Particle Model 5

Name: ____________________

Class: ____________________

Date: ____________________

Time: **90 minutes**

Marks: **84 marks**

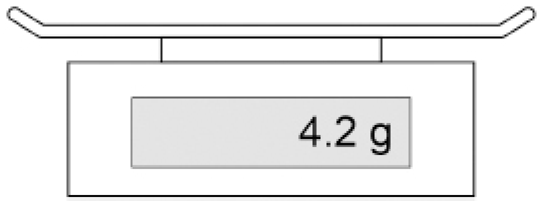
Comments:

1. A student determined the density of a cube made of bronze.

The student used a balance to measure the mass of the bronze cube.

Figure 1 shows the balance before the cube was added.

Figure 1



(a) What type of error is shown on the balance?

____

(1)

(b) How could the student get a correct value for the mass of the cube from the balance?

____

____

(1)

(c) The student measured the length of the bronze cube using Vernier callipers and then using a micrometer.

Table 1 shows the results.

Table 1

Equipment	**Length in mm**
Vernier callipers	20.1
Micrometer	20.14

Complete the sentence.

The results in **Table 1** show that the Vernier callipers and the micrometer have a different ____________________.

(1)

The student wanted to determine the density of a bronze coin.

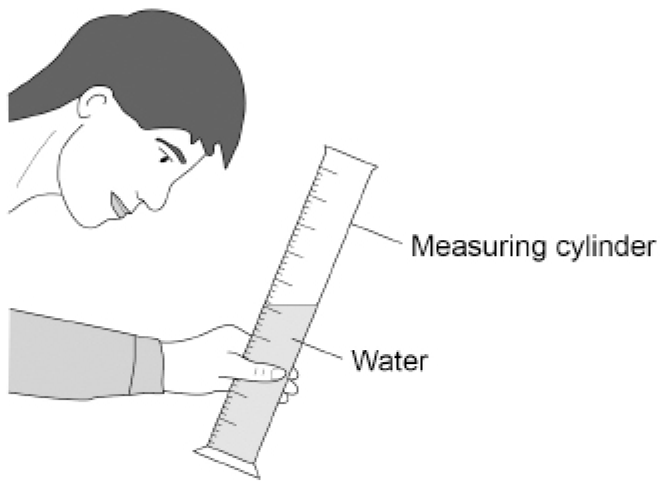
The student had several identical coins.

The volume of each coin was very small.

(d) The student added water to a measuring cylinder.

Figure 2 shows the student reading the volume of water in the measuring cylinder.

Figure 2



Give **two** changes the student should make to increase the accuracy of the volume measurement.

1 ____

____

2 ____

____

(2)

(e) Describe how the student could use a displacement method to determine an accurate value for the volume of a single coin.

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(3)

(f) Old penny coins were made from a disc of bronze.

New penny coins are made from a disc of a different metal.

Figure 3 shows a disc of metal.

Figure 3

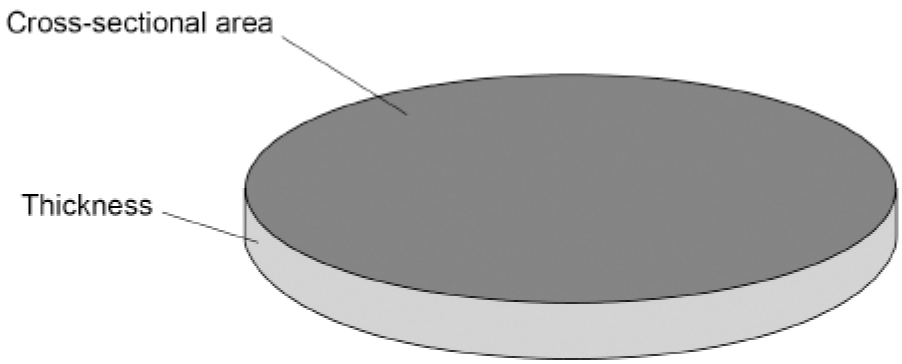


Table 2 shows information about the discs used to make each coin.

