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K&U PS

C

NATIONAL QUALIFICATIONS 2013

PHYSICS
STANDARD GRADE
Credit Level

MONDAY, 27 MAY
10.50 AM – 12.35 PM

3220310 1

3220/31/01

Fill in these boxes and read what is printed below.

Full name of centre | Town

Forename(s) | Surname | Number of seat

Date of birth
Day | Month | Year

Scottish candidate number

Reference may be made to the Physics Data Booklet.

1 All questions should be answered.

2 The questions may be answered in any order but all answers must be written clearly and legibly in this book.

3 Write your answer where indicated by the question or in the space provided after the question.

4 If you change your mind about your answer you may score it out and rewrite it in the space provided at the end of the answer book.

5 If you use the additional space at the end of the answer book for answering any questions, you **must** write the correct question number beside each answer.

6 Before leaving the examination room you must give this book to the Invigilator. If you do not, you may lose all the marks for this paper.

7 Any necessary data will be found in the **data sheet** on page three.

8 Care should be taken to give an appropriate number of significant figures in the final answers to questions.

Use **blue** or **black ink**. Pencil may be used for graphs and diagrams only.

SQA ©

3220310 1

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DATA SHEET

Speed of light in materials

Material	*Speed in* m/s
Air	$3{\cdot}0 \times 10^8$
Carbon dioxide	$3{\cdot}0 \times 10^8$
Diamond	$1{\cdot}2 \times 10^8$
Glass	$2{\cdot}0 \times 10^8$
Glycerol	$2{\cdot}1 \times 10^8$
Water	$2{\cdot}3 \times 10^8$

Speed of sound in materials

Material	*Speed in* m/s
Aluminium	5200
Air	340
Bone	4100
Carbon dioxide	270
Glycerol	1900
Muscle	1600
Steel	5200
Tissue	1500
Water	1500

Gravitational field strengths

	Gravitational field strength on the surface in N/kg
Earth	10
Jupiter	26
Mars	4
Mercury	4
Moon	1·6
Neptune	12
Saturn	11
Sun	270
Venus	9

Specific heat capacity of materials

Material	*Specific heat capacity in* J/kg °C
Alcohol	2350
Aluminium	902
Copper	386
Glass	500
Glycerol	2400
Ice	2100
Lead	128
Silica	1033
Water	4180

Specific latent heat of fusion of materials

Material	*Specific latent heat of fusion in* J/kg
Alcohol	$0{\cdot}99 \times 10^5$
Aluminium	$3{\cdot}95 \times 10^5$
Carbon dioxide	$1{\cdot}80 \times 10^5$
Copper	$2{\cdot}05 \times 10^5$
Glycerol	$1{\cdot}81 \times 10^5$
Lead	$0{\cdot}25 \times 10^5$
Water	$3{\cdot}34 \times 10^5$

Melting and boiling points of materials

Material	*Melting point in* °C	*Boiling point in* °C
Alcohol	–98	65
Aluminium	660	2470
Copper	1077	2567
Glycerol	18	290
Lead	328	1737
Turpentine	–10	156

Specific latent heat of vaporisation of materials

Material	*Specific latent heat of vaporisation in* J/kg
Alcohol	$11{\cdot}2 \times 10^5$
Carbon dioxide	$3{\cdot}77 \times 10^5$
Glycerol	$8{\cdot}30 \times 10^5$
Turpentine	$2{\cdot}90 \times 10^5$
Water	$22{\cdot}6 \times 10^5$

SI Prefixes and Multiplication Factors

Prefix	*Symbol*	*Factor*
giga	G	$1\,000\,000\,000 = 10^9$
mega	M	$1\,000\,000 = 10^6$
kilo	k	$1000 = 10^3$
milli	m	$0{\cdot}001 = 10^{-3}$
micro	μ	$0{\cdot}000\,001 = 10^{-6}$
nano	n	$0{\cdot}000\,000\,001 = 10^{-9}$

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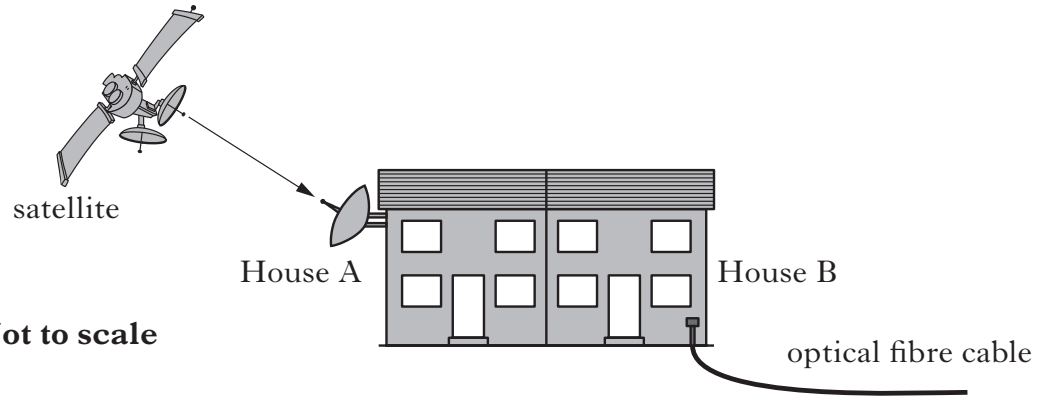
1. Two next door neighbours are watching a football match on television. The event is being broadcast live. Signals are sent at the same time to a geostationary satellite and to an optical fibre system. House A receives the television signal from the satellite while House B receives the signal through an optical fibre cable.



Not to scale

(*a*) State what is meant by a geostationary satellite.

.....

.....

1

(*b*) What is an optical fibre?

.....

1

(*c*) Complete the table below by entering the speed of each signal.

