

Particle Model 3

Name: _____

Class: _____

Date: _____

Time: **66 minutes**

Marks: **61 marks**

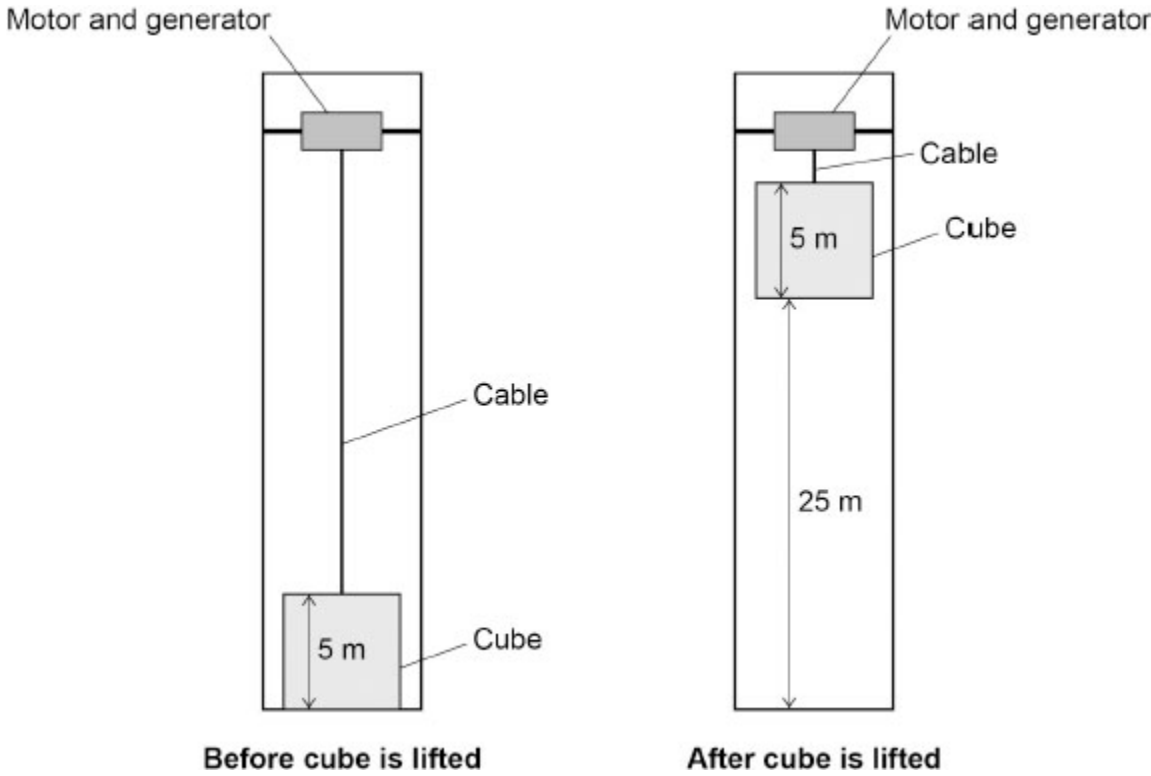
Comments:

1.

A system is designed to store excess energy from the National Grid.

- Excess energy from the National Grid powers a motor that lifts a large cube.
- To transfer the energy back to the National Grid, the cube is allowed to fall.
- The falling cube turns a generator which produces electricity.

The figure below shows the cube before it is lifted and after it is lifted.



(a) The cube has a density of 4200 kg/m^3 .

Determine the mass of the cube.

Use the Physics Equations Sheet.

Mass = _____ kg

(4)

(b) Explain why the cube is made from a material with a high density.

(2)

(c) The system is designed to store excess energy from the National Grid.

Explain how the efficiency of the system could be determined.

(2)

(d) The system in the figure above needs to be able to store excess energy as quickly as possible.

Explain **one** change to this system that would allow the same amount of energy to be stored more quickly.

Do **not** refer to efficiency in your answer.

(2)

(Total 10 marks)

2.

The figure below shows an outdoor swimming pool.

The water in the swimming pool comes from the sea.



The water in the pool is heated using a geothermal energy resource.