Table 2

Disc	**Mass in g**	**Density in g/cm^3**	**Thickness in cm**
Old penny	3.6	8.9	0.16
New penny	3.6	**X**	0.17

The discs used to make the old and the new coins have the **same** cross-sectional area.

Calculate value **X** in **Table 2**.

Give your answer to 2 significant figures.

The volume of a disc can be calculated using the equation:

volume of a disc = cross-sectional area × thickness

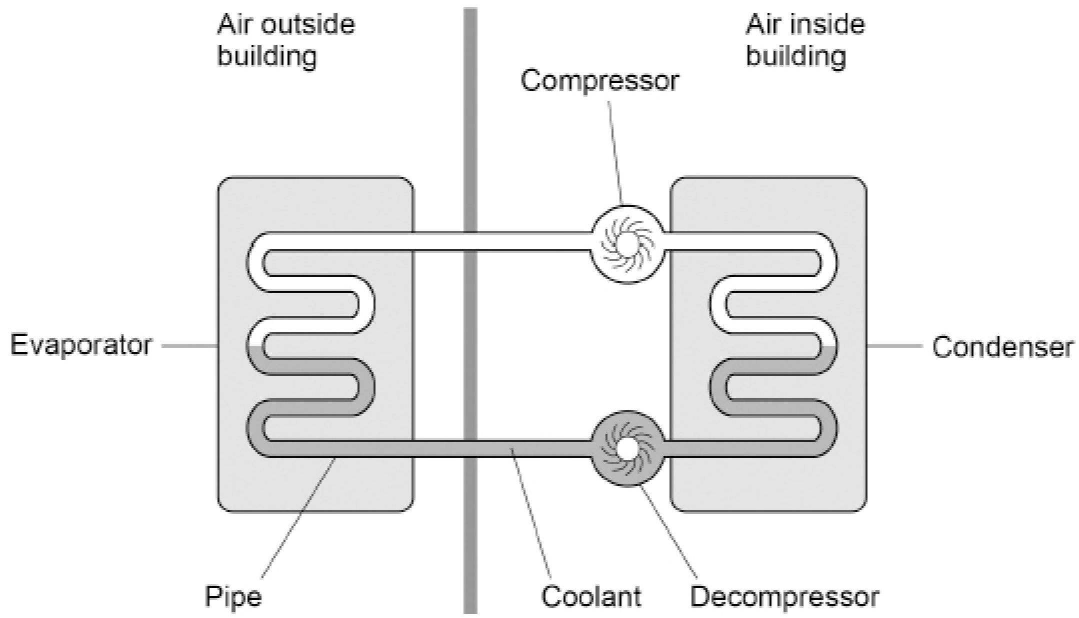
Density (2 significant figures) = ________________ g/cm^3

(5)

(Total 13 marks)

2. An air source heat pump transfers energy from the air outside a building to increase the temperature of the air inside the building.

The figure below shows an air source heat pump.



The compressor is connected to the mains electricity supply.

The pipe in the heat pump contains a substance called coolant.

In the evaporator, energy is transferred from the air outside the building to the liquid coolant.

The temperature of the coolant increases and it evaporates.

(a) Explain what happens to the internal energy of the coolant as its temperature increases.

(2)

(b) What name is given to the energy needed to change the state of the liquid coolant?

(1)

(c) What happens to the mass of the coolant as it evaporates and becomes a vapour?

Tick (✓) **one** box.

Decreases ☐

Stays the same ☐

Increases ☐

(1)

(d) The compressor increases the density and temperature of the coolant vapour inside the pipe.

Explain why the pressure in the pipe increases.

____

____

____

____

(2)

(e) The condenser transfers energy from the coolant to the air in the building.

When the total energy input to the heat pump system is 1560 kJ the temperature of the air in the building increases from 11.6 °C to 22.1 °C.

The efficiency of the heat pump system is 87.5%.

The mass of the air inside the building is 125 kg.

Calculate the specific heat capacity of the air in the building.

Give your answer in standard form.