Signal	*Transmission speed in* m/s
Satellite	
Optical fibre	

2

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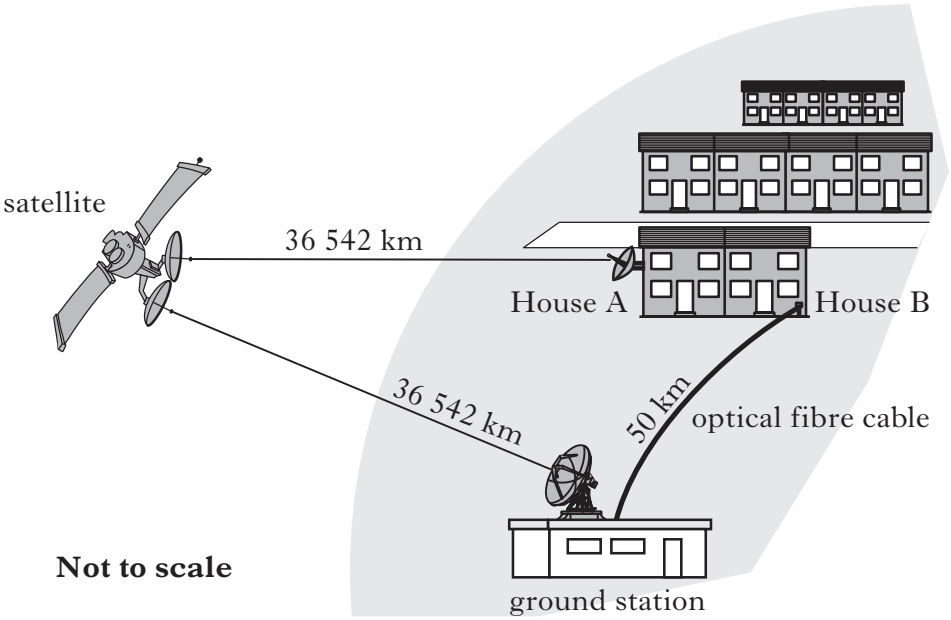
1. (continued)

(*d*) The distance travelled by each signal is shown on the diagram.



Not to scale

One neighbour hears cheering from the house next door before seeing a goal being scored.

Calculate the time delay between hearing the cheer and seeing the goal being scored.

Space for working and answer

3

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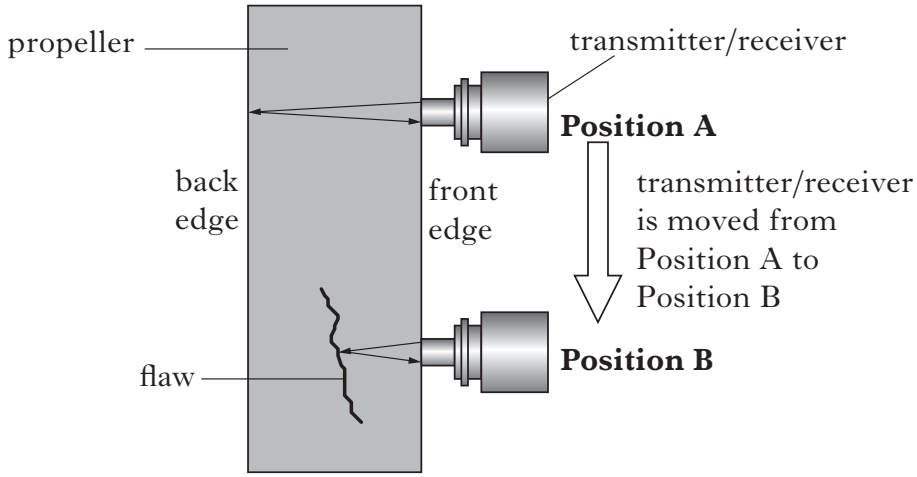
2. In the aircraft industry non-destructive metal testing is used to look for flaws in aluminium propellers.

Ultrasound pulses are sent from a transmitter into the propeller being tested. If there are no flaws in the propeller the ultrasound will be reflected from the back edge of the propeller as shown at position A. The reflected signal is detected by a receiver. If a flaw is present inside the propeller a reflection from the flaw will take place inside the propeller as shown at position B.



(*a*) What is meant by ultrasound?

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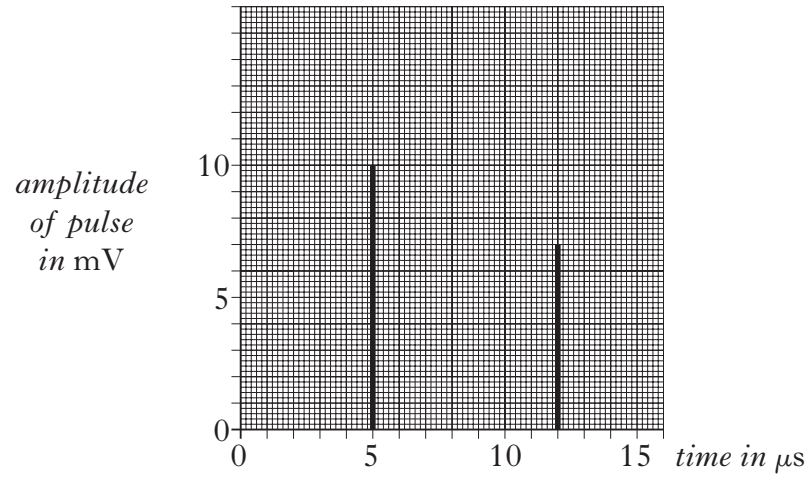
1

(*b*) The graph shows the time taken between transmitting and receiving the pulses at positions A and B.



2. (*b*) (continued)

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(i) State the time taken between transmitting and receiving the pulse at position B.

.....

1

(ii) Use the data sheet to find the speed of the ultrasound waves in the aluminium propeller.

.....

1

(iii) Calculate the distance of the flaw from the front edge of the propeller.

