FOR OFFICIAL USE

C

K & U	PS

Total Marks

3220/402

NATIONAL QUALIFICATIONS 2000

WEDNESDAY, 31 MAY
10.50 AM – 12.35 PM

PHYSICS
STANDARD GRADE
Credit Level

Fill in these boxes and read what is printed below.

Full name of centre

Town

Forename(s)

Surname

Date of birth
Day Month Year

Scottish candidate number

Number of seat

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 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.

6 Any necessary data will be found in the **data sheet** on page two.

SCOTTISH QUALIFICATIONS AUTHORITY

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
Diamond	530
Glass	500
Glycerol	2400
Ice	2100
Lead	128
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	$22{\cdot}6 \times 10^5$

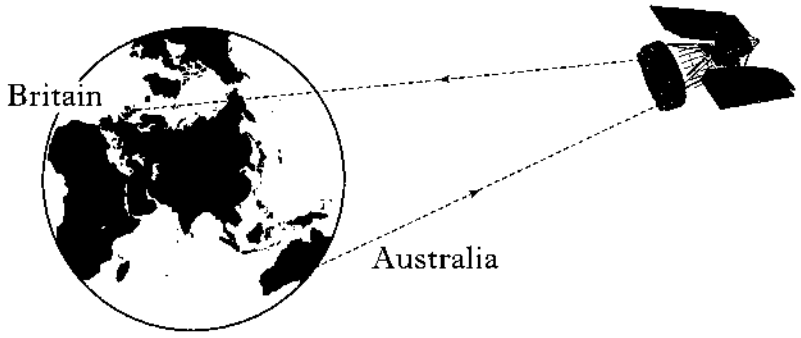
SI Prefixes and Multiplication Factors

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	0·001 $= 10^{-3}$
micro	μ	0·000 001 $= 10^{-6}$
nano	n	0·000 000 001 $= 10^{-9}$

DO NOT WRITE IN THIS MARGIN

Marks	K&U	PS

1. Radio signals from the Olympic Games in Australia are transmitted to Britain. The signals are sent at a frequency of 6 GHz (6×10^9 Hz) to a satellite which is in a geostationary orbit. Using a different frequency, the satellite then retransmits the signals to a ground station in Britain.



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

.....

.....

2

(*b*) Calculate the wavelength of the signals which are sent to the satellite.

Space for working and answer

3

(*c*) One of the layers in the atmosphere is the ionosphere. The radio signals pass through the ionosphere as they travel between Earth and the satellite. Radio waves of frequencies below 30 MHz are reflected by the ionosphere.

Circle the frequency that is suitable for **retransmitting** the signals from the satellite to the Earth.

20 MHz 4 GHz 6 GHz

1

[Turn over

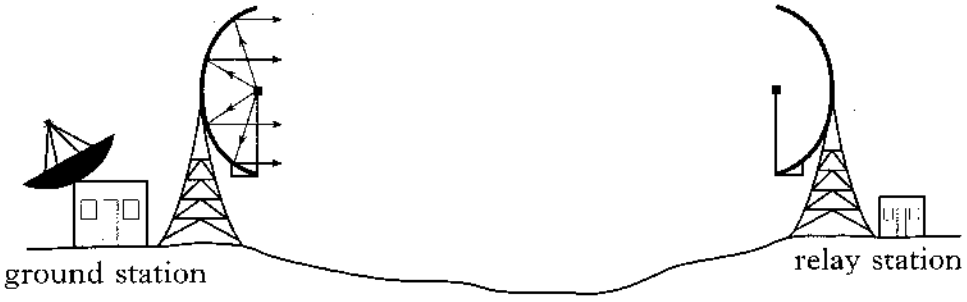
DO NOT WRITE IN THIS MARGIN

Marks	K&U	PS

1. (continued)