____

____

____

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____

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____

Specific heat capacity (standard form) = ________________ J/kg °C

(6)

(f) The air in the building gains 400 J for every 100 J of energy transferred from the mains electricity supply to the compressor.

An advertisement claims that the heat pump system has an efficiency of 400%.

Explain why the advertisement is **not** correct.

____

____

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____

____

____

(3)

(Total 15 marks)

3. A scientist had a balloon which was filled with air.

(a) Which statement describes how air particles move?

Tick (✓) **one** box.

At random speeds in random directions	☐
At random speeds in the same direction	☐
At the same speed in random directions	☐
At the same speed in the same direction	☐

(1)

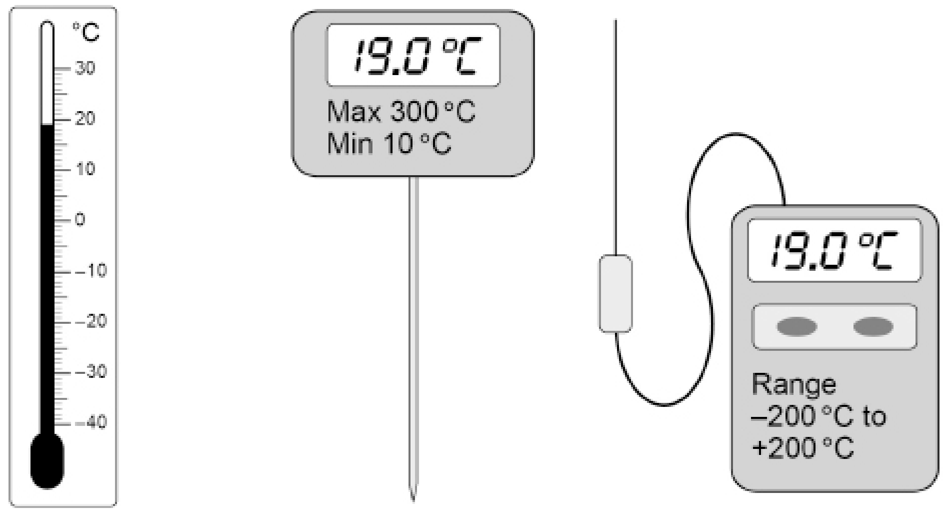
The temperature of the air was 19 °C

The scientist dipped the balloon into liquid nitrogen.

The temperature of the liquid nitrogen was −196 °C

(b) Which thermometer could be used to measure the temperature of the liquid nitrogen?

Tick (✓) **one** box.



☐ ☐ ☐

(1)

(c) The scientist wore special insulating gloves when putting the balloon into the liquid nitrogen.

Suggest why.

____

____

(1)

(d) When the balloon was put into liquid nitrogen the temperature of the air in the balloon decreased.

Complete the sentences.

Choose answers from the box.

Each answer may be used once, more than once or not at all.

decreased	**stayed the same**	**increased**

As the air in the balloon cooled down, the speed of the particles

_______________. This is because the kinetic energy of the

particles _______________.

(2)

(e) The air in the balloon had a mass of 0.00320 kg

The temperature of the air in the balloon decreased by 215 °C

The change in thermal energy of the air in the balloon was 860 J

Calculate the specific heat capacity of the air in the balloon.

Use the Physics Equations Sheet.

____

____

____

____

____

____

Specific heat capacity = ________________ J/kg°C

(3)

(f) The liquid nitrogen boiled.

What happens to the temperature of nitrogen as it boils?

Tick (✓) **one** box.

Temperature decreases ☐

Temperature increases ☐

Temperature stays the same ☐

(1)

The scientist recorded measurements to calculate the specific latent heat of vaporisation of nitrogen.

(g) What is meant by vaporisation?

Tick (✓) **one** box.

A change of state from liquid to gas	☐
A change of state from solid to gas	☐
A change of state from solid to liquid	☐

(1)

(h) The mass of nitrogen that vaporised was 0.0072 kg

1440 J of energy was transferred to the nitrogen as it vaporised.

Calculate the specific latent heat of vaporisation of nitrogen.