Space for working and answer

3

(iv) The frequency of the ultrasound pulses is 15 MHz.

Calculate the wavelength of the ultrasound pulses in the propeller.

Space for working and answer

2

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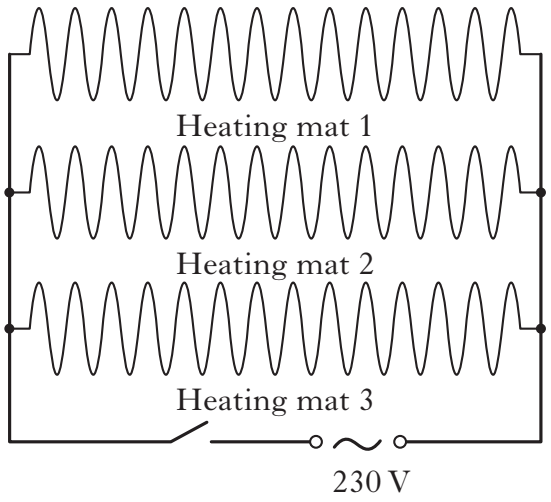
3. A house owner installs a heating system under the floor of a new conservatory.

Three heating mats are fitted. The mats contain resistance wires and are laid underneath the floor.

Each mat is designed to operate at 230 V and has a power of 300 W.



(*a*) State how the three heating mats are connected together to operate at their correct voltage.

.....

1

(*b*) Calculate the current in each heating mat when switched on.

Space for working and answer

2

3. (continued)

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(*c*) Calculate the total resistance of the heating system when all three mats are switched on.

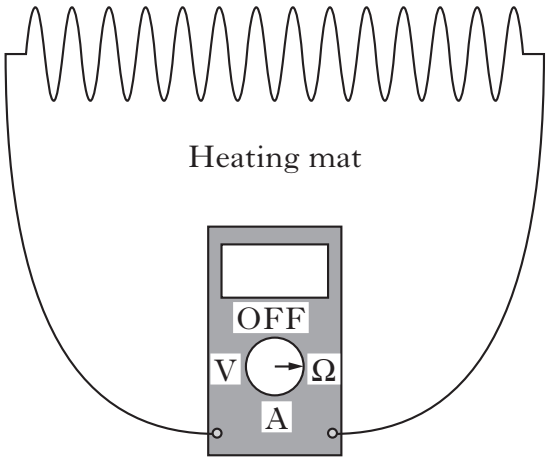
Space for working and answer

3

(*d*) One day, when the heating system is switched on, one section of the floor remains cold.

The house owner suspects that one of the heating mats is faulty.

After disconnecting this mat from the supply it is connected to an ohmmeter.



Explain how the reading on the ohmmeter would help confirm that this mat was faulty.

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1

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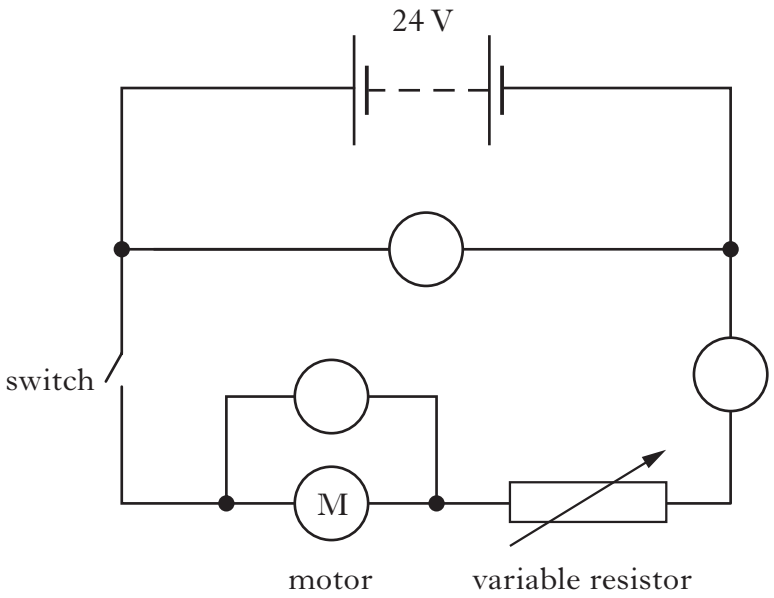
4. A student has designed a simple electric cart. The cart uses 2 large 12 V rechargeable batteries to drive an electric motor. The speed of the cart is controlled by adjusting a variable resistor. The circuit diagram for the cart is shown.



(*a*) The circuit contains two voltmeters and an ammeter.

Complete the diagram by labelling the meters. **1**

(*b*) When the cart is moving at a certain speed the voltage across the motor is 18 V and the resistance of the variable resistor is 2·1 Ω.

Calculate the current in the motor.

Space for working and answer

3

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4. (continued)

(*c*) The batteries take 10 hours to fully recharge using a constant charging current of 3·2 A.

Calculate how much charge is transferred to the batteries in this time.

Space for working and answer

2

(*d*) For the cart to be able to reverse, the motor has to rotate in the opposite direction.

State **one** change which could be made to the circuit to make the motor rotate in the opposite direction.

.....

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1

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5. A wildlife photographer uses a camera to take photographs while on safari.

(*a*) The camera lens has a focal length of 400 mm.

Calculate the power of the lens.

Space for working and answer

2

(*b*) The photographer is short sighted.

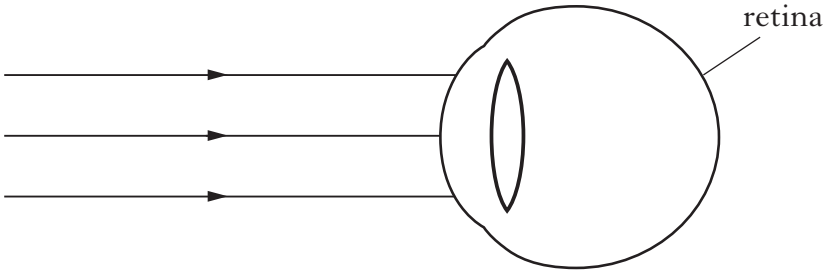
(i) State what is meant by short sight.

