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| Name: | Class: | Class Register Number: |
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中正中学

CHUNG CHENG HIGH SCHOOL (MAIN)

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## PRELIMINARY EXAMINATION 2026 SECONDARY 4

### PHYSICS

Paper 2

6091/02

27 August 2026

1 hour 45 minutes

Candidates answer on the Question Paper.

No Additional Materials are required.

### READ THESE INSTRUCTIONS FIRST

Write your name, class and class register number clearly in the spaces provided at the top of this page.

Write in dark blue or black pen.

You may use an HB pencil for any diagrams or graphs.

Do not use staples, paper clips, glue or correction fluid.

#### Section A

Answer **all** questions. Write your answers in the spaces provided.

#### Section B

Answer **one** question. Write your answers in the spaces provided.

Candidates are reminded that **all** quantitative answers should include appropriate units.

The use of an approved scientific calculator is expected, where appropriate.

Candidates are advised to show all their workings in a clear and orderly manner, as more marks are awarded for sound use of Physics than for correct answers.

The number of marks is given in brackets [ ] at the end of each question or part question.

| For Examiner's Use |      |
|--------------------|------|
| Section A          | / 70 |
| Section B          | / 10 |
|                    |      |
|                    |      |
| Total              | / 80 |

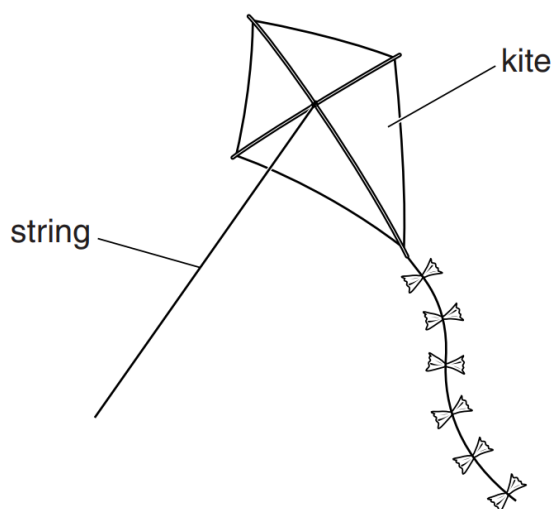
This document consists of **22** printed pages and **2** blank pages.

[Turn over

## Section A

Answer **all** questions.

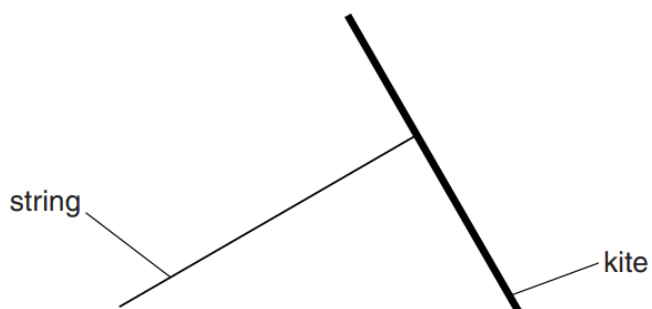
- 1 Fig. 1.1 shows a kite flying in a steady wind.



**Fig. 1.1**

Figs. 1.2 and 1.3 are side views of the same kite.

- (a) In Fig. 1.2, the kite is flying with the string attached. The kite is in equilibrium.

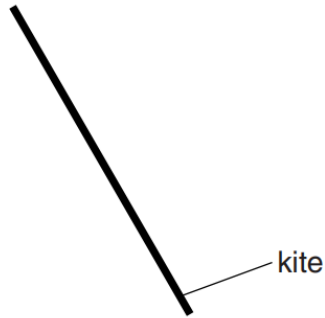


**Fig. 1.2**

By drawing labelled force vectors on Fig. 1.2, show the approximate direction of the force of the wind on the kite.

[3]

- (b) In Fig. 1.3, the string has become detached.



**Fig. 1.3**

Explain why, without the pull of the string, the kite in Fig. 1.3 cannot be in equilibrium.  
You may use Fig. 1.3 to illustrate your answer.

.....

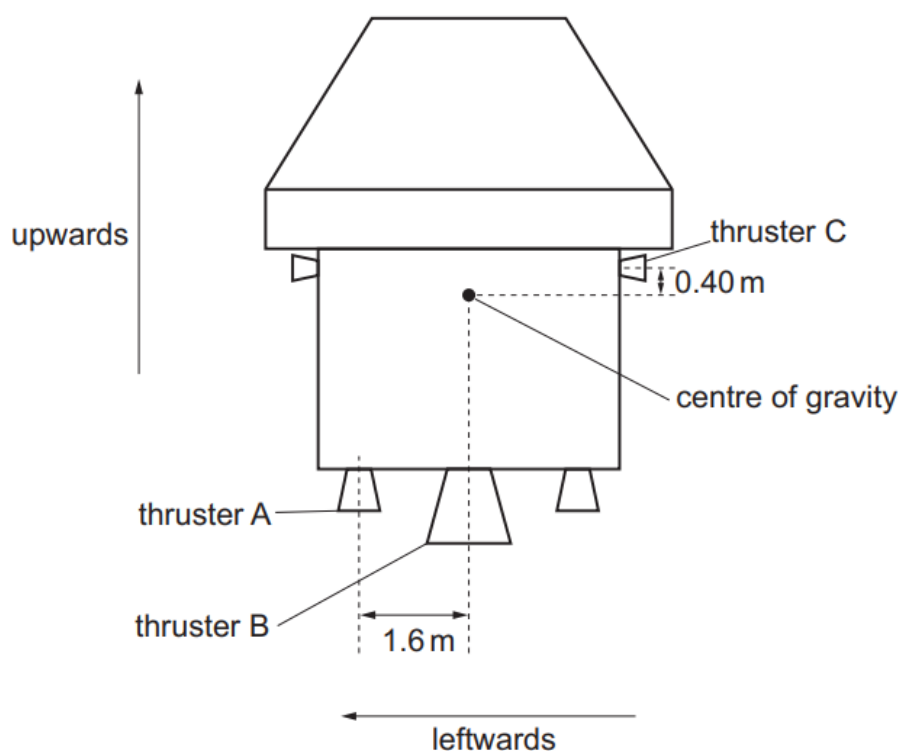
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..... [1]

[Total: 4]

**[Turn over**

- 2 A spacecraft in deep space uses jets of hot gas from its thrusters to change its velocity. Fig. 2.1 shows a side view of the spacecraft and some of its thrusters.



**Fig. 2.1** (not to scale)

Thruster A is a distance of 1.6 m leftwards from the centre of gravity of the spacecraft. Thruster C is a distance of 0.40 m upwards from the centre of gravity of the spacecraft.

