
(b)(ii)	conduction	**B1**
	convection	**B1**
(c)	particles collide with the walls / container	**B1**
	(particles) exert a force on the walls **OR** collision with walls produces a change in momentum (of particles)	**B1**
	pressure is force per unit area **OR** $p = F / A$ **OR** pressure is rate of change of momentum per unit area	**B1**

Q9.

Question	Answer	Marks
(a)(i)	evaporation	**B1**
(a)(ii)	air is drier	**B1**
	because water vapour has condensed / turned back to liquid in the condenser	**B1**
(b)(i)	gravitational (force) **OR** weight	**B1**
(b)(ii)	(force is) perpendicular to the motion (of the clothes)	**B1**
(c)	uses (solar / wind) energy which is renewable **OR** energy (re)sources not used to generate electricity **OR** greenhouse gases not produced **OR** does not use (fossil) fuels	**B1**

Q10.

(b)	1.5×10^4 J	**A2**
	$c = (\Delta)E / m\Delta\theta$ ($\Delta E =$) $mc\Delta\theta$ OR ($\Delta E =$) $0.18 \times 4200 \times 20$	C1
(c)	3900 Pa	**A2**
	($\Delta p =$) $\rho g(\Delta)h$ OR ($\Delta p =$) $1.0 \times 10^3 \times 9.8 \times 0.4$ OR ($\Delta p =$) $1.0 \times 10^3 \times 9.8 \times 40$ OR ($\Delta p =$) 3.9×10^N	C1

Q11.

Question	Answer	Marks
(a)(i)	$c = (\Delta)E / m\Delta\theta$ **OR** $(\Delta E =)\ mc\Delta\theta$	**B1**
	$(\Delta\theta =)$ 21.5 – 19 OR $(\Delta\theta =)$ 2.5 (°C)	**B1**
	$(\Delta E =)$ 0.6(0) × 4200 × 2.5 **OR** $(\Delta E =)$ 0.6(0) × 4200 × {21.5 – 19}	**B1**
(a)(ii)	(maximum possible efficiency =) 3.1% or 0.031	**A4**
	$E = Pt$ **OR** $(E =)\ Pt$ **OR** $(E =)$ 13 × 500 **OR** $(E =)$ 6500	C1
	(useful energy output =) 6500 – 6300 **OR** (useful energy output =) 200	C1
	efficiency = useful energy (output) / total energy (input) (× 100%) **OR** (efficiency =) useful energy (output) / total energy (input) (× 100%) **OR** (efficiency =) {6500 – 6300} / 6500 **OR** (efficiency =) 200 / 6500 (× 100%)	C1
	OR	
	$P = E/t$ **OR** $(P =)$ E / t **OR** $(P =)$ 6 300 / 500 OR $(P =)$ 12.6 (W)	(C1)
	(useful power output =) total power (output) – wasted power (output) **OR** (useful power output =) 13 – {6300 / 500} **OR** (useful power output =) 13–12.6	(C1)
	efficiency = useful power (output) / total power (input) (× 100%) **OR** (efficiency =) useful power (output) / total power (input) (× 100%) **OR** (efficiency =) 0.4 / 13 (× 100%)	(C1)
(b)	any **one** from: • temperature change is an underestimate (due to thermal energy losses) • (thermal energy is) transferred from the water (to air / beaker / bench) • energy (other than light) transferred in lamp (filament / glass / internal structure) • (some) water evaporates	**B1**

Q12.

Question	Answer	Marks
(a)(i)	$\rho = m / V$ **OR** $m = \rho V$	**B1**
	$(m =)$ 1.2 × 4.5 × 6.1 × 2.4 (= 79 kg) **OR** $(m =)$ 79.056 (kg)	**B1**
(a)(ii)	290 s	**A4**
	$c = (\Delta)E / m\Delta\theta$ **OR** $(\Delta E =)\ mc\Delta\theta$ **OR** $(\Delta E =)$ 79 × 1000 × 4(.0) **OR** $(\Delta E =)$ 316 000 **OR** $(\Delta\theta =)$ 4(.0)	C1
	$P = (\Delta)E / t$ **OR** $(\Delta E =)\ Pt$ **OR** $(\Delta E =)$ 1100 × t	C1
	$(t =)\ mc\Delta\theta / P$ **OR** $(t =)$ 79 × 1000 × 4(.0) / 1100 **OR** $(t =)$ 316 000 / 1100	C1
(a)(iii)	any **one** from: • (thermal) energy is transferred to furniture / walls / objects (in the room) • (thermal) energy is transferred through windows / doors / floor / ceiling / from the room	**B1**
(b)	conduction **AND** convection	**B1**

Q13.

(b)	(–)3.5 × 10^3 J	**A2**
	$E = CDT$ in any form **or** 89 × (21 – (–18) **or** 89 × (3) **or** 89 × 39	C1

Q14.