.....

.....

1

(ii) The diagram below shows light rays from a distant object entering the photographer's eye.



Complete the diagram to show how the light rays reach the retina of the photographer's eye.

1

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5. (*b*) (continued)

(iii) Name the type of lens used to correct short sight.

.....

1

(*c*) The photographer has laser eye surgery. The laser used in the procedure produces 250 pulses of light per second. Each light pulse transfers 60 mJ of energy.

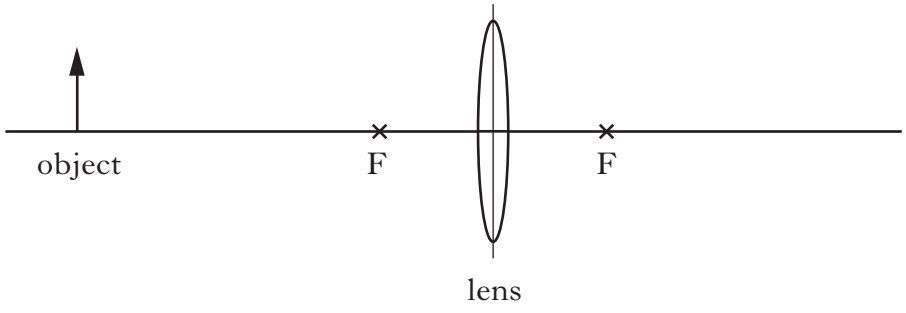
Calculate the average power produced by each pulse of light.

Space for working and answer

3

(*d*) Complete the diagram below to show how the lens in the eye produces an image of the object shown.

The points marked F are one focal length from the centre of the lens.



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6. The thyroid gland is important for good health as it regulates the rate at which the body produces energy.

Two radioactive sources of iodine are used in medicine. The table shows some of the properties of these sources.

Radioactive Source	*Radiation Emitted*	*Half-Life*
Iodine-123	Gamma	13 hours
Iodine-131	Beta	8 days

One of the sources is injected into the body of a patient as a tracer to diagnose problems in the thyroid gland. The other source is injected into the body to treat cancer of the thyroid gland.

(*a*) Explain why Iodine-123 should be used as a tracer to diagnose problems in the thyroid gland.

.....

.....

1

(*b*) The patient is injected with a sample of Iodine-123. The sample has an activity of 12 MBq when injected.

The patient had a check-up at 8 am on May 3rd and the activity is now 1·5 MBq.

Calculate the time and date when the Iodine-123 was injected.

Space for working and answer

2

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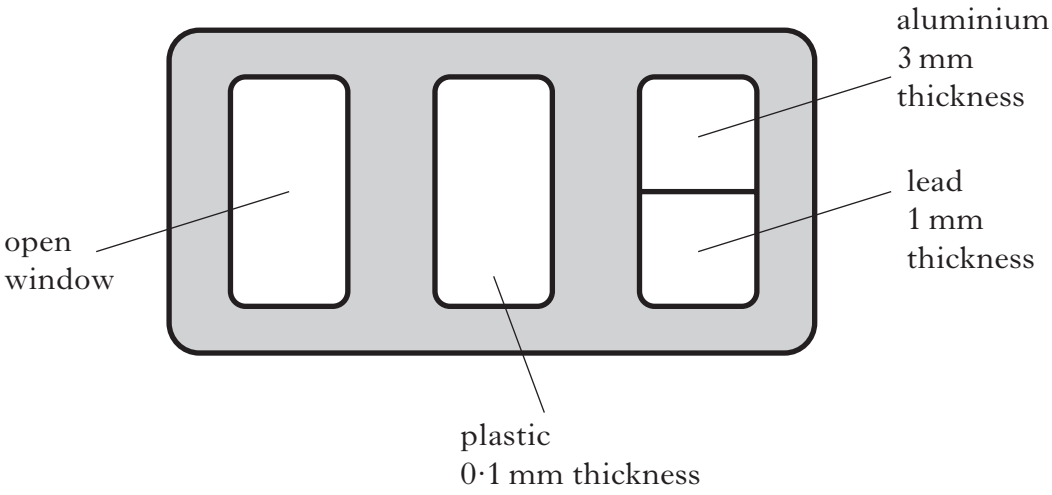
6. (continued)

(*c*) Some hospital staff wear film badges to monitor their exposure to radiation. The film is contained in a plastic holder with windows of different materials as shown in the diagram. Light cannot reach the film.



(i) Shade the window or windows where the film would be affected if the wearer is exposed to the Iodine-123 isotope. **1**

(ii) Describe how the badge would be used to indicate how much radiation the member of staff has been exposed to.

.....

..... **1**

[Turn over

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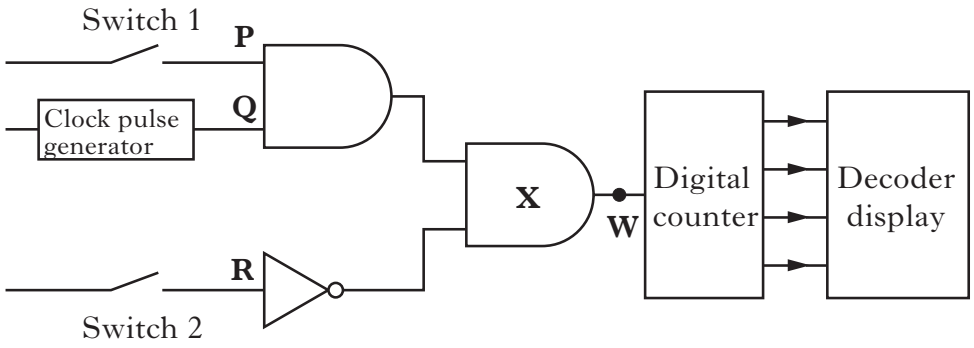
7. A teacher constructs a simple reaction timer to test a student's reaction time. The circuit diagram for the timer is shown.