(a) Which of the following describes a geothermal energy resource?

Tick (✓) **one** box.

A non-renewable energy resource with high carbon emissions.

A non-renewable energy resource with low running costs.

A renewable energy resource that uses hot rocks underground.

A renewable energy resource that uses the tides.

(1)

(b) 15 kg of seawater is heated before it is added to the pool.

specific heat capacity of seawater = 3800 J/kg °C

Calculate the change in thermal energy of 15 kg of seawater when its temperature is increased by 9.0 °C.

Use the equation:

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

Change in thermal energy = _____ J

(2)

(c) The energy transferred from 1.0 m² of the surface of the pool to the air is 80 J each second.

The surface area of the pool is 120 m².

Calculate the energy transferred from the whole surface of the pool to the air each second.

Energy transferred each second = _____ J

(1)

(d) Which of the following units is the same as 1 J/s?

Tick (✓) **one** box.

1 N

1 Pa

1 W

(1)

(e) The pool is above sea level.

5.0 kg of water is pumped from sea level into the pool.

The water gains 196 J of gravitational potential energy.

gravitational field strength = 9.8 N/kg

Calculate the height of the pool above sea level.

Use the equation:

$$\text{height} = \frac{\text{gravitational potential energy}}{\text{mass} \times \text{gravitational field strength}}$$

Height = _____ m

(2)

(f) The water in some swimming pools is heated by burning fossil fuels.

Explain **one** environmental **disadvantage** of burning fossil fuels.

(2)

(Total 9 marks)

3.

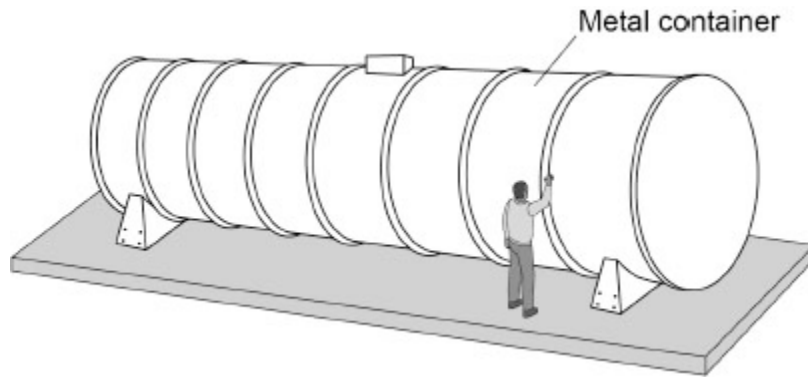
Data-storage computers get very hot.

Scientists investigated using the sea to cool data-storage computers.

The computers were set up inside a large metal container.

Figure 1 shows the metal container before it was lowered into the sea.

Figure 1



(a) Why is the container made of metal?

Tick (✓) **one** box.

Metal has a high thermal conductivity.

Metal is a good thermal insulator.

Metal is a poor conductor of thermal energy.

(1)

(b) The walls of the container are solid.

Figure 2 shows an arrangement of six particles in a solid.

Figure 2



The air inside the container is a gas.

Draw an arrangement of six particles in a gas in the box below.



(1)

(c) How does the air in the container exert pressure on the container?

Tick (✓) **one** box.

Air particles absorb energy from the container.

Air particles collide with the walls of the container.

Air particles expand to fill the container.

(1)

(d) As the container is lowered into the sea, the temperature of the air in the container decreases.

Complete the sentence.

Choose the answer from the box.

decreases	stays the same	increases
------------------	-----------------------	------------------

When the temperature of the air in the container decreases, the average speed of the air particles _____ .

(1)

- (e) After the temperature of the air in the container had decreased, the computers were switched on.

The computers caused the temperature of the air to then increase.

Describe how the air pressure in the container changed as the temperature decreased and then increased.

(2)

- (f) The container has a length of 12 m.

The container has a cross-sectional area of 7.5 m^2 .

Calculate the volume of the container.

Use the equation:

$$\text{volume} = \text{length} \times \text{cross-sectional area}$$

$$\text{Volume} = \text{_____} \text{ m}^3$$

(1)

Use the Physics Equations Sheet to answer parts (g) and (h).