Use the Physics Equations Sheet.

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Specific latent heat of vaporisation = ________________ J/kg

(3)

(Total 13 marks)

4. Ice cream is made by cooling a mixture of liquid ingredients until they freeze.

(a) Which statement describes the motion of the particles in solid ice cream?

Tick (✓) **one** box.

They are stationary.	☐
They move freely.	☐
They vibrate about fixed positions.	☐

(1)

(b) How do the kinetic energy and the potential energy of the particles change as a liquid is cooled and frozen?

Tick (✓) **one** box.

Kinetic energy	**Potential energy**	
Decreases	Decreases	☐
Decreases	Does not change	☐
Does not change	Decreases	☐
Does not change	Does not change	☐

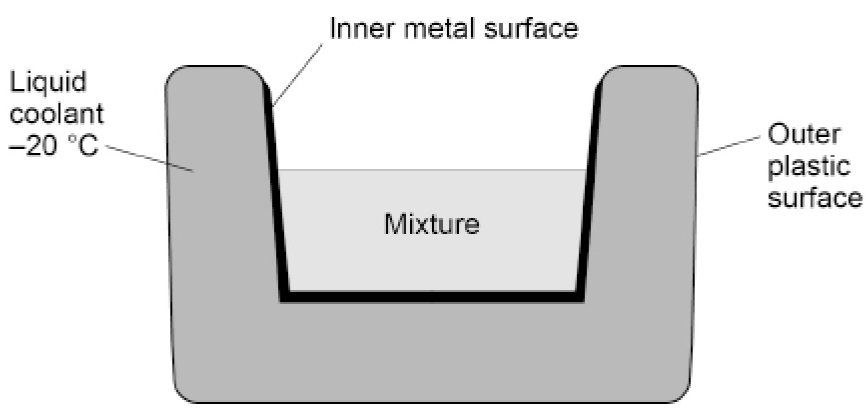
(1)

The diagram below shows a bowl used for making ice cream.

The walls of the bowl contain a liquid coolant.

The bowl is cooled to –20 °C before the mixture is put in the bowl.

The bowl causes the mixture to cool down and freeze.



(c) Explain why the different thermal conductivities of metal and plastic are important in the design of the bowl.

Metal ____

____

____

____

Plastic ____

____

____

____

(4)

(d) The liquid coolant has a freezing point below –20 °C

Explain **one** other property that the liquid coolant should have.

____

____

____

____

(2)

(e) The initial temperature of the mixture was +20 °C. The mixture froze at –1.5 °C.

A total of 165 kJ of internal energy was transferred from the mixture to cool and freeze it.

specific heat capacity of the mixture = 3500 J/kg °C

specific latent heat of fusion of the mixture = 255 000 J/kg

Calculate the mass of the mixture.

Give your answer to 2 significant figures.

___

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___

___

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___

___

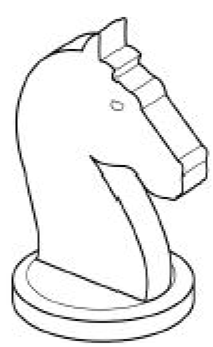
Mass (2 significant figures) = ________________ kg

(6)

(Total 14 marks)

5. A student wanted to determine the density of the irregular shaped object shown in **Figure 1**

Figure 1



(a) Plan an experiment that would allow the student to determine the density of the object.

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(6)

(b) Another student did a similar experiment.

He determined the density of five common plastic materials.