When the teacher closes Switch 1 the timer starts and a lamp lights. The student sees the lamp light and closes Switch 2, stopping the timer.

When Switch 1 is closed the logic level at **P** changes from 0 to 1.

When Switch 2 is closed the logic level at **R** changes from 0 to 1.

Clock pulses are produced at **Q**.

(*a*) Name the logic gate **X**.

.....

1

(*b*) The table shows the different possible combinations of logic levels (0 or 1) for the inputs at **P**, **Q**, **R** and output **W** from gate **X**. The top and bottom rows of column **W** have been completed.

Complete the last column of the table by **drawing** the output **W** from gate **X**.

P	Q	R	W
1 0			
1 0			
1 0			
1 0			

2

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7. (continued)

(*c*) The circuit contains a digital counter, decoder and display.

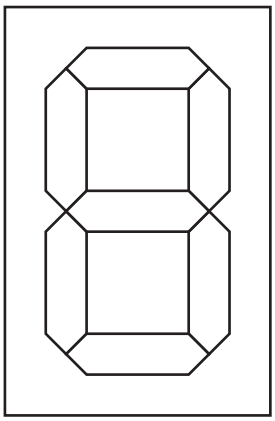
The counter is reset and after one reaction test the output of the counter is 0111.

(i) Convert the counter output from binary to decimal.

Space for working and answer

1

(ii) On the diagram of the display below shade in the sections which should be illuminated to show this number.



1

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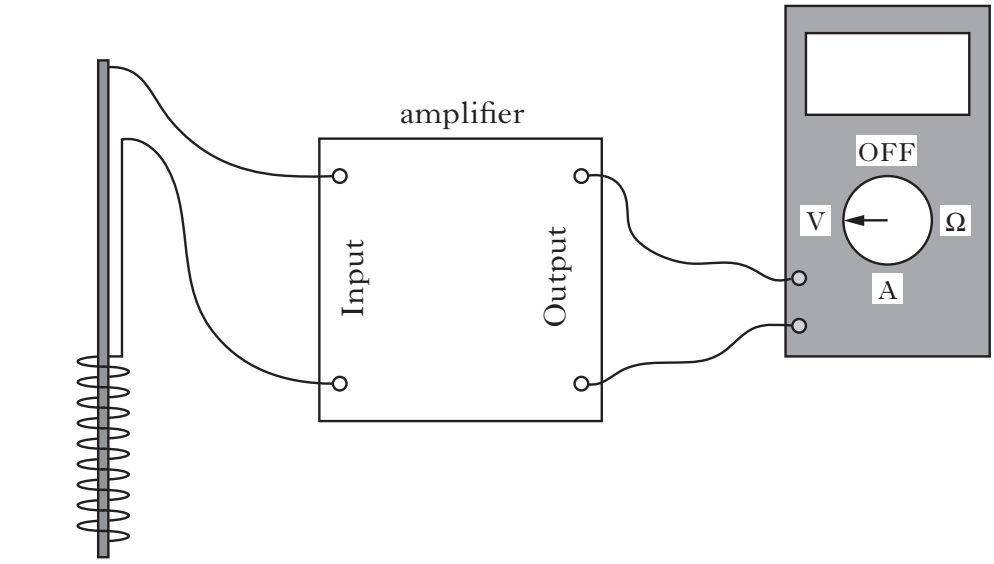
8. A student designs a circuit for an electronic thermometer.



thermocouple

The circuit uses a thermocouple which generates a small voltage when heated. This voltage is amplified and displayed on the voltmeter. The reading on the voltmeter can be converted into a temperature reading.

(*a*) At a temperature of 40 °C the thermocouple produces a voltage of 0·02 mV. The voltmeter reading at this temperature is 0·5 V.

Calculate the voltage gain of the amplifier.

Space for working and answer

2

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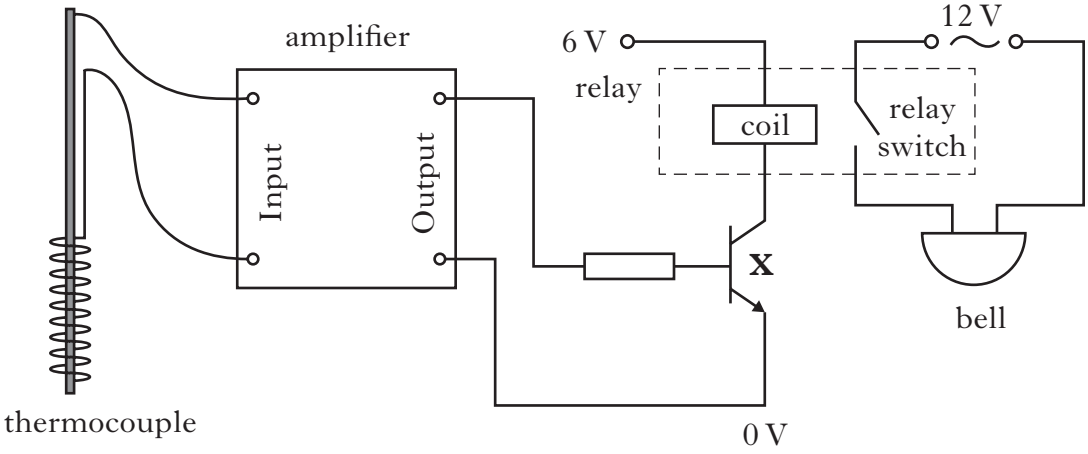
8. (continued)

(*b*) The student modifies the circuit as shown to act as a high temperature warning circuit.