- (g) Write down the equation that links density (ρ), mass (m) and volume (V).

(1)

(h) The average density of the container and its contents is 1100 kg/m^3 .

Calculate the mass of the container and its contents.

Use your answer to part (f)

Mass = _____ kg

(3)

(Total 11 marks)

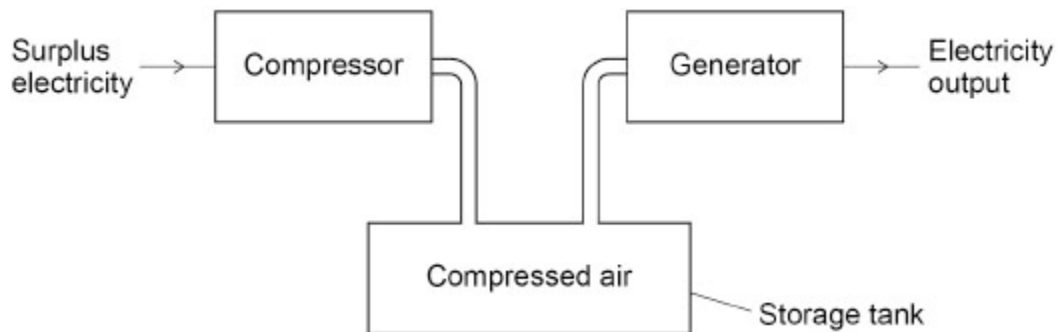
4.

Energy can be stored using a Compressed Air Energy Storage (CAES) system.

When more electricity is generated than is needed, a CAES system uses the surplus electricity to compress air in a storage tank.

When there is a greater demand for electricity, the CAES system releases the compressed air to generate electricity.

The figure below shows a diagram of the CAES system.



- (a) The CAES system has two processes:
- compressing air to store energy. This process has an efficiency of 0.72
 - releasing the air to generate electricity. This process has an efficiency of 0.86

Calculate the efficiency of the CAES system.

Give your answer to 2 significant figures.

Efficiency of the CAES system (2 significant figures) = _____

(3)

The generator works when forces from the compressed air cause a turbine to rotate.

When particles of air collide with the turbine they transfer energy to the turbine.

In warm weather the temperature of the compressed air increases, increasing the pressure inside the storage tank.

- (b) Explain how the motion of the particles in warmer air causes an increase in the power transferred to the turbine.

(4)

- (d) The UK government wants the amount of carbon dioxide released into the atmosphere to be reduced.

Explain why efficient energy storage is important in reducing the amount of carbon dioxide released when generating electricity.

(4)

(Total 17 marks)

5.

A piece of steel is heated until it has all melted.

- (a) Calculate the change in thermal energy when the temperature of the piece of steel is increased by 50 °C.

mass of steel = 4.0 kg

specific heat capacity of steel = 420 J/kg °C

Use the equation:

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

Change in thermal energy = _____ J

(2)

(b) The internal energy of the steel increases as the steel is heated.

What is meant by 'internal energy of the steel'?

Tick (✓) **one** box.

The change in energy of the steel particles as the steel melts.

The energy added to the steel particles as they are heated.

The total kinetic energy and potential energy of the steel particles.

(1)

(c) Solid steel cannot be poured.

Which statement about the particles in a solid gives the reason why?

Tick (✓) **one** box.

The number of particles always stays the same.

The particles are close together.

The particles are in fixed positions.

The particles have a fixed size.

(1)

(d) Complete the sentence.

Choose the answer from the box.

