Question 1

272160 J *(–1 for omission of or incorrect units)* **(7)**

(4 marks for $\Delta E/\Delta t = AU\Delta\theta$)

(3 marks for 9 °C or 3600 s)

Question 2

(*c*) Define specific latent heat.

heat needed to change the state **(3)**

of 1 kg of a substance (with no change in temperature) **(3)**

A drinking glass contains 500 g of water at a temperature of 24 °C. Three cubes of ice, of side 2.5 cm, are removed from a freezer and placed in the water. The temperature of the ice is –20 °C.

Calculate the mass of the ice.

$m = \rho V$ **(3)**

m = 43.125 g *(–1 for omission of or incorrect units)* **(3)**

(–1 if one lump of ice used)

Calculate the minimum temperature of the water when the ice has melted.

any $mc\Delta\theta$ *(stated or implied)* **(3)**

ml *(stated or implied)* **(3)**

$$m_{ice}c_{ice}\Delta\theta_1 + m_{ice}l_{ice} + m_{ice}c_{water}\Delta\theta_2 = m_{water}c_{water}\Delta\theta_3$$

$$(0.043125\times2100\times20) + (0.043125\times3.3\times10^5) + (0.043125\times4200\times T) = (0.5 \times 4200 \times (24 - T))$$

(4 × 2)

$$1811.25 + 14231.25 + 181.125T = 50400 - 2100T$$

$$2281.125T = 34357.5$$

T = 15.06 °C *(–1 for omission of or incorrect units)* **(2)**

density of ice	$= 0.92\ g\ cm^{-3}$
specific heat capacity of water	$= 4200\ J\ kg^{-1}\ K^{-1}$
specific heat capacity of ice	$= 2100\ J\ kg^{-1}\ K^{-1}$
specific latent heat of fusion of ice	$= 3.3 \times 10^5\ J\ kg^{-1}$

Question 3

(*d*) Storage heaters are frequently used to heat buildings. State the principle that underlies the operation of an electrical storage heater.

large heat capacity 4

heated when electricity is inexpensive (off peak) / store a large quantity of energy / release energy slowly (during the day) *(any one)* 3

Question 4

(i) Explain the shape of the graph.

temperature of ice increased (from $\approx -3^\circ$ to 0°C as energy is added) 3

ice temperature stays at 0°C while ice is <u>melting</u> / <u>changing state</u> 3

reference to latent heat 3

(once melted) <u>ice melt</u> /<u>water</u> temperature increases (to 1°C) 3

(ii) Describe how energy could have been supplied at a constant rate.

(heating) coil/element 3
joulemeter / ammeter + rheostat 3
(water bath … 6 marks; hotplate …3 marks)

(iii) Using the graph, estimate the specific latent heat of fusion of ice.

energy (E) required to melt 0.15 kg of ice = (59 – 10) / 49 (kJ) 3
$E = m L$ 3
$L = \frac{49 \times 10^3}{0.150}$ / $3.26(7) \times 10^5$ J kg^{-1} **(–1 for omission of or incorrect units)** 4

Question 5

Question 2

In an experiment to measure the specific latent heat of vaporisation of water, a student used a copper calorimeter containing water and a sensitive thermometer. The water was cooled below room temperature before adding dry steam to it. The following measurements were recorded.

Mass of copper calorimeter	=	34.6 g
Initial mass of calorimeter and water	=	96.4 g
Mass of dry steam added	=	1.2 g
Initial temperature of calorimeter and cooled water	=	8.2 °C
Final temperature of calorimeter and water	=	20.0 °C

How was the water cooled below room temperature?
reference to appropriate use of ice / water taken from fridge 6
(–3 for inappropriate use of ice)

How was the steam dried?
use of steam trap / delivery tube sloped upwards 6

Describe how the mass of the steam was determined.
final mass of calorimeter plus contents/water – initial mass of calorimeter and contents/water 6

Why was a sensitive thermometer used?
for greater accuracy / to reduce(%) error / more significant figures / e.g. to read to 0.1 °C 6

24

Using the data, calculate the specific latent heat of vaporisation of water.