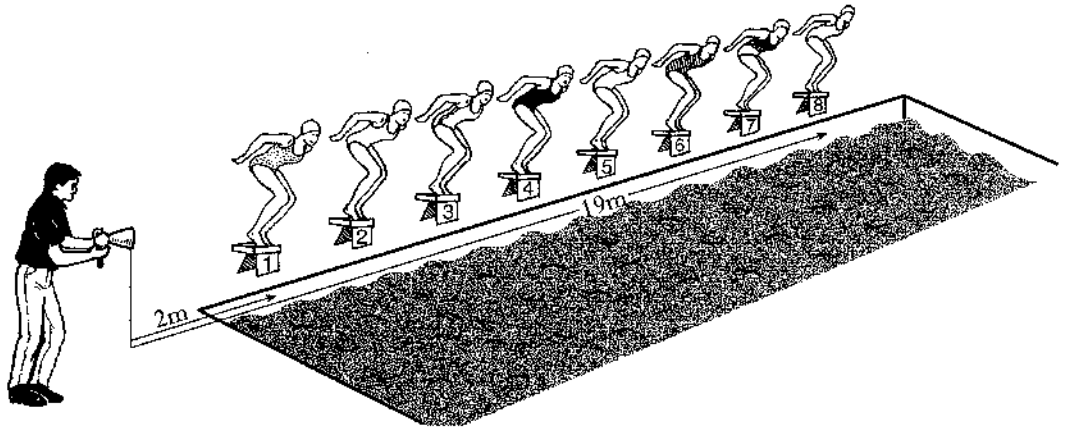
(*d*) At the ground station in Britain, the signals are transmitted as a parallel beam of microwaves to a relay station, using curved reflectors.

Complete the diagram below to show the effect of the curved reflector at the relay station.



2

2. At a local swimming gala, the swimmers start when they hear the sound of the starting horn. This horn also sends an electronic signal to start timing the race.



At the start of the race, the swimmer in lane 1 is a distance of 2 m from the horn and the swimmer in lane 8 is a distance of 19 m from the horn.

(*a*) The swimmer in lane 1 hears the sound of the horn first. Calculate how much later the swimmer in lane 8 hears this sound.

Space for working and answer

3

DO NOT WRITE IN THIS MARGIN

Marks | K&U | PS

2. (continued)

(*b*) As each swimmer finishes the race, an electronic touch sensor detects the swimmer's arrival at the finishing point. After the race, the scoreboard gives the following information.

Place	*Lane*	*Time* (s)
1st	1	20·52
2nd	8	20·55
3rd	5	21·91

(i) Using your answer to part (*a*), or otherwise, explain why the swimmer in lane 8 should have been awarded first place.

.....

.....

..... **2**

(ii) Suggest an improvement to the starting, or timing, system that would reduce the unfairness of the timing.

..... **1**

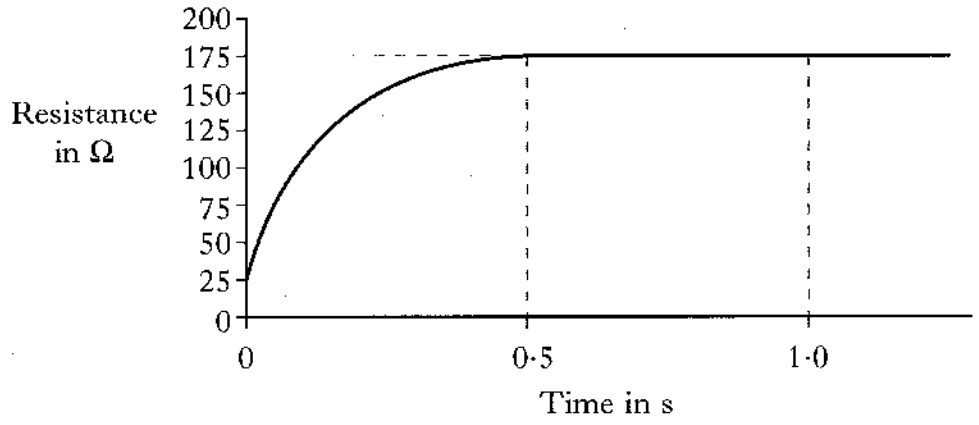
[Turn over

DO NOT WRITE IN THIS MARGIN

Marks	K&U	PS

3. A floodlight is fitted with a 230 V mains filament lamp. The filament takes 0·5 s to reach its operating temperature.

The graph shows how the resistance of the filament varies after being switched on.