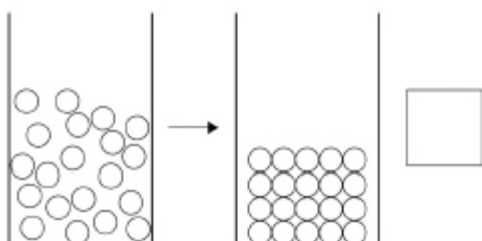
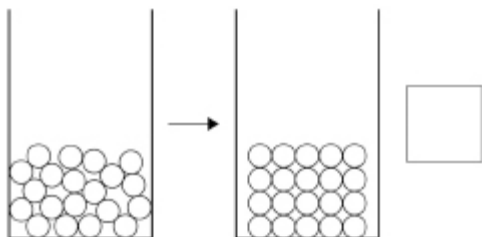
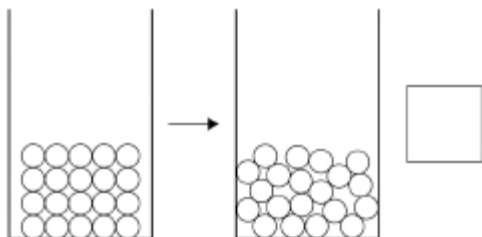
decreases	stays the same	increases
------------------	-----------------------	------------------

As the piece of solid steel melts, the mass of the steel _____.

(1)

- (e) Which diagram shows how the arrangement of particles changes when a solid melts and becomes a liquid?

Tick (✓) **one** box.



(1)

- (f) The density of steel decreases as it melts.

How does the spacing of the particles change as the steel melts?

(1)

- (g) Complete the sentence.

Choose the answer from the box.

chemical	permanent	physical
-----------------	------------------	-----------------

Melting is an example of a _____ change.

(1)

(h) Steel is a mixture of iron and a small amount of carbon.

The table below shows the mass of carbon in 1.0 kg of different types of steel.

Type of steel	Mass of carbon in 1.0 kg of steel
Low carbon	2.0 g
Medium carbon	4.5 g
High carbon	7.0 g

A 4.0 kg piece of steel contains 18 grams of carbon.

Determine which type of steel the 4.0 kg piece is made from.

You should include a calculation in your answer.

Type of steel _____

(3)

(i) The 4.0 kg piece of solid steel was heated until it reached its melting point.

The additional energy required to melt the piece of steel was 280 000 J.

Calculate the specific latent heat of fusion of the steel.

Use the Physics Equations Sheet.

Specific latent heat of fusion of steel = _____ J/kg

(3)

(Total 14 marks)

Mark schemes

1.

(a) $V (= 5 \times 5 \times 5) = 125 \text{ (m}^3\text{)}$

*do **not** allow subsequent marks unless volume is used
subsequent marks may be awarded if volume is incorrectly
calculated*

1

$$4200 = \frac{m}{125}$$

1

$$m = 4200 \times 125$$

1

$$m = 525\,000 \text{ (kg)}$$

1

(b) (the greater the density) the greater the mass (for a given volume)

1

(so) a greater amount of energy can be stored

OR

(the greater the density) the smaller the volume (for a given mass) (1)

(so) the same amount of energy can be stored (for a smaller volume) (1)

1

- (c) measure the energy input from the National Grid **and** measure the energy output to the National Grid

*allow measure the energy input to the motor **and** measure the energy output from the generator*

1

(then) use the equation:

$$\text{efficiency} = \frac{\text{energy output}}{\text{energy input}}$$

MP2 dependent on MP1

if no other mark awarded, allow **1** mark for:

$$\text{efficiency} = \frac{\text{energy released when lowering the block}}{\text{energy stored when raising block}}$$

1

- (d) use a motor with a greater power

allow increase the power of the motor

1

(so) the cube / weight / mass is lifted more quickly

MP2 dependent on MP1

1

[10]

2.

- (a) a renewable energy resource that uses hot rocks underground

1

- (b) $\Delta E = 15 \times 3800 \times 9.0$

1

513 000 (J)

1

- (c) 9600 (J)

1

- (d) 1 W

1

- (e)

$$\text{height} = \frac{196}{5.0 \times 9.8}$$

1

4 (m)

allow 4.0 (m)

1

(f) **EITHER**

releases carbon dioxide

ignore references to pollution

1

which contributes to global warming

allow climate change for global warming

allow which is a greenhouse gas

allow which contributes to the greenhouse effect

OR

releases sulfur / nitrogen dioxide (1)

allow other oxides of nitrogen

which causes acid rain (1)

OR

releases soot (1)

allow carbon for soot

allow particulates

which can cause global dimming (1)

allow reduces air quality

allow causes smog

1

[9]

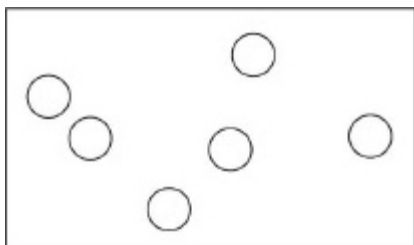
3.