(i) Name component **X**.

.....

1

(ii) Explain how the circuit operates to sound the bell when the temperature of the thermocouple reaches a certain value.

.....

.....

.....

.....

.....

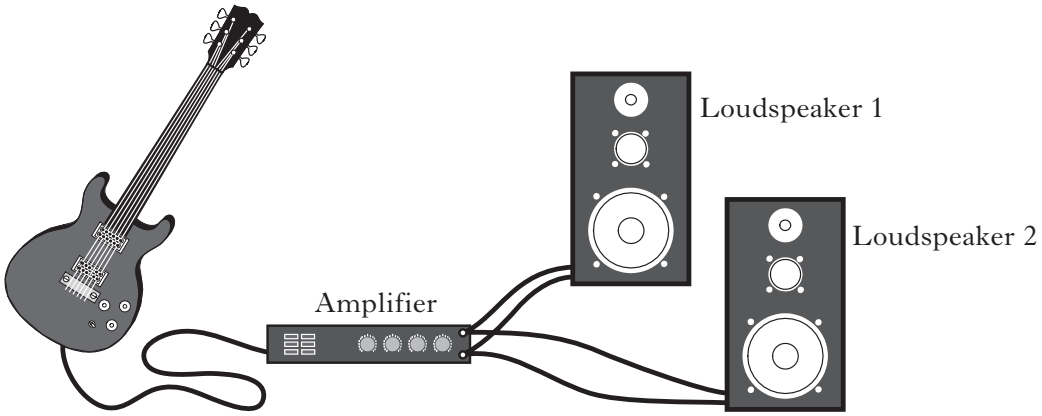
2

[Turn over

8. (continued)

Marks

(*c*) The student also plays an electric guitar. The guitar is connected to a different amplifier and two loudspeakers as shown.



(i) The guitar produces a maximum power of 20 mW. The amplifier has a power gain of 4000.

Calculate the output power of the amplifier.

Space for working and answer

2

(ii) Each loudspeaker has a resistance of 16 Ω.

Calculate the combined resistance of the two loudspeakers when connected as shown.

Space for working and answer

2

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[Turn over for Question 9 on *Page twenty-two*

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9. At an athletics meeting runners are trying to qualify for the Commonwealth Games in Glasgow in 2014.

In order to qualify for the 200 m race, the runners have to complete the race in a time of 21·4 s or less.

The table gives some information about the runner in each lane.

Lane	*Average speed* (m/s)
1	9·26
2	9·46
3	9·31
4	9·42
5	9·38
6	9·34

(*a*) What is meant by the term "average speed"?

.....

.....

1

(*b*) Which runners qualify for the Commonwealth Games?

You must justify your answer.

Space for working and answer

3

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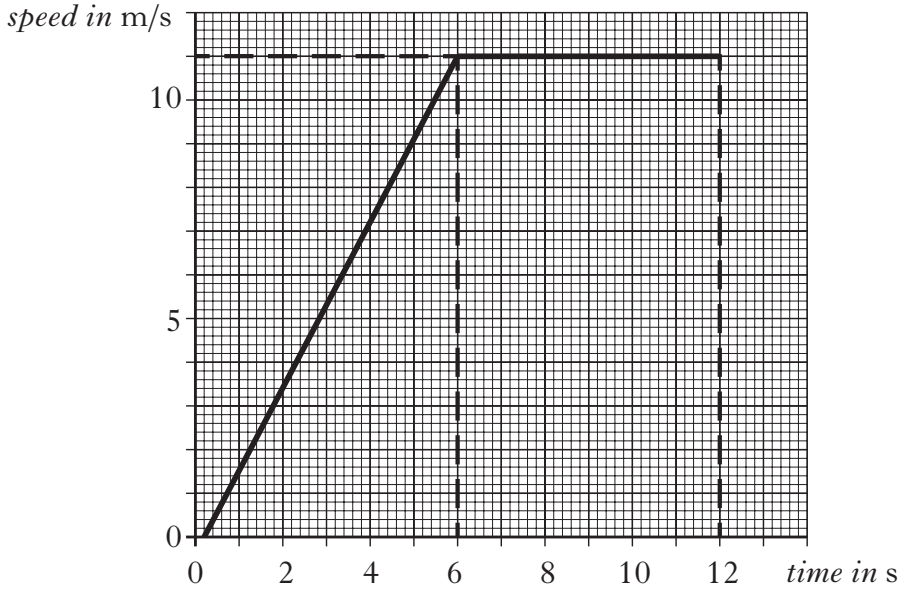
9. (continued)

(*c*) The graph shows the motion of the runner in lane 5 for the first 12 s of the race.



(i) Calculate the acceleration of the runner.

Space for working and answer

2

(ii) Calculate the distance travelled by the runner in the first 12 s.

Space for working and answer

2

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10. A child of mass 42 kg is playing on a water slide at a water park.