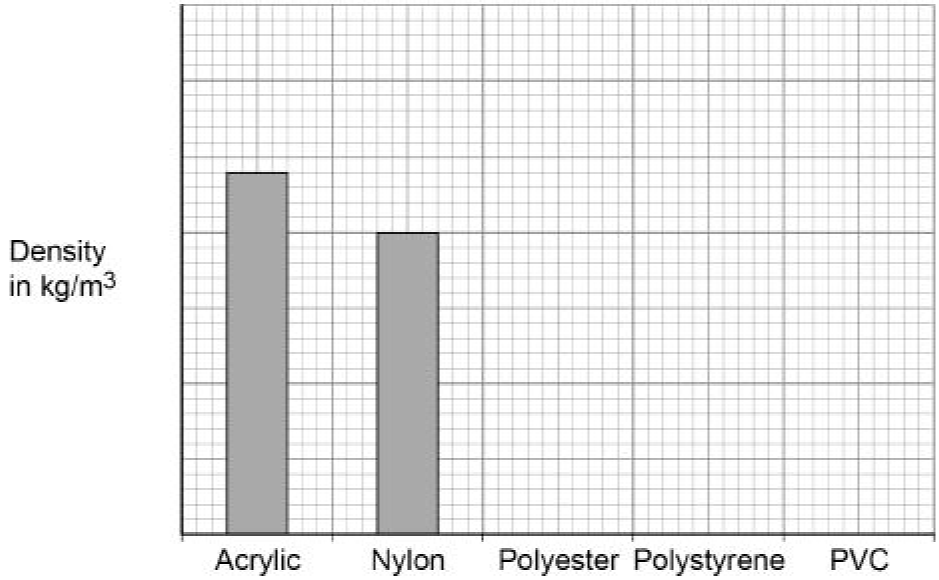
Table 1 shows the results.

Table 1

Plastic material	**Density in kg/m^3**
Acrylic	1200
Nylon	1000
Polyester	1380
Polystyrene	1040
PVC	1100

Figure 2 shows the results plotted in a bar chart.

Figure 2



Complete **Figure 2**

You should:

- Write the correct scale on the y-axis.
- Draw the bars for polyester, polystyrene and PVC.

(4)

(c) The student is given a piece of a different plastic material.

The student determined the density of the material three times.

Table 2 shows the results.

Table 2

	Density in kg/m^3
1	960
2	1120
3	1040

Determine the uncertainty in the student's results.

____

____

Uncertainty = ________________ kg/m^3

(2)

(Total 12 marks)

6. Water exists as ice, water or steam.

(a) Complete the sentences.

Choose the answers from the box.

ice	**steam**	**water**

The particles are arranged in a regular pattern in ____________________ .

The particles are close together but not in a pattern in ____________________ .

The particles move quickly in all directions in ____________________ .

(2)

(b) Which will have the most internal energy?

Tick **one** box.

1 kg of ice ☐

1 kg of steam ☐

1 kg of water ☐

(1)

(c) Which will have the lowest density?

Tick **one** box.

Ice ☐

Steam ☐

Water ☐

(1)

The image shows an iceberg floating in the sea.

(d) The iceberg has a mass of 11 200 kg

The volume of the iceberg is 12.0 m^3

Calculate the density of the iceberg.

Use the equation:

$$\text{density} = \frac{\text{mass}}{\text{volume}}$$

____

____

Density = ____________________ kg/m^3

(2)

(e) Explain why the iceberg will melt.

____

____

____

____

(2)

(Total 8 marks)

7. **Figure 1** shows a student making potato soup.

Figure 1

(a) The student places 0.5 kg of potato into a pan of water.

During cooking, the temperature of the potato increases from 20 °C to 100 °C

The specific heat capacity of the potato is 3400 J/kg °C

Calculate the change in thermal energy of the potato.

Use the equation:

change in thermal energy = mass × specific heat capacity × temperature change

____

____

____

____

____

____

Change in thermal energy = ____________________ J

(3)

(b) Why is the energy supplied by the cooker greater than that calculated in part (a)?

____

(1)

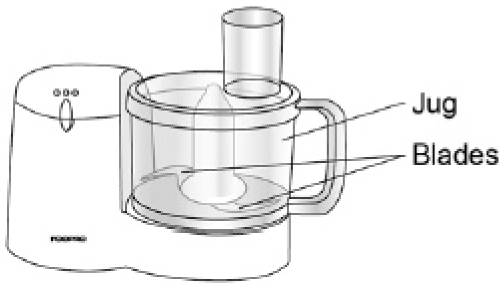
(c) Suggest **one** way that the student could reduce the time to heat the potato to 100 °C

____

(1)

Figure 2 shows a food processor.