[heat lost by steam = heat gained by water and calorimeter]

[$m_s = 1.2\times10^{-3}$ (kg) and] $m_w = 6.18\times10^{-2}$ (kg) h/m 3

$\Delta\theta_{sv} = 80$ (K) and $\Delta\theta_w$ $(= \Delta\theta_{cu}) = 11.8$ (K) 3

$(ml)_s + (mc\Delta\theta)_{s/v} = (mc\Delta\theta)_w + (mc\Delta\theta)_{cu}$ 4

(zero marks if *ml* component missing: otherwise, for omission of or incorrect quantity, –1 per quantity)

$\left(1.2\times10^{-3}\right)l_v + \left(1.2\times10^{-3}\right)(4180)(80) = \left(6.18\times10^{-2}\right)(4180)(11.8) + \left(3.46\times10^{-2}\right)(11.8)(390)$

/ $\left(1.2\times10^{-3}\right)l_v + 401.3 = 30482 + 159.2$

(–1 per each incorrect substitution) 3

$l_v = 2.34\times10^{6}\ \text{Jkg}^{-1}$

(–1 for omission of or incorrect units) 3

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Question 11

(*a*) **What is the maximum energy that can fall on an area of 8 m^2 in one hour if the solar constant is 1350 W m^{-2}?**

$1350 \times 8 \times 3600$ **(–1 if *hour* not converted to *second*)** 4
$E_{max} = 3.9 \times 10^7$ J **(–1 for omission of or incorrect unit)** 3

(*b*) **Why is the bottom of a flat-plate collector blackened?**

good absorber 4
of heat/energy/radiation 3

(*c*) **How much energy is required to raise the temperature of 500 litres of water from 20 °C to 50 °C?**

$m = \rho V$ // $m = (10^3)(500 \times 10^{-3})$ // $m = 500$ (kg) 4
$E = mc\Delta\theta$ // $E = (500)(4200)(30)$ // $E = 6.3 \times 10^7$ (J) 3

(*d*) **The liquid in a vacuum-tube solar collector has a large specific latent heat of vaporisation.**
Explain why.

more energy released/absorbed (per kg in the heat exchanger) 4
during change of state 3

(*e*) **Name the three ways that heat could be lost from a vacuum-tube solar collector.**

conduction, convection, radiation 3+3+1

(*f*) **How is the sun's energy trapped in a vacuum-tube solar collector?**

silvered walls prevent radiation 4
evacuated walls prevent conduction and convection 3
(marks reversible)

(*g*) **Describe, in terms of heat transfer, the operation of a heat pump.**

energy taken from body/place (making it colder) 4
to another body/place (making it hotter) 3

(*h*) **Give an advantage of a geothermal heating system over a solar heating system.**

geothermal system functions all the time // constant 4
solar heating system works only during daytime // varies 3

56

Question 7

Question 2
The specific heat capacity of water was found by adding hot copper to water in a copper calorimeter. The following data was recorded.

mass of calorimeter	55.7 g
mass of calorimeter + water	101.2 g
mass of copper + calorimeter + water	131.4 g
initial temperature of water	16.5 °C
temperature of hot copper	99.5 °C
final temperature of water	21.0 °C

Describe how the copper was heated and how its temperature was measured.

any source of energy 6

thermometer / temperature sensor (or probe) / reference to 100 °C (if copper in boiling water) / temperature of (boiling) water 3

Using the data, calculate:

(i) **the energy lost by the hot copper**

$E = m\ c\ \Delta\theta$ 4

$E = (3.02 \times 10^{-2})(390)(78.5)$ or 924.57 or 924.6 J 3

(-1 for omission of or incorrect units)

(ii) **the specific heat capacity of water.**

Heat lost by hot copper = heat gained by calorimeter + water **(stated or implied)** 3

$924.57 = (0.0557)(390)(4.5) + (0.0455)(c_w)(4.5)$ **or** $924.57 = 97.75 + 0.2048\ c_w$ 3

$c_w = 4.038 \times 10^3 \approx 4.04 \times 10^3\ J\ kg^{-1}\ K^{-1}$ 3

(-1 for omission of or incorrect units)

accept range: $(4.03 \leftrightarrow 4.04)10^3\ J\ kg^{-1}\ K^{-1}$ **(-1 if outside range)**

Give two precautions that were taken to minimise heat loss to the surroundings.
insulate calorimeter /use lid /transfer copper(pieces) quickly / use cold water (below room temperature) /avoid splashing / polish calorimeter / low heat capacity thermometer, etc. any two …. 6 + 6