Thrusters A and B can produce forces on the spacecraft in the upwards direction only. Thruster C can produce a force on the spacecraft in the leftwards direction only. All the thrusters shown produce forces entirely in the same plane as the centre of gravity.

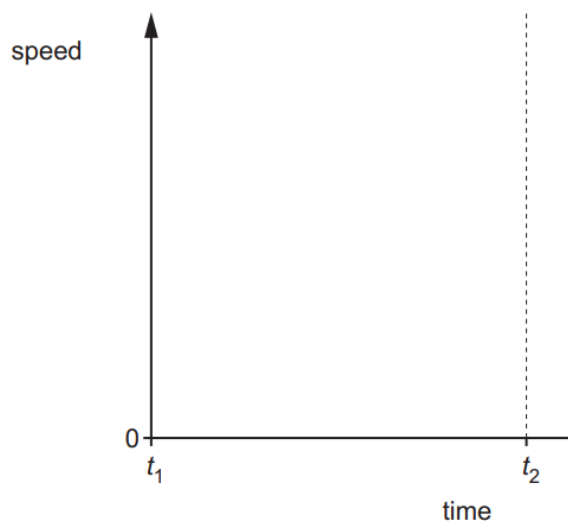
- (a) Thruster A is activated, producing a force of 60 N upwards on the spacecraft. Thruster C is also activated, producing a force of 220 N in the leftwards direction on the spacecraft.

Calculate the resultant moment due to these forces about the centre of gravity.

resultant moment = ..... [2]

- (b) Thrusters A and C are now switched off and the spacecraft is stationary. Thruster B is activated at time  $t_1$ , producing a constant force on the spacecraft until the fuel runs out at time  $t_2$ . As the fuel is used, the total mass of the spacecraft decreases.

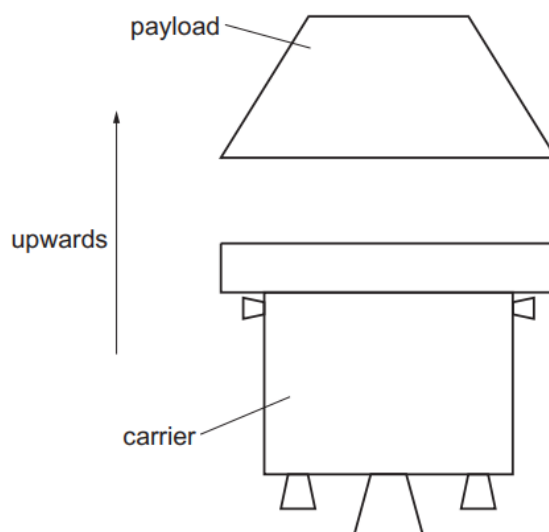
On Fig. 2.2, sketch the variation of speed of the spacecraft with time from  $t_1$  to  $t_2$ .



**Fig. 2.2**

[2]

- (c) The spacecraft now splits apart into a carrier and a payload as shown in Fig. 2.3.



**Fig. 2.3**

During the split, an average force of 5500 N acts on the payload for a time of 0.36 s. The velocity of the payload increases by 8.5 m/s in the upwards direction.

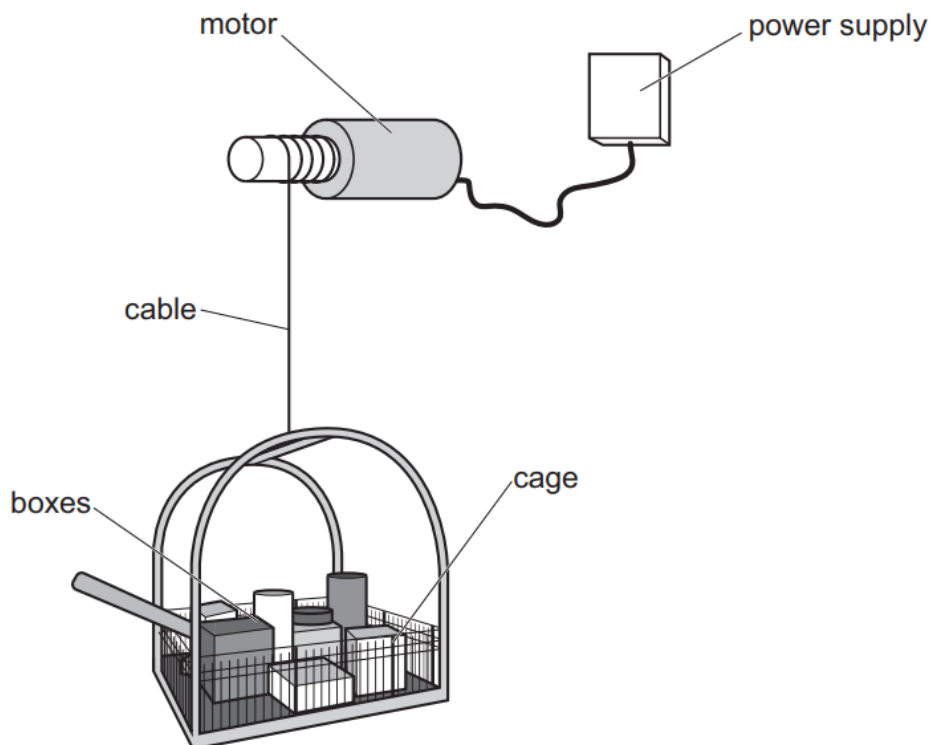
Calculate the mass of the payload.

mass = ..... [2]

[Total: 6]

**[Turn over**

- 3 In a factory, an electric motor is used to lift the boxes shown in Fig. 3.1.



**Fig. 3.1**

The boxes are placed in a cage and the motor winds a cable around a cylinder to lift the cage and boxes.

The total mass of the boxes is 37 kg and they are lifted vertically through 13 m to a storage area. The gravitational field strength of the Earth is 10 N/kg.

**(a)** Calculate:

- (i)** the total weight of the boxes

weight = ..... [1]

- (ii)** the useful work done in lifting the boxes to the storage area.

useful work done = ..... [2]

- (b) The e.m.f. of the power supply for the motor is 230 V. The current in the motor is 5.6 A.  
It takes 11 s for the motor to lift the cage and boxes to the storage area.  
Calculate the total energy transferred electrically to the motor in 11 s.

energy = ..... [2]

- (c) Some of the energy transferred by the motor during the lifting process is not transferred usefully.

State **two** reasons why the efficiency of the lifting process is less than 100%.

- 1 .....  
.....  
2 .....  
.....