(*a*) (i) What is the value of the resistance of the lamp when it is operating normally?

.....

1

(ii) Calculate the current in the lamp when it is operating normally.

Space for working and answer

2

(iii) The floodlight could have been fitted with a lamp with a power rating of 150 W or 300 W or 500 W.

Show by calculation which lamp **is** fitted in the floodlight.

Space for working and answer

3

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	Marks	K&U	PS

3. (continued)

(*b*) The lamp filament is most likely to "blow" or fail during the first 0·5 s after switch-on.

Using information from the graph, explain why this happens.

.....

.....

.....

..... **2**

[Turn over

DO NOT WRITE IN THIS MARGIN

Marks	K&U	PS

4. A lawnmower has a label which gives the following information.

Happycutter Manufacturing Co
Model HM96–150
230 V a.c. 50 Hz 1500 W
Class II BEAB approved

(*a*) (i) State why this lawnmower has only two wires in the flex.

.....

..... 1

(ii) State the colours of the insulation on the two wires in the flex.

.....

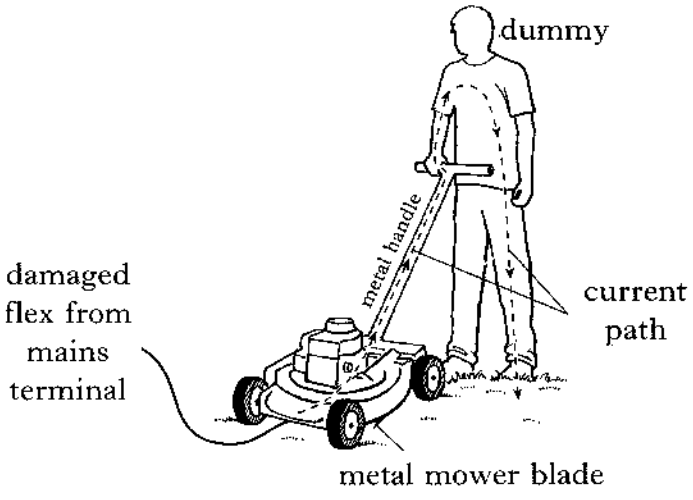
..... 2

(iii) State the value of the fuse that should be fitted in the plug of this lawnmower.

..... 1

(*b*) Care must be taken to make sure that the lawnmower does not cut its own flex. When this happens, there is a current path from the damaged flex, through the metal handle and the person using the lawnmower, to earth.

A dummy is used to investigate the safety of this lawnmower. In one test, the resistance of the current path through the dummy is 5000 Ω. This is approximately the same resistance as the current path when the lawnmower is used by a person.



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Marks | K&U | PS

4. (*b*) (continued)

(i) Show by calculation that the current which passes through the dummy is 46 mA.

Space for working and answer

2

(ii) Explain why, in a situation like this, the fuse in the plug **would not** protect a person using the lawnmower.

.....

.....

..... 2

(iii) What is the purpose of the fuse in the plug?

.....

..... 1

(iv) Water is now sprayed on the dummy and the investigation repeated. State and explain the effect that this has on the current through the dummy.

.....

.....

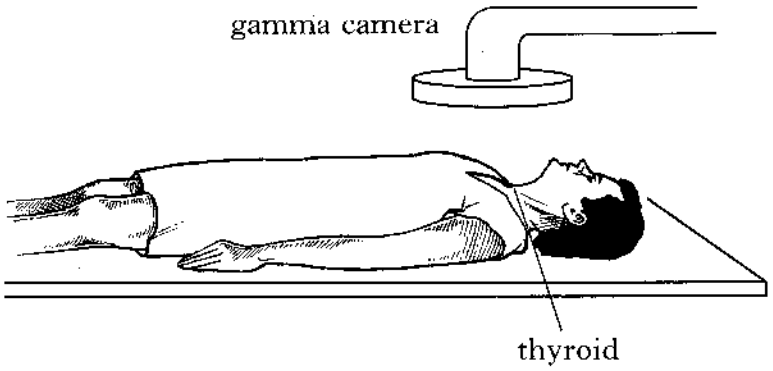
..... 2

[Turn over

DO NOT WRITE IN THIS MARGIN

Marks	K&U	PS

5. Iodine-131 is a radioactive substance which emits beta particles and gamma radiation. A small quantity of iodine-131 is injected into a patient to investigate the thyroid gland. The radiation emitted is detected using a gamma camera.