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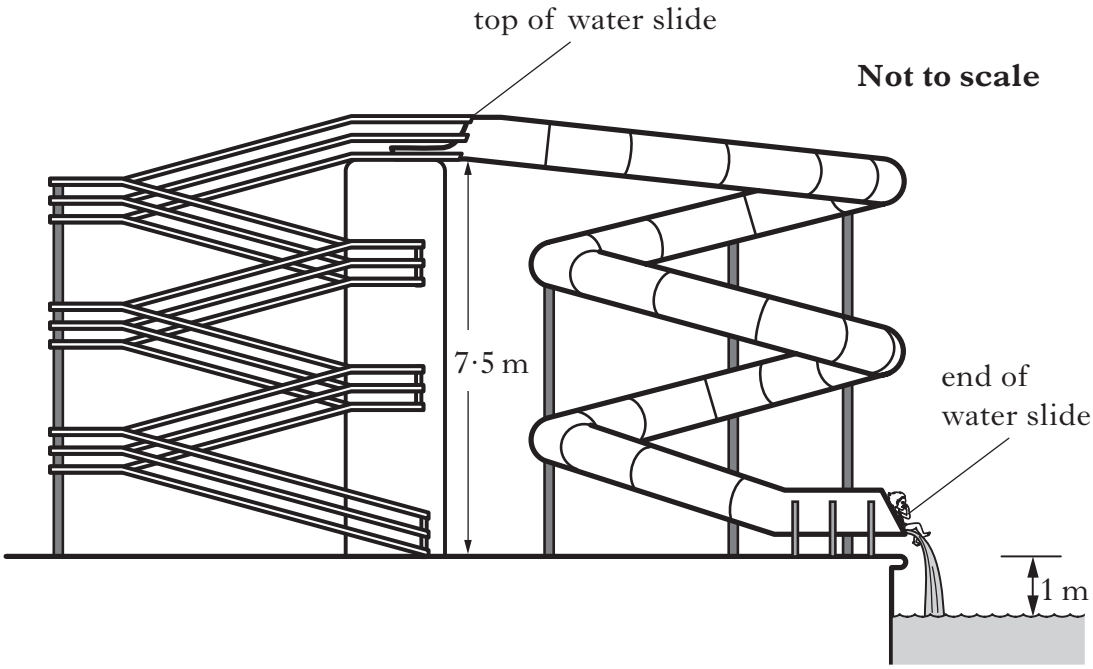

(*a*) The child climbs 7·5 m to the top of the slide.

Calculate the gain in potential energy of the child.

Space for working and answer

2

(*b*) When sliding down, an average frictional force of 15 N acts on the child. This causes 1050 J of heat energy to be produced.

Calculate the length of the slide.

Space for working and answer

2

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10. (continued)

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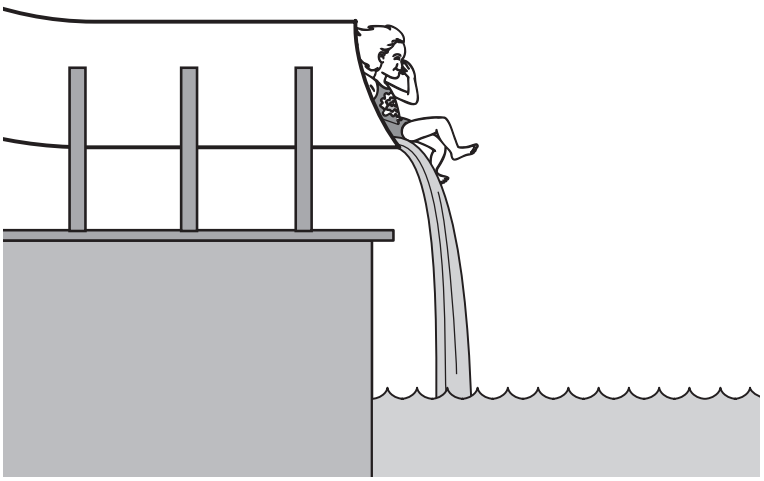
(*c*) Calculate the speed of the child at the end of the slide.

Space for working and answer

3

(*d*) Sketch the path the child would take on leaving the end of the slide.



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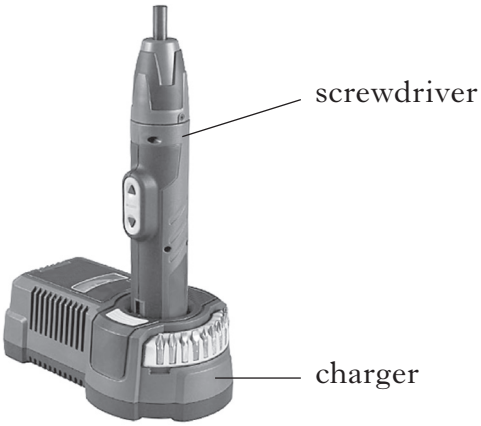
11. A transformer is used in a charger for a rechargeable screwdriver.



The transformer steps down the mains voltage from 230 V to 2·9 V. The screwdriver is placed in the charger to recharge its battery.

(*a*) The primary coil of the transformer has 4760 turns.

Calculate the number of turns in the secondary coil, assuming that the transformer is 100% efficient.

Space for working and answer

2

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11. (continued)

(*b*) The output power of the transformer is 4·06 W.
In practice the transformer is only 35% efficient.
Calculate the current in the primary coil.

Space for working and answer

3

(*c*) State **one** reason why transformers are not 100% efficient.

.....