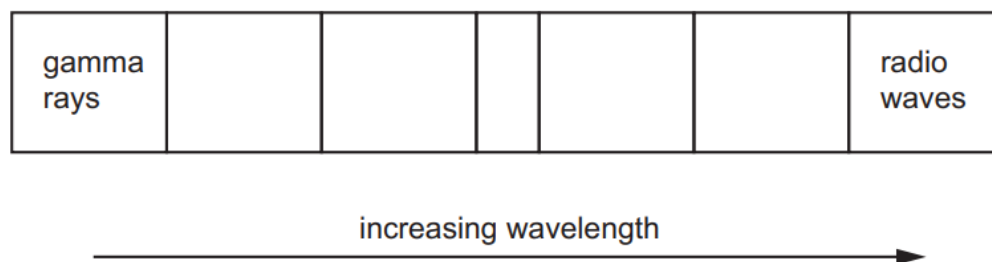
[2]

[Total: 7]

[Turn over

4 The microwave region is one region of the electromagnetic spectrum.

(a) Fig. 4.1 represents the electromagnetic spectrum divided into the seven main regions.



**Fig. 4.1**

The regions are arranged from left to right in order of increasing wavelength.

On Fig. 4.1:

- indicate the microwave region by marking it with the letter M
- indicate the ultraviolet region by marking it with the letters UV.

[1]

(b) The frequency used by microwave ovens is 2.5 GHz.

(i) The speed of microwaves in air is  $3.0 \times 10^8$  m/s.

Calculate the wavelength of these microwaves in air.

wavelength = ..... [2]

(ii) All microwave ovens have a switch that turns the oven off when the door is opened.

Suggest why it is important for a microwave oven to be switched off when the door is opened.

.....

.....

.....

..... [2]

- (c) State and explain which wire in the microwave oven's mains cable the safety switch should be connected to.

.....

.....

.....

..... [2]

[Total: 7]

[Turn over

- 5 A student wishes to plot the  $V$ - $I$  characteristic graph of a 12.0 V, 24.0 W tungsten filament lamp. The circuit used must enable the potential difference (p.d.) across the lamp to be varied continuously from 0 to 12.0 V. The power supply used is a 12.0 V battery.

(a) On Fig. 5.1, draw an appropriate circuit that includes the power supply shown.

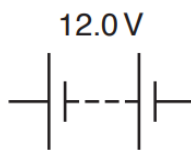
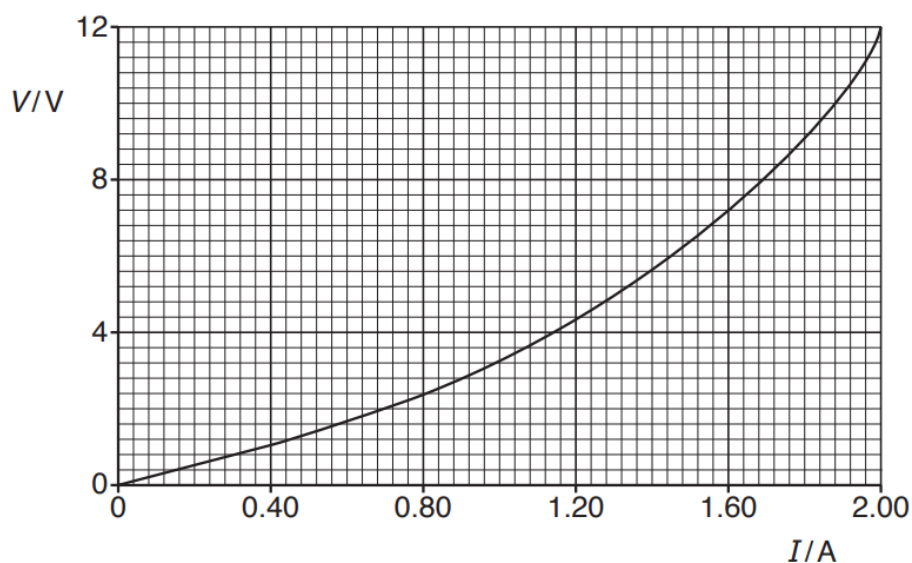


Fig. 5.1

[2]

- (b) The lamp is connected in series with the 12.0 V battery and a switch. The switch is closed and the potential difference across the lamp increases from 0 to 12.0 V almost immediately.

Fig. 5.2 is the  $V$ - $I$  characteristic graph obtained.



**Fig. 5.2**

- (i) Use Fig. 5.2 to determine the resistance of the lamp when it is operating at 12.0 V.

resistance = ..... [1]

- (ii) Use Fig. 5.2 to estimate the resistance of the lamp when it is switched off.

resistance = ..... [1]

- (iii) Hence, on Fig. 5.3, sketch a graph to suggest how the current in the lamp changes from the moment the lamp is switched on, until the moment the filament reaches its normal operating temperature.



**Fig. 5.3**

[2]

[Total: 6]

**[Turn over**

- 6 A battery of e.m.f. 20 V supplies a current of 8.0 A to the circuit shown in Fig. 6.1.

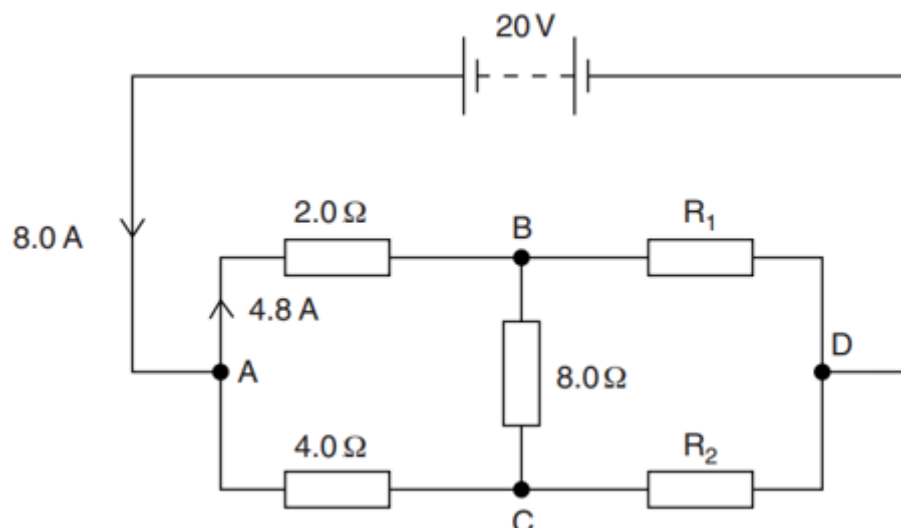


Fig. 6.1

- (a) State what is meant by an e.m.f.

.....  
 .....  
 ..... [1]

At point A, the current divides and there is a current of 4.8 A in the 2.0 Ω resistor.