Question	Answer	Marks
(a)	(E =) 410 000 000 J **OR** 410 MJ **OR** 4.1 × 10^8 J	**A3**
	$\Delta E = mc\Delta T$ **OR** (ΔE =) $mc\Delta T$ **OR** 1200 × 960 × 360	C1
	(ΔT =) 360 (°C)	C1

Q15.

Question	Answer	Marks
(a)	fast(er) / high(er) speed / (more) energetic molecules escape (into air)	**B1**
	average speed / average kinetic energy of molecules decreases	**B1**
	temperature related to speed / energy of molecules **or** slow(er) / low(er) speed / less energetic molecules remain (in water)	**B1**

Q16.

Question	Answer		Marks
(a)	temperature		**B1**
	at which liquid becomes a gas **or** liquid and gas exist together		**B1**
(b)(i)	1.8 × 10^5 J		**A2**
	(E =) VIt (in any form) **or** 230 × 13 × 60 **or** 230 × 13 **or** 3000		C1
(b)(ii)	9.1 × 10^{-3} kg / s	9.1 × 10^{-3} kg / s	**A4**
	(ΔT =) 100 – 22 **or** 78	**or** (ΔT =) 100 – 22 **or** 78	C1
	$m = E / c\Delta T$ (in any form) **or** 1.8 × 10^5 / (4200 × 78)	**or** (rate =) $P / c\Delta T$ (in any form) **or** $m = E / c\Delta T$ **and** $E = Pt$	C1
	1.8 × 10^5 / (4200 × 78 × 60) **or** 5.5 × 10^N **or** 9.1/9.2 × 10^N	**or** 3000 / (4200 × 78) **or** 230 × 13 / (4200 × 78) **or** 9.1 / 9.2 × 10^N	C1

Q17.

Question	Answer	Marks
(a)	statement: bore of constant (cross sectional) area	**B1**
	explanation: idea of same movement / change in length of liquid / thread AND for same increase in volume / expansion (of liquid)	**B1**
	statement: (liquid has) constant thermal expansion	**B1**
	explanation: liquid moves same distance for each °C temperature rise	**B1**
(b)	heat capacity / it is small	**B1**
	only uses / needs a small amount of (thermal) energy (to raise its temperature)	**B1**
(c)	36 J	**A3**
	(E =) $C\Delta T$ in any form	C1
	(E =) $0.11 \times (345 - 20)$ OR (ΔT =) 325 (°C)	C1

Q18.

Question	Answer	Marks
(a)	aluminium is a (good) conductor (of heat) **and** plastic is a poor conductor / does not conduct (heat)	**B1**
(b)(i)	increase in kinetic energy of molecules **or** increase in potential energy of molecules	**B1**
(b)(ii)	any **three** from: • atoms (touching the hotplate) / lattice vibrate (faster) • atoms pass on energy / vibration to neighbouring atoms / to other atoms by collision • atoms pass on energy to electrons • electrons hit distant atoms **or** electrons move (through lattice)	**B3**
(b)(iii)	molecules escape from the liquid (as a vapour)	**B1**
	bonds broken / (attractive) forces overcome	**B1**
	molecules gain potential energy **or** work done (to separate molecules / break bonds / overcome forces)	**B1**
(b)(iv)	840 W	**A3**
	(E =) ml_v in any form **or** $0.11 \times 2.3 \times 10^6$ **or** 2.53×10^5	**C1**
	(rate =) ml_v / t in any form **or** $0.11 \times 2.3 \times 10^6 / 300$ **or** $2.53 \times 10^5 / 300$	**C1**

Q19.

Question	Answer	Marks
(a)(i)	random / haphazard / zig-zag / irregular	B1
(a)(ii)	(liquid / water) molecules move fast OR (pollen) particles massive	B1
	collide / bombard	B1
	uneven collisions / collisions from different directions (cause random movement) OR (liquid / water) molecules move randomly	B1
(b)(i)	cooling	B1
	(thermal) energy used / needed to evaporate (ethanol) / overcome attractive forces(between molecules / particles)	B1
	thermal energy taken from skin / patient / person	B1
	alternative route for last two m.p.s	
	more / most energetic (liquid) molecules / particles escape OR less / least energetic (liquid) remain	(B1)
	less / least energetic molecules / particles linked to lower temp (of skin)	(B1)
(b)(ii)	greater / increases / faster / higher	B1

Q20.

(c)(i)	molecules overcome forces / gain potential energy as the liquid boils	B1
(c)(ii)	(m =) ρV (in any form) **or** 0.86×50 **or** 43 (g)	C1
	(l_v =) $Q \div m$ (in any form) **or** 18 000 / 43 **or** 18 000 / (0.86×50)	C1
	420 J / g **or** 4.2×10^5 J / kg	A1

Q21.

Question	Answer	Marks
(a)	E = mcΔT in any form OR (E =) mcΔT	C1
	efficiency = (energy) output / (energy) input in any form	C1
	$15 \times 4200 \times \Delta T = 5000 \times 3600 \times 0.2$	C1
	($\Delta T = 5000 \times 3600 \times 0.2 / 15 \times 4200$ =) 57 °C	A1