Explain why adding a larger mass of copper would improve the accuracy of the experiment.

smaller % error (-1 if % omitted) / greater rise (or change) in (water) temperature 3

(specific heat capacity of copper = $390\ J\ kg^{-1}\ K^{-1}$)

Question 8

(c) **Why does the temperature of an athlete reduce when she perspires?**

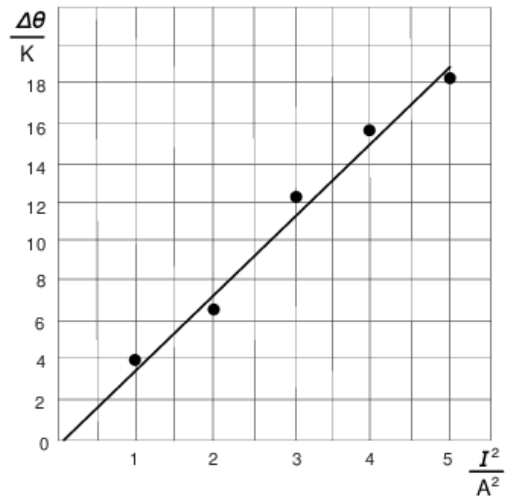
(latent) heat / energy taken from body 4

as perspiration / water evaporates // as water / liquid changes into steam / vapour /gas 3

Question 9

Question 4

In an experiment to verify Joule's law a student passed a current through a heating coil in a calorimeter containing a fixed mass of water and measured the rise in temperature $\Delta\theta$ for a series of different values of the current I. The student allowed the current to flow for three minutes in each case.



Describe, with the aid of a labelled diagram, how the student arranged the apparatus. (12)

apparatus: power supply, coil, ammeter (3 marks per component) 3 x 3

correct arrangement with a means of varying voltage/current and reference to thermometer 3

(-1 if no thermometer)

Why was a fixed mass of water used throughout the experiment? (6)

temperature and current are the variables (in this experiment)
/ cannot involve a third variable (i.e different mass of water)
/ the rise in temperature depends on mass of water 6

(any reference to '*a variable*' merits 3 marks)

The student drew a graph, as shown. Explain how this graph verifies Joule's law. (7)

straight line graph through origin 3
$\Delta\theta \propto I^2$ / $P \propto I^2$ / $P = RI^2$ / P = (constant) I^2 4

Given that the mass of water in the calorimeter was 90 g in each case, and assuming that all of the electrical energy supplied was absorbed by the water, use the graph to determine the resistance of the heating coil. The specific heat capacity of water is 4200 J kg^{-1} K^{-1}. (15)

$RI^2\ t = mc\Delta\theta$ 3
correct substitution of values into formula (-1 for each incorrect substitution) 3
correct coordinates of one (or two) point(s) on line // correct Δx and Δy values 3
correct value for slope [acceptable range: 3.7 ↔ 3.9 (K A^{-2})] 3
R = (7.8 ↔ 8.2) Ω **(-1 for omission of or incorrect unit)** 3

[If a data point (in bold) is used in determining slope, … max. 4 x 3]

Question 10

Calculate a value for the specific latent heat of vaporisation of water. (24)

[specific heat capacity of copper is 390 J kg^{-1} K^{-1} and the specific heat capacity of water is 4200 J kg^{-1} K^{-1}.]

$m_s l_w + m_s c_w \Delta\theta_s = m_w c_w \Delta\theta_w + m_c c_c \Delta\theta_c$ (or equivalent composite subscripts) 3×3

(each term omitted or incorrectly represented … –3)

$\Delta\theta_s = 75$ (°C) and $\Delta\theta_w$ $(= \Delta\theta_c) = 15$ (°C) 3

$(0.0011)\, l_w + (0.0011)(4200)(75) = (0.0407)(4200)(15) + (0.0505)(390)(15)$ 3×3

(each incorrectly substituted value … –3)

$[(0.0011)\, l_w + 346.5 = 2564.1 + 295.425]$

$l_w = 2.28 \times 10^6$ J kg^{-1} [accept range: $(2.28 \sim 2.30)10^6$] 3

(-1 for omission of or incorrect unit)