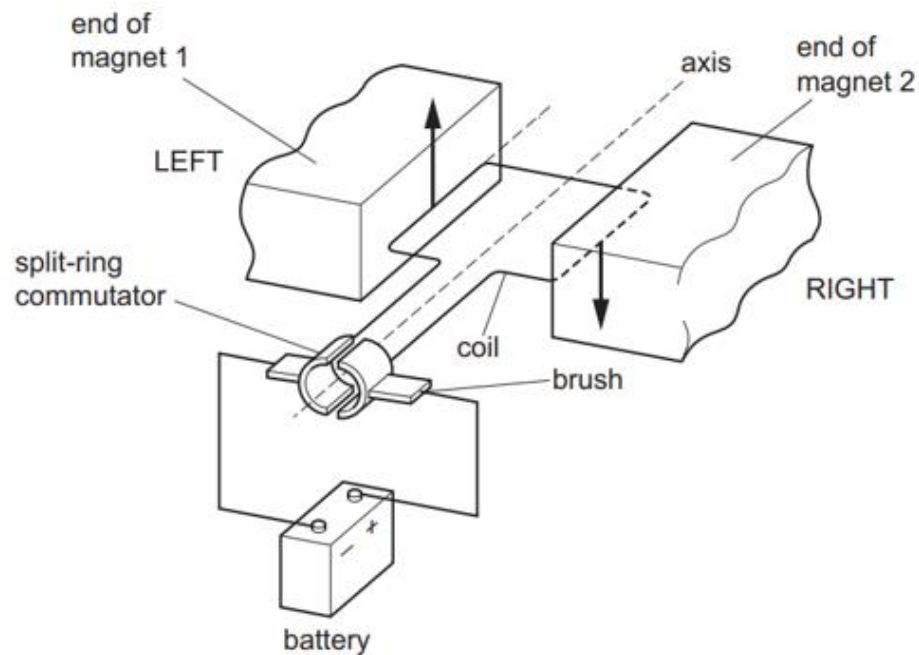
Determine the following values.

You may find it helpful to mark your calculated values on Fig. 6.1 as you proceed.

- |     |                                       |                      |     |
|-----|---------------------------------------|----------------------|-----|
| (b) | p.d. between A and B                  | p.d. = ..... V       | [1] |
| (c) | current from A to C in 4.0 Ω resistor | current = ..... A    | [1] |
| (d) | p.d. between A and C                  | p.d. = ..... V       |     |
| (e) | p.d. between B and C                  | p.d. = ..... V       | [1] |
| (f) | current from B to C in 8.0 Ω resistor | current = ..... A    | [1] |
| (g) | current from B to D in $R_1$          | current = ..... A    |     |
| (h) | current from C to D in $R_2$          | current = ..... A    |     |
| (i) | p.d. between C and D                  | p.d. = ..... V       | [1] |
| (j) | resistance of $R_2$                   | resistance = ..... Ω | [1] |
| (k) | current from D to battery             | current = ..... A    | [1] |

[Total: 8]

- 7 Fig. 7.1 shows a simple d.c. motor. The poles at the ends of the magnets are not labelled.



**Fig. 7.1**

- (a) State the purpose of the split-ring commutator and the brushes.

split-ring commutator .....

.....

brushes .....

.....[2]

- (b) There is an upward force shown on the left side of the coil.  
There is a magnetic field in the space between the ends of the magnets.

State the direction of this magnetic field. Explain how you determined this direction.

.....

.....

.....[3]

- (c) State what happens to the rotation of the coil if the magnetic field and the current in the coil are both reversed at the same time.

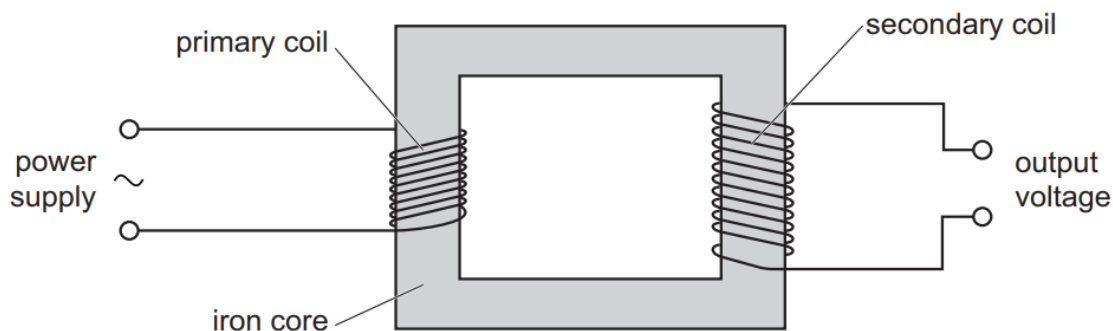
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.....[1]

[Total: 6]

**[Turn over**

- 8 Fig. 8.1 shows an alternating current (a.c.) power supply connected to a transformer.



**Fig. 8.1**

- (a) Explain how an alternating current in the primary coil produces an alternating output voltage.

.....  
 .....  
 .....  
 .....  
 ..... [3]

- (b) A student uses a voltmeter set on a 0 – 10 V range to measure the input and output voltages. She obtains the values shown in Table 8.1.

**Table 8.1**

| input voltage / V | output voltage / V |
|-------------------|--------------------|
| 1.2               | 2.4                |
| 2.3               | 4.6                |
| 4.8               | 9.6                |
| 6.4               | no reading         |

- (i) Suggest why no output voltage reading is obtained with this voltmeter when the input voltage is 6.4 V.

.....  
 ..... [1]

- (ii) The number of turns on the primary coil is 48.

Calculate the number of turns on the secondary coil.