(a) metal has a high thermal conductivity

1

(b) 6 particles all spread apart irregularly within the box

e.g.



1

(c) air particles collide with the walls of the container

1

(d) decreases

1

(e) (the pressure) decreased as temperature decreased

1

(the pressure) increased as temperature increased

allow 2 marks for it decreased then increased

1

(f) 90 (m³)

1

(g)

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

or

$$\rho = \frac{m}{V}$$

1

(h)

$$1100 = \frac{m}{90}$$

allow ecf from part (f)

1

$$\text{mass} = 90 \times 1100$$

1

99 000 (kg)

1

[11]

4.

(a) efficiency = 0.72 × 0.86

1

$$\text{efficiency} = 0.61(92)$$

1

0.62

allow use of percentages if % is seen

1

(b) (at higher temperatures) the (average) speed of the particles is greater
allow the (average) kinetic energy of the particles is greater
*do **not** accept vibrations*

1

so the frequency of collisions (between particles and the turbine) increases

1

and the force of each collision (between a particle and the turbine) is greater

1

so more energy transferred (each second)

dependent on MP2 or MP3

ignore increases the power

1

(c)

$$48 = \frac{\text{mass}}{5.0 \times 10^5}$$

1

$$\text{mass} = 48 \times 5.0 \times 10^5$$

1

$$\text{mass} = 24\,000\,000$$

the equation $\text{density} = \frac{\text{mass}}{\text{volume}}$ must have been used to score subsequent marks

1

$$E = 24\,000\,000 \times 1100 \times 15$$

allow a correct substitution using their calculated value for mass

1

$$E = 396\,000\,000\,000$$

allow an answer consistent with their calculated value for mass

1

$$E = 3.96 \times 10^{11}(\text{J})$$

allow a correctly converted answer consistent with their calculated value for energy using the equation $\Delta E = m c \Delta \theta$

1

(d) (efficient energy storage means) less energy is wasted

1

(to reduce carbon dioxide emissions) less fossil fuel used / burned

allow named fossil fuel

1

the amount of energy generated from renewable resources will need to increase

allow named renewable resources

or

(most) renewable resources do not generate electricity all the time

allow renewable resources are unreliable

1

(so) efficient energy storage will help to meet the demand for energy / electricity

1

[17]

5.

(a) $\Delta E = 4.0 \times 420 \times 50$

1

$$\Delta E = 84\,000 \text{ (J)}$$

1

(b) the total kinetic energy and potential energy of the steel particles

1

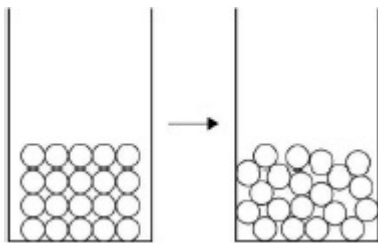
(c) the particles are in fixed positions

1

(d) stays the same

1

(e)



1

(f) (the space between the particles) increases
allow the particles move further apart

1

(g) physical

1

(h) $\text{mass per kg} = \frac{18}{4.0}$

1

mass per kg = 4.5 g

1

medium carbon

dependent on MP2

OR

mass in 4.0 kg of medium carbon steel = 4.5×4.0 (1)

allow mass in 4.0 kg of low carbon steel = 8 (g)

allow mass in 4.0 kg of high carbon steel = 28 (g)

mass in 4.0 kg of medium carbon steel = 18 g (1)

dependent on MP1

medium carbon (1)

dependent on MP2

1

(i) $280\,000 = 4.0 \times L$

1

$$L = \frac{280\,000}{4.0}$$

1

$$L = 70\,000 \text{ (J/kg)}$$

1

[14]