1

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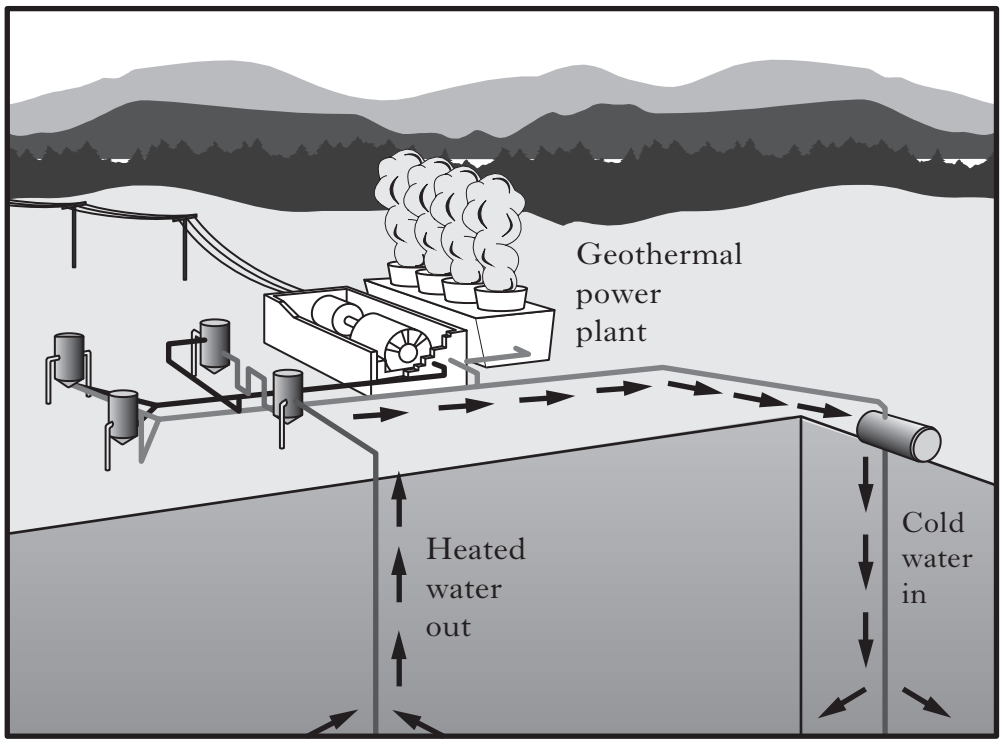
12. An experimental geothermal power plant uses heat energy from deep underground to produce electrical energy. A pump forces water at high pressure down a pipe. The water is heated and returns to the surface. At this high pressure the boiling point of water is 180 °C.



The plant is designed to pump 82 kg of heated water, to the surface, each second. The specific heat capacity of this water is 4320 J/kg °C.

(*a*) The water enters the ground at 20 °C and emerges at 145 °C.

Calculate the heat energy absorbed by the water each second.

Space for working and answer

2

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12. (continued)

(*b*) The hot water is fed into a heat exchanger where 60% of this heat energy is used to vapourise another liquid into gas. This gas is used to drive a turbine which generates electrical energy.

The specific latent heat of vapourisation for this liquid is $3{\cdot}42 \times 10^5$ J/kg .

Calculate the mass of this liquid which is vapourised each second.

Space for working and answer

3

(*c*) Geothermal is a source of renewable energy.

(i) State **one** other renewable energy source.

.....

1

(ii) State **one** advantage and **one** disadvantage of this source.

Advantage .....

Disadvantage .....

1

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13. In 2014 the European Space Agency will fly a manned mission to the International Space Station (ISS).

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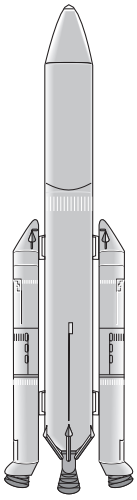

A spacecraft with booster rockets attached will be launched.

(*a*) On the diagram above draw and label the two forces acting on the spacecraft at lift off. **1**

(*b*) The combined mass of the spacecraft and booster rockets is $3{\cdot}08 \times 10^5$ kg and the initial thrust on the rocket at lift off is 3352 kN. The frictional forces acting on the rocket at lift off are negligible.

(i) Calculate the weight of the spacecraft and booster rockets at lift off.

Space for working and answer

2

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13. (*b*) (continued)

(ii) Calculate the acceleration of the spacecraft and booster rockets at lift off.

Space for working and answer

3

(*c*) The ISS orbits at a height of approximately 360 km above the Earth. Explain why the ISS stays in orbit around the Earth.

.....

.....

.....

2

(*d*) An astronaut on board the ISS takes part in a video link-up with a group of students. The students see the astronaut floating.

(i) Explain why the astronaut appears to float.

.....

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1

(ii) The astronaut then pushes against a wall and moves off. Explain in terms of Newton's Third Law why the astronaut moves.

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1

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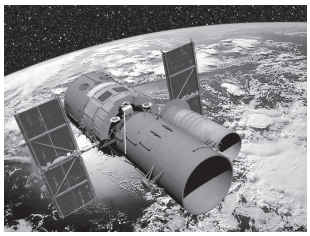
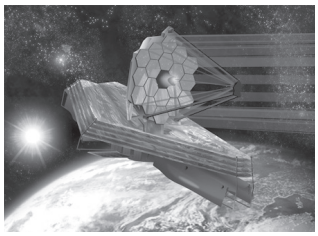
14. Images from outer space can be obtained using space telescopes.

Radioastron



Hubble



James Webb

Two space telescopes which orbit the Earth are the Hubble space telescope and the Radioastron space telescope.

The Hubble space telescope completes one orbit of the Earth in 97 minutes.

The Radioastron space telescope completes one orbit of the Earth in 9·5 days.

(*a*) How does the orbital height of the Hubble space telescope compare with the orbital height of the Radioastron space telescope?

.....

1

(*b*) The telescopes detect radiations which are members of the electromagnetic spectrum.

A diagram showing the electromagnetic spectrum is shown.

Gamma rays	P	Q	Visible light	Infra red	Microwave	Radio and TV

Electromagnetic Spectrum

Name radiations P and Q.

P .....

Q .....

1

14. (continued)

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(*c*) The Hubble space telescope is nearing the end of its useful life and will be replaced with the James Webb space telescope.

The James Webb space telescope is designed to detect infra-red radiation from outer space.

Name a detector of infra-red radiation.

.....

1

[*END OF QUESTION PAPER*]

ADDITIONAL SPACE FOR ANSWERS

Make sure you write the correct question number beside each answer.

DO NOT WRITE IN THIS MARGIN

K&U	PS

ADDITIONAL SPACE FOR ANSWERS

Make sure you write the correct question number beside each answer.

DO NOT WRITE IN THIS MARGIN

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ACKNOWLEDGEMENTS

Question 14—Photograph of the Radioastron telescope. Permission is being sought from Astro Space Centre, Moscow.

Question 14—Photographs of the Hubble and James Webb telescopes are reproduced by kind permission of NASA.