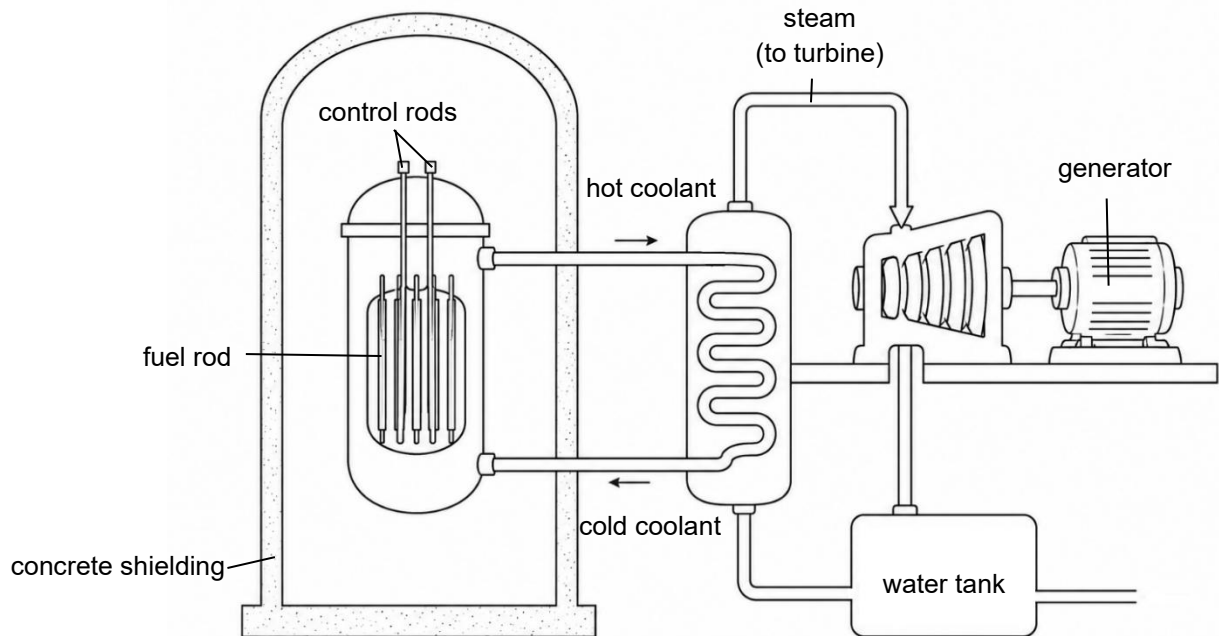
number of turns = ..... [2]  
 [Total: 6]

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**[Turn over**

- 9 Singapore is exploring Small Modular Reactors (SMRs) as a low-carbon energy source. Unlike traditional large power plants, SMRs use smaller amounts of enriched Uranium-235 fuel to produce electricity.

Fig. 9.1 is a diagram of part of a nuclear power plant.



**Fig. 9.1**

Uranium found in nature consists of two main isotopes: uranium-238 and uranium-235.

- (a) State one similarity and one difference between the nuclei of uranium-238 and uranium-235.

similarity .....

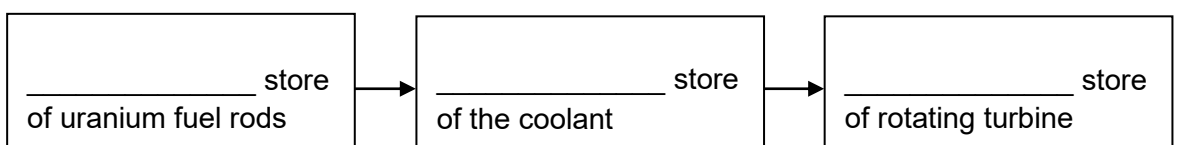
difference .....

[2]

- (b) In the reactor, a slow-moving neutron is absorbed by a uranium-235 nucleus, causing it to become unstable and split.

The splitting of the nucleus releases energy that is transferred to a coolant. This coolant is then used to turn a turbine connected to a generator.

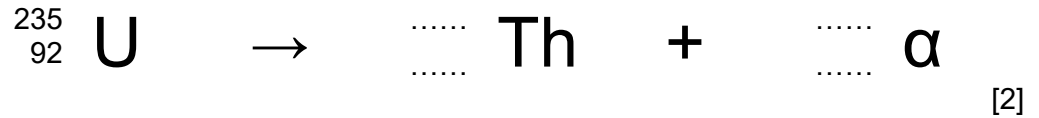
Complete the energy transfer chain below by naming the energy stores:



[2]

- (c) Uranium-235 is unstable and eventually decays by emitting an alpha-particle ( $\alpha$ ) to become a nucleus of Thorium (Th).

(i) Complete the following nuclide equation for this decay:



- (ii) Explain why an alpha-emitter inside a reactor's fuel rod is not a hazard to workers outside the concrete shielding, but would be more hazardous if the radioactive dust were breathed in.

.....  
 .....  
 ..... [2]

- (d) Nuclear fuel is often criticized because its waste remains radioactive for a long time. A sample of radioactive waste from an SMR has an initial count rate of 800 counts/min. Its half-life is 24,000 years.

(i) Calculate the time taken for the count rate of this waste to fall to 100 counts/min.

time taken = ..... [2]

- (ii) A specific SMR receives an energy input of 300 MJ every second and produces a power output of 105 MW. Calculate the efficiency of this SMR.

efficiency = ..... [2]

[Total: 12]

[Turn over

- 10** A company is planning to construct a new office building. It is considering installing an AI-controlled energy management system that automatically adjusts the lighting and air-conditioning according to the number of occupants and the outdoor temperature.

Before making its decision, the company studies data collected from an existing office building fitted with the AI-controlled system. The company also compares the energy consumption with that of a similar office building using conventional controls.

Table 10.1 shows the operating conditions of the building fitted with the AI-controlled system during a typical 12-hour working day.

**Table 10.1**

| time | number of occupants | outdoor temperature / °C | lighting power / kW | air-conditioning power / kW |
|------|---------------------|--------------------------|---------------------|-----------------------------|
| 0800 | 30                  | 28                       | 18                  | 46                          |
| 1000 | 120                 | 31                       | 45                  | 82                          |
| 1200 | 190                 | 34                       | 60                  | 95                          |
| 1400 | 170                 | 35                       | 55                  | 92                          |
| 1600 | 90                  | 33                       | 34                  | 70                          |
| 1800 | 20                  | 29                       | 12                  | 40                          |

Table 10.2 shows the electrical energy consumed during the same working day.

**Table 10.2**

| System                      | conventional building / kWh | AI-controlled building / kWh |
|-----------------------------|-----------------------------|------------------------------|
| Lighting                    | 620                         | 448                          |
| Air-conditioning            | 980                         | 850                          |
| Other electrical appliances | 150                         | 150                          |
| Total                       | 1750                        | 1448                         |

- (a)** Although the number of occupants increases significantly between 0800 and 1200, the indoor temperature remains at a comfortable level.

Explain why the AI system increases the air-conditioning power between 0800 and 1200.

.....

.....

..... [2]

- (b) Determine which electrical system contributes most to the reduction in the total electrical energy consumed.

Support your answer using calculations from Table 10.2.

.....  
 .....  
 ..... [2]

- (c) The office operates for 300 working days each year.

The cost of electricity is \$0.32 per kWh.

- (i) Calculate the annual electricity cost saving achieved by using the AI-controlled system.

cost saving = ..... [2]

- (ii) The AI-controlled system costs \$120 000 to install.  
 The management team expects the AI-controlled system to operate for 8 years.

Using the information provided and your answer to (c)(i), evaluate whether installing the AI-controlled system is a worthwhile investment.

.....  
 .....  
 ..... [2]

[Total: 8]

[Turn over

## Section B

Answer **one** question from this section.