Why was dry steam used? (6)

condensed steam would already have lost its (s).l.h. (outside calorimeter) / calculations assume that only steam /no water is added / would not be possible to measure mass of any water added with steam 6

How was the steam dried? (4)

water trap / steam trap / insulated delivery tube / sloped delivery tube / allow steam to issue freely (initially) 4

A thermometer with a low heat capacity was used to ensure accuracy. Explain why. (6)

absorbs no/less heat from system/water (in calorimeter) / calculations assume that no energy is transferred to the thermometer 6

Question 11

Question 2

In an experiment to measure the specific latent heat of fusion of ice, warm water was placed in a copper calorimeter. Dried, melting ice was added to the warm water and the following data was recorded.

mass of calorimeter	60.5 g
mass of calorimeter + water	118.8 g
temperature of warm water	30.5 °C
mass of ice	15.1 g
temperature of water after adding ice	10.2 °C

Explain why warm water was used.

to speed up the melting of the ice / in order to melt a larger mass of ice / (concept of) balancing energy losses before and after the experiment 3

Why was dried, melting ice used?

to remove any <u>water</u>/<u>melted ice</u> // melted ice would have already gained latent heat //so that only ice is added // so that no water is added 3

melting ice is at 0 °C 4

Describe how the mass of the ice was found

final mass of calorimeter + contents minus mass of calorimeter + water (state/imply) 6

What should be the approximate room temperature to minimise experimental error?

20 ± 1.0 / midway between initial and final temperatures (of the water in the calorimeter) 6

Calculate:

(i) the energy lost by the calorimeter and the warm water;

{energy lost = } $(mc\Delta\theta)_{cal} + (mc\Delta\theta)_{warm\ water}$ 3

$= (0.0605)(390)(20.3) + (0.0583)(4200)(20.3)$ 3

$= 5449.6365$ / 5449.6 J 3

(–1 for omission of or incorrect units)

(ii) **the specific latent heat of fusion of ice.**

{energy gained by ice and by melted ice =}

$(ml)_{ice} + (mc\Delta\theta)_{melted\ ice}$ / $(0.0151)l + (0.0151)(4200)(10.2)$ / $0.0151\,l + 646.884$ 3

(equate:) $0.0151\,l + 646.884 = 5449.6365$ 3

$l = 3.181 \times 10^5 \approx 3.2 \times 10^5$ J kg^{-1} 3

(–1 for omission of or incorrect units)

(specific heat capacity of copper = 390 J kg^{-1} K^{-1};
specific heat capacity of water = 4200 J kg^{-1} K^{-1})

Question 12

(b) **Why is a filament light bulb not an efficient source of light?**
any reference to the production of: *heat* (*energy*) 7
["The output / light energy is only a small percentage / fraction of the input / electrical energy". … 7 marks]

Question 13

(c) **Define (i) power, (ii) specific heat capacity. (9)**
(i) work done per second / rate at which work is done 3

(ii) energy/heat required to raise the temperature 3
of 1 kg (of a substance) by 1 K / 1 ºC 3

400 g of water at a temperature of 15 °C is placed in an electric kettle. The power rating of the kettle is 3.0 kW.
Calculate
(i) the energy required to raise the temperature of the water to 100 °C;
(ii) the energy supplied by the kettle per second;
(iii) the least amount of time it would take to heat the water to 100 °C. (15)

$E = mc\Delta\theta$ 3
$E = (0.40)(4200)(85)$ / 1.428×10^5 J 3
(-1 for omission of or incorrect units)

3000 J (per second) / 3000 W / 3 kW 3
(-1 for omission of or incorrect units)

time taken = $(1.428 \times 10^5) / (3000)$ 3
time = 47.6 s ≈ 48 s 3
(-1 for omission of or incorrect units)

In reality, the time taken to heat the water will be greater. Explain why. (4)
energy will be lost to surroundings / absorbed by kettle / lost by evaporation
// limescale on element 4

(specific heat capacity of water = 4200 J kg^{-1} K^{-1})

Question 14

(i) emf; (ii) length/height/volume **(4 + 3)**

Question 15

(*c*) Why is it necessary to have a standard thermometer?
different thermometers have different thermometric properties 4
give different readings (at the same temperature) 3

Question 16

(c) What is the thermometric property of a thermocouple? (7)
emf / *E* / voltage / *V* / p.d. 7