Figure 2



(d) The student places the cooked potato into the jug of the food processor.

The food processor contains a motor that spins blades to chop the potato.

The total power input to the motor is 500 W

The useful power output from the motor is 300 W

Calculate the efficiency of the motor in the food processor.

Use the equation:

$$\text{efficiency} = \frac{\text{useful power output}}{\text{total power input}}$$

____

____

____

Efficiency = ____________________

(2)

(e) The jug is made of plastic with a low thermal conductivity.

Explain why this is an advantage.

____

____

____

____

(2)

(Total 9 marks)

Mark schemes

1. (a) zero error

allow systematic error

1

(b) reset the balance to zero g

allow subtract the reading shown on the balance from the reading taken

1

(c) resolution

this answer only

1

(d) place the measuring cylinder on a horizontal surface

1

view with eye in line with the level of the water

allow read from the bottom of the meniscus

1

(e) add several coins to the measuring cylinder

allow a minimum of 5 coins if a number of coins is given

1

measure the change in the water level in the measuring cylinder

1

divide by the number of coins added

1

(f) $8.9 = \frac{3.6}{\text{area} \times 0.16}$

allow $8.9 = \frac{3.6}{\text{volume}}$

1

$\text{area} = \frac{3.6}{8.9 \times 0.16}$

allow area = 2.5(28…) (cm^2)

1

$\text{density} = \frac{3.6}{2.528 \times 0.17}$

allow $\frac{3.6}{\text{their calculated area} \times 0.17}$

1

density = 8.37… (g/cm^3)

allow a correct calculation using their calculated area

1

density = 8.4 g/cm^3

this mark can only be scored for a correct rounding of a value of density calculated using correct equations

1

[13]

2. (a) the kinetic energy (and the potential energy) of the particles increases

allow the speed of the particles increases

1

so the internal energy increases because it is the sum of kinetic and potential energy (of the particles)

1

(b) latent heat (of vaporisation)

allow specific latent heat (of vaporisation)

1

(c) stays the same

1

(d) more collisions per second

1

a greater force per collision

1

(e) $0.875 = \frac{\text{useful output energy transfer}}{1\ 560\ 000}$

allow a correct substitution using incorrectly/not converted values of efficiency and/or energy

1

useful output energy transfer = 1 365 000(J)

this answer only

the equation

efficiency = $\frac{\text{useful output energy transfer}}{\text{total input energy transfer}}$

must have been used to score subsequent marks

1

1 365 000 = 125 × c × (22.1–11.6)

allow a correct substitution using their calculated value of useful output energy

1

$c = \frac{1\ 365\ 000}{125 \times 10.5}$

allow a correct re-arrangement using their value of useful output energy

1

c = 1040 (J/kg °C)

allow a correct calculation using with their value of useful output energy

1

c = 1.04×10^3 (J/kg °C)

this mark can only be awarded for a calculation using the correct equations

1

(f) the advertisement has ignored the energy input from the surrounding air

1

so the total energy input is greater than the energy supplied from the electricity

an answer that the total energy input comes from the electricity supply and the air outside the building gains the first two marking points

1

the efficiency must be less than 100%

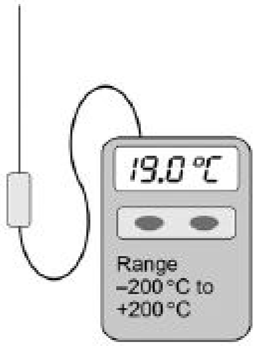
1

[15]

3. (a) at random speeds in random directions

1

(b) 3rd thermometer ticked



1

(c) to prevent (frost/cold) burns

allow to prevent frostbite

or

to prevent injury from the cold nitrogen

1

(d) decreased

1

decreased

1

(e) $860 = 0.00320 \times c \times 215$

1

$c = \frac{860}{0.00320 \times 215}$

1

c = 1250 (J/kg°C)

1

(f) temperature stays the same

1

(g) a change of state from liquid to gas

1

(h) $1440 = 0.0072 \times L$

1

$L = \frac{1440}{0.0072}$

1

L = 200 000 (J/kg)

1

[13]

4. (a) they vibrate about fixed positions.