- 11 Fig. 11.1 shows a ray of light striking the left-hand surface of a thin glass converging lens.

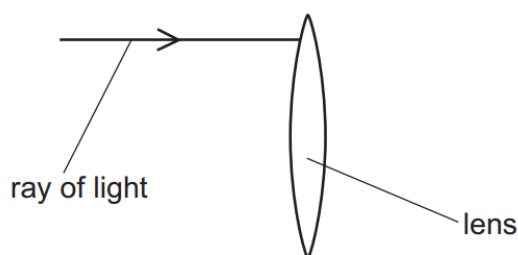


Fig. 11.1

- (a) Explain why the ray refracts and changes direction as it enters the glass.

.....

.....

.....

..... [2]

- (b) Explain what is meant by:

- (i) the principal focus of a lens,

.....

.....

.....

..... [2]

- (ii) the focal length of a lens.

.....

..... [1]

- (c) An object O of height 1.8 cm is placed at a point 2.2 cm to the left of the centre of the lens.

Fig. 11.2 is a full-scale diagram that shows the converging lens, its principal axis and its two principal foci,  $F_1$  and  $F_2$ .

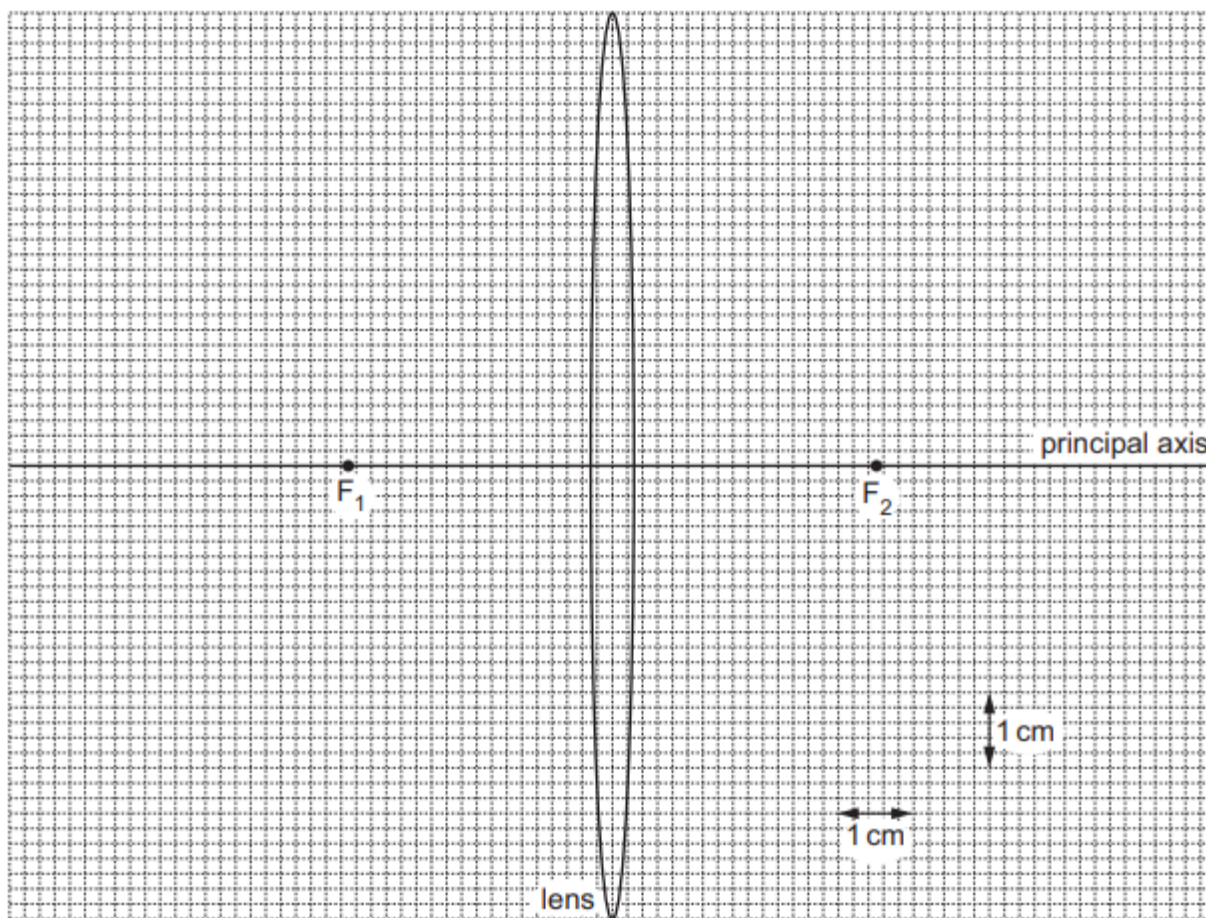


Fig. 11.2

- (i) On Fig. 11.2, draw an arrow to represent the height and position of object O. The arrow should start on the principal axis. [1]
- (ii) On Fig. 11.2, draw two rays from the tip of the arrow drawn in (c)(i) to locate the position of the tip of the image I of object O.

Draw an arrow to represent the image I of the object O. Label the image I. [3]

- (iii) State whether the image I of the object O is a real or a virtual image, and explain your answer.

.....

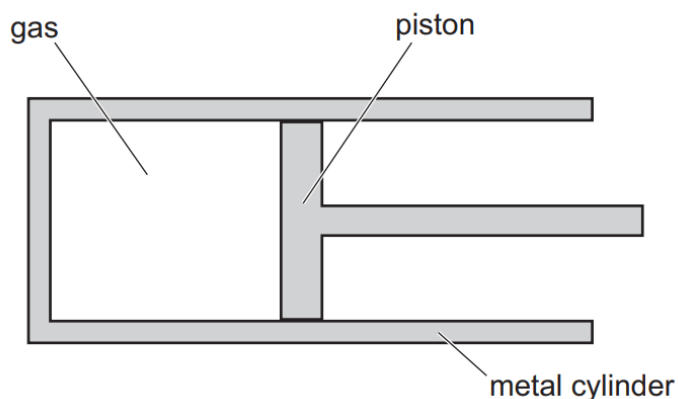
.....

..... [1]

[Total: 10]

[Turn over

- 12 Fig. 12.1 shows gas at room temperature. The gas is trapped in a metal cylinder by a metal piston fixed in position.



**Fig. 12.1**

The pressure of the gas inside the metal cylinder is equal to atmospheric pressure,  $1.0 \times 10^5 \text{ Pa}$ .

The volume of the gas inside the metal cylinder is  $1.2 \times 10^{-4} \text{ m}^3$ .

The area of the end of the piston that is in contact with the gas is  $3.5 \times 10^{-3} \text{ m}^2$ .

The friction between the piston and the metal cylinder is negligible.

- (a) (i) Calculate the force on the piston due to the pressure of the gas inside the metal cylinder.

force = ..... [2]

- (ii) The force on the piston in (a)(i) acts to the right.

Explain why the piston does not move to the right.

.....  
 .....  
 .....  
 ..... [2]

- (b) The metal cylinder is immersed in boiling water and the temperature of the trapped gas increases.

Explain, in terms of electrons and the atoms of the metal, how energy is transferred through the walls of the metal cylinder.

.....

.....

.....

.....

.....

..... [3]

- (c) The piston is fixed in position so the pressure of the gas increases as the temperature of the gas increases.

- (i) State what happens to the motion of the particles of the gas as the temperature increases.

.....

..... [1]

- (ii) Explain, in terms of the particles of the gas, why the pressure the gas exerts on the walls of the metal cylinder increases as the temperature increases.

.....

.....

.....

.....

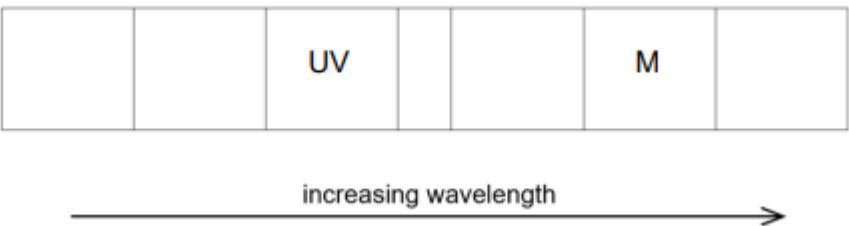
..... [2]

[Total: 10]

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## Answer Key

| No.              | Answer                                                                                                                                                                                     | Marks          |
|------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------|
| <b>Section A</b> |                                                                                                                                                                                            |                |
| 1a               | (In Fig. 1.2) weight vertically down and (tension) force in string<br>force of wind on kite upwards and to right<br>three forces shown in equilibrium (by eye)                             | B1<br>B1<br>B1 |
| 1b               | There is now a resultant force acting on the kite, (which causes it to accelerate).                                                                                                        | B1             |
| 2a               | $60 \times 1.6$ (= 96 N m) or $220 \times 0.40$ (= 88 N m)<br>resultant moment = $96 - 88$<br>= 8.0 Nm (clockwise)                                                                         | C1<br>A1       |
| 2b               | line with a positive gradient from $(t_1, 0)$ to $t_2$<br>line with increasing positive gradient from $t_1$ to $t_2$                                                                       | B1<br>B1       |
| 2c               | $F = ma$ and $a = (\Delta)v / (\Delta)t$<br>( $m =$ ) $5500 / (8.5 / 0.36) = 230$ kg or 233 kg                                                                                             | C1<br>A1       |
| 3ai              | 370 N                                                                                                                                                                                      | B1             |
| 3aii             | (work done = ) $Fs$ or $370 \times 13$<br>4800 J or 4810 J                                                                                                                                 | C1<br>A1       |
| 3b               | (energy =) $VIt$ or $230 \times 5.6 \times 11$<br>$1.4 \times 10^4$ J                                                                                                                      | C1<br>A1       |
| 3c               | any <b>two</b> from:<br><br>(work done / GPE) to lift the cage / cable<br>(energy transferred) electrically to internal store of motor<br>(work done) overcoming friction / air resistance | B2             |
| 4a               |                                                                                                        | B1             |
| 4bi              | $(\lambda =) \frac{c}{f}$ or $(3.0 \times 10^8)/(2.5 \times 10^9)$ or $1.2 \times 10^x$ m<br>0.12 m                                                                                        | C1<br>A1       |
| 4bii             | to prevent microwaves escaping / leaving the oven / spreading out of the device<br>can cause burns (in living tissue / people) / damage to tissue through heating / blisters               | B1<br>B1       |
| 4c               | the live wire<br>ensure the high-voltage supply is isolated from the appliance when the door is open                                                                                       | B1<br>B1       |
| 5a               | variable potential divider (powering lamp)<br>ammeter, voltmeter and lamp connected correctly<br><i>reject rheostat</i>                                                                    | B1<br>B1       |
| 5bi              | $6.00 \Omega$ <b>cao</b>                                                                                                                                                                   | B1             |
| 5bii             | 2.35 – 2.65 ( $\Omega$ )                                                                                                                                                                   | B1             |
| 5biii            | decreasing resistance/negative gradient<br>decreasing resistance/negative gradient and then horizontal section                                                                             | C1<br>A1       |
| 6a               | work done by a source to drive a unit charge around a complete circuit                                                                                                                     | B1             |