1

(b) kinetic energy decreases potential energy decreases

1

(c) metal: has a high thermal conductivity

1

which increases the rate of energy transfer from the mixture

allow ice cream for mixture

1

plastic: has a low thermal conductivity

1

which reduces the rate of energy transfer from the surroundings (to the liquid coolant at –20°C)

ignore references to insulation throughout

1

(d) a high specific heat capacity

1

so it can absorb a large amount of energy with only a small temperature change

1

(e) 165 kJ = 165000 J

1

$\Delta E = m \times 3500 \times 21.5$

and

$\Delta E = m \times 255000$

1

165000 = 75250 m + 255000 m

or

165000 = 330250 m

this mark may be awarded if E is incorrectly/not converted

1

$m = \frac{165000}{75250 + 255000}$

or

this mark may be awarded if E is incorrectly/not converted

1

$m = \frac{165000}{330250}$

allow an answer consistent with their value of E

m = 0.499621 (kg)

1

m = 0.50 (kg)

this answer only

If no marks awarded other than the first marking point:

either

*165 000 = m × 3500 × 21.5 scores **1** mark*

*m = 2.192… scores **1** mark*

*m = 2.2 (kg) scores **1** mark.*

these marks may be awarded if E is incorrectly/not converted

or

*165 000 = m × 255 000 scores **1** mark*

*m = 0.647 scores **1** mark*

*m = 0.65kg scores **1** mark.*

these marks may be awarded if E is incorrectly/not converted

1

[14]

5. (a) **Level 3:** The method would lead to the production of a valid outcome. All key steps are identified and logically sequenced.

5–6

Level 2: The method would not necessarily lead to a valid outcome. Most steps are identified, but the method is not fully logically sequenced.

3–4

Level 1: The method would not lead to a valid outcome. Some relevant steps are identified, but links are not made clear.

1–2

No relevant content

0

Indicative content

- measure mass
- use a top pan balance or scales

- part fill a measuring cylinder with water
- measure initial volume
- place object in water
- measure final volume
- volume of object = final volume − initial volume

- fill a displacement / eureka can with water
- water level with spout
- place object in water
- collect displaced water
- measuring cylinder used to determine volume of displaced water

- use of:

$$\text{density} = \frac{\text{mass}}{\text{volume}}$$

(b) all *y*-axis values correct (minimum of 3)

*allow **1** mark for two correct values*

2

all bars drawn to the correct height

*allow **1** mark for two correct bars*
allow ± ½ small square

2

(c) $\frac{(1120 - 960)}{2}$

ignore + and / or − signs

1

= 80 (kg/m^3)

*an answer of 160 scores **1** mark*

1

*an answer of 80 scores **2** marks*

[12]

6. (a) ice
water
steam

*allow **1** mark for 1 or 2 correct answers*

2

(b) 1 kg of steam

1

(c) steam

1

(d) ρ = 11 200 / 12.0

1

ρ = 933 (kg/m^3)

*an answer of 933 (kg/m^3) scores **2** marks*

1

(e) the internal energy of the iceberg increases

allow there is a temperature difference between ice and water / air

1

because

therefore

energy is transferred from the sea/water to the ice(berg)

1

[8]

7. (a) 80 °C

1

ΔE = 0.5 × 3400 × 80

1

ΔE = 136 000 (J)

*an answer of 136 000 (J) scores **3** marks*

1

(b) energy is dissipated into the surroundings

allow any correct description of wasted energy

1

(c) put a lid on the pan

allow any sensible practical suggestion

eg add salt to the water

1

(d) efficiency = 300/500

1

efficiency = 0.6

*an answer of 0.6 or 60% scores **2** marks*

allow efficiency = 60%

*an answer of 0.6 with a unit scores **1** mark*

*an answer of 60 without a unit scores **1** mark*

1

(e) lower rate of energy transfer

1

(so) potato soup will remain at a higher temperature

1

[9]