[Turn over

|      |                                                                                                                                                                                                                                                                                                                                                                                 |                        |
|------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------|
| 6b   | 9.6(V) (pd AB = $4.8 \text{ A} \times 2.0 \Omega$ )                                                                                                                                                                                                                                                                                                                             | 1                      |
| 6c   | 3.2(A) (current A to C = $8.0 \text{ A} - 4.8 \text{ A}$ )                                                                                                                                                                                                                                                                                                                      | 1                      |
| 6d   | 12.8(V) (pd AC = $3.2 \text{ A} \times 4.0 \Omega$ ) <b>ecf from (c)</b>                                                                                                                                                                                                                                                                                                        | Both                   |
| 6e   | 3.2(V) (pd BC = $12.8 \text{ V} - 9.6 \text{ V}$ ) <b>ecf from (b) and (d)</b>                                                                                                                                                                                                                                                                                                  | 1                      |
| 6f   | 0.4(A) (current BC = $3.2 \text{ V} / 8.0 \Omega$ ) <b>ecf from (e)</b>                                                                                                                                                                                                                                                                                                         | 1                      |
| 6g   | 4.4(A) (current BD = $4.8 \text{ A} - 0.4 \text{ A}$ ) <b>ecf from (f)</b>                                                                                                                                                                                                                                                                                                      | All                    |
| 6h   | 3.6(A) (current CD = $8.0 \text{ A} - 4.4 \text{ A}$ ) <b>ecf from (g)</b>                                                                                                                                                                                                                                                                                                      | three                  |
| 6i   | 7.2V (pd CD = $20 \text{ V} - 12.8 \text{ V}$ ) <b>ecf from (d)</b>                                                                                                                                                                                                                                                                                                             | 1                      |
| 6j   | 2.0( $\Omega$ ) (resistance $R_2 = 7.2 \text{ V} / 3.6 \text{ A}$ ) <b>ecf from (h) and (i)</b>                                                                                                                                                                                                                                                                                 | 1                      |
| 6k   | 8.0(A) (current from D to battery)                                                                                                                                                                                                                                                                                                                                              | 1                      |
| 7a   | split ring commutator: to reverse the direction of current in the coil every half turn / revolution / twice in one turn / every $180^\circ$ / when coil is vertical<br><br>brushes: to connect coil / commutator or (split) rings to battery / (external) circuit or to provide current to coil, commutator or (split) rings<br>or to avoid wires (to coil) tangling / twisting | B1<br><br>B1           |
| 7b   | direction: (from left) to right / from magnet 1 to magnet 2<br>explanation:<br>current is from plus to minus / towards front / out of plane / page / outwards / top to bottom of wire / downwards along wire / towards the split ring on the left<br>left-hand rule mentioned and explained using two of current, field or motion / force                                       | B1<br><br>B1<br><br>B1 |
| 7c   | no change                                                                                                                                                                                                                                                                                                                                                                       | B1                     |
| 8a   | magnetic field produced by current (in primary)<br>(iron) core links / transmits magnetic field to secondary coil<br>changing / reversing / alternating magnetic field induces output voltage (in secondary coil)                                                                                                                                                               | B1<br>B1<br>B1         |
| 8bi  | off the scale (of the voltmeter) / too large (for voltmeter)                                                                                                                                                                                                                                                                                                                    | B1                     |
| 8bii | $V_s / V_p = N_p / N_s$ in any form<br>96                                                                                                                                                                                                                                                                                                                                       | C1<br>A1               |
| 9a   | similarity: (same) number of protons<br>difference: (different) number of neutrons                                                                                                                                                                                                                                                                                              | B1<br>B1               |
| 9b   | nuclear (store of uranium fuel rods)<br>internal (store of the coolant)<br>kinetic (store of rotating turbine)<br><br><i>award B1 for any 1 correct</i>                                                                                                                                                                                                                         | B2                     |
| 9ci  | 231 nucleon number and 90 proton number of Th<br>4 nucleon number and 2 proton number of alpha                                                                                                                                                                                                                                                                                  | B1<br>B1               |
| 9cii | alpha particles have <u>low penetrating ability</u> / are absorbed by the fuel rod and concrete shielding (and cannot reach workers outside the reactor)<br>if breathed in, alpha particles are emitted inside the body where they are <u>highly ionising</u> , causing damage to body cells                                                                                    | B1<br><br>B1           |
| 9di  | $800 \rightarrow 400 \rightarrow 200 \rightarrow 100$ or any indication of 3 half lifes<br>72000 years                                                                                                                                                                                                                                                                          | C1<br>A1               |
| 9dii | useful power output / total power input $\times 100$ or $105/300$<br>35%                                                                                                                                                                                                                                                                                                        | C1<br>A1               |
| 10a  | more occupants and/or a higher outdoor temperature increase indoor temperature                                                                                                                                                                                                                                                                                                  | B1                     |

|                  |                                                                                                                                                                                                                                                                                                                                   |                                                                                                                                 |
|------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------|
|                  | (to maintain a constant indoor temperature,) the air-conditioning system must transfer more energy out of the building at the same rate.                                                                                                                                                                                          | B1                                                                                                                              |
| 10b              | lighting: $620 - 448 = 172$ kWh <b>AND</b> air-conditioning: $980 - 850 = 130$ kWh<br>lighting contributes the greater reduction                                                                                                                                                                                                  | M1<br>A1                                                                                                                        |
| 10ci             | energy saved per day: $1750 - 1448 = 302$ kWh<br>annual energy saved: $302 \times 300 = 90\,600$ kWh<br>cost saving: $90\,600 \times 0.32 = \$28\,992 \approx \$29\,000$                                                                                                                                                          | C1<br>A1                                                                                                                        |
| 10cii            | payback period: $120000 \div 28992 = 4.1$ years<br>worthwhile investment as cost is recovered before the expected operating lifetime<br><i>allow ecf from 10ci</i>                                                                                                                                                                | cost savings: $\$28992 \times 8 = \$232000$<br>worthwhile investment as cost savings is more than installation cost<br>M1<br>A1 |
| <b>Section B</b> |                                                                                                                                                                                                                                                                                                                                   |                                                                                                                                 |
| 11a              | any <b>two</b> from:<br>(in glass) light travels more slowly / at a different speed<br>enters (an optically) denser medium/ medium with different refractive index<br>wavelength changes (and frequency stays the same)<br>angle of incidence is greater than 0                                                                   | B2                                                                                                                              |
| 11bi             | point where parallel rays meet / converge (after refraction)<br>point where rays parallel to principal axis meet / converge (after refraction / passing through lens)                                                                                                                                                             | C1<br>A1                                                                                                                        |
| 11bii            | <u>distance</u> between principal focus / focal point and (centre of) lens                                                                                                                                                                                                                                                        | B1                                                                                                                              |
| 11ci             | arrow of height 1.8 cm <b>and</b> 2.2 cm <b>and</b> on left of the centre of the lens                                                                                                                                                                                                                                             | B1                                                                                                                              |
| 11cii            | any <b>two</b> from:<br>paraxial ray from tip of O to lens <b>and</b> from lens to $F_2$<br>straight ray through centre of lens<br>ray that seems to come from $F_1$ from tip of O to lens <b>and</b> emerges paraxially from lens<br>two rays traced back to image labelled I<br><i>deduct 1 mark for missing arrows from M2</i> | M2<br>A1                                                                                                                        |
| 11ciii           | virtual and rays seem / appear to come from I / do not pass through the image / object distance less than focal length / the image is upright                                                                                                                                                                                     | B1                                                                                                                              |
| 12ai             | ( $F =$ ) pA <b>or</b> $1.0 \times 10^5 \times 3.5 \times 10^{-3}$<br>350 N                                                                                                                                                                                                                                                       | C1<br>A1                                                                                                                        |
| 12aii            | force to left <b>or</b> force due to atmospheric pressure / pressure of air surrounding the syringe<br>no resultant force (on piston) <b>or</b> (two) forces balance <b>or</b> forces in equilibrium                                                                                                                              | B1<br>B1                                                                                                                        |
| 12b              | vibrating atoms / particles (ignore electrons) collide and pass energy<br>atoms collide with electrons which move (a long distance) through metal<br>(moving) electrons collide / interact with distant atoms (ignore electrons) or electrons carry energy (through metal)                                                        | B1<br>B1<br>B1                                                                                                                  |
| 12ci             | their / the particles' (average) speed increases                                                                                                                                                                                                                                                                                  | B1                                                                                                                              |
| 12cii            | particles collide with the walls more frequently <b>AND</b> with greater force<br>pressure is the average force exerted per unit area                                                                                                                                                                                             | B1<br>B1                                                                                                                        |

[Turn over