(*a*) (i) Why are the beta particles less likely to reach the camera than the gamma radiation?

.....

..... **1**

(ii) What effect does radiation have on living cells?

.....

..... **1**

(*b*) Two safety precautions necessary when using radioactive sources are:

- wear a film badge attached to clothing
- keep as large a distance as possible away from the source.

(i) (A) What happens to photographic film when it is exposed to a radioactive source?

.....

..... **1**

(B) Describe how information obtained from a film badge is used to indicate the dose of radiation that has been received.

.....

.....

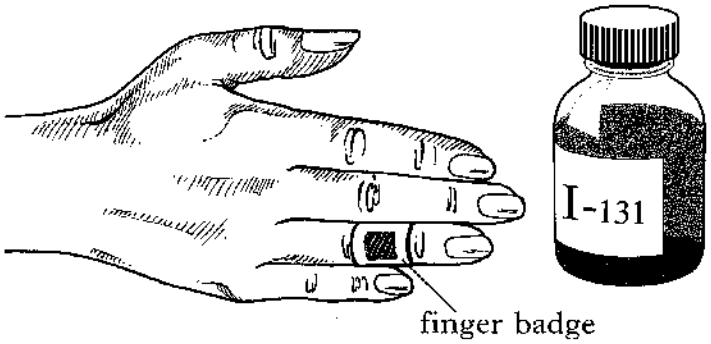
..... **1**

DO NOT WRITE IN THIS MARGIN

	Marks	K&U	PS

5. (*b*) (continued)

(ii) As well as these precautions, a technician wears an additional film badge on a finger when handling a bottle of iodine-131 solution.



What is the reason for this **additional** film badge?

.....

..... 2

(iii) State one **other** safety precaution necessary when dealing with radioactive substances.

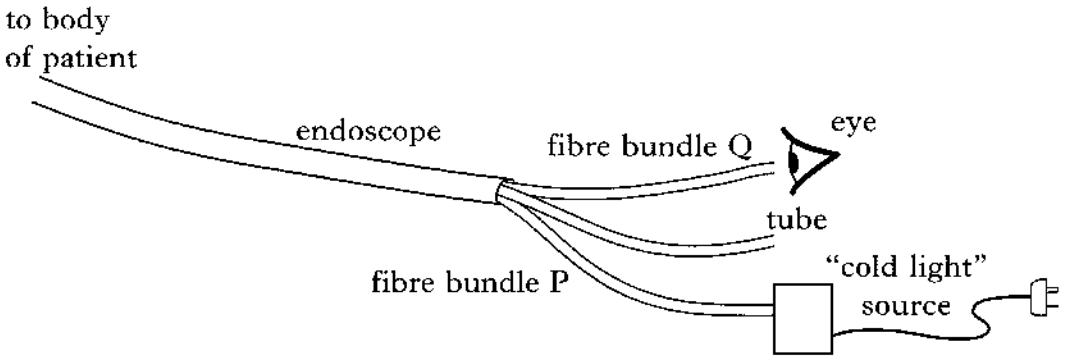
..... 1

[Turn over

DO NOT WRITE IN THIS MARGIN

Marks	K&U	PS

6. A health physicist is developing a system for measuring temperatures inside the body. A thermocouple is inserted through a tube beside the optical fibres of an endoscope. The endoscope allows the doctor to see where the thermocouple is being positioned. The endoscope consists of two fibre bundles and a "cold light" source.



(*a*) (i) Explain the purpose of each of the two bundles of fibres in the endoscope.

Fibre bundle P

.....

.....

Fibre bundle Q

.....

..... **2**

(ii) What is meant by a "cold light" source?

.....

..... **1**

(iii) Explain whether a filament lamp or a discharge lamp would be more suitable for the light source of the endoscope.

.....

.....

..... **2**

DO NOT WRITE IN THIS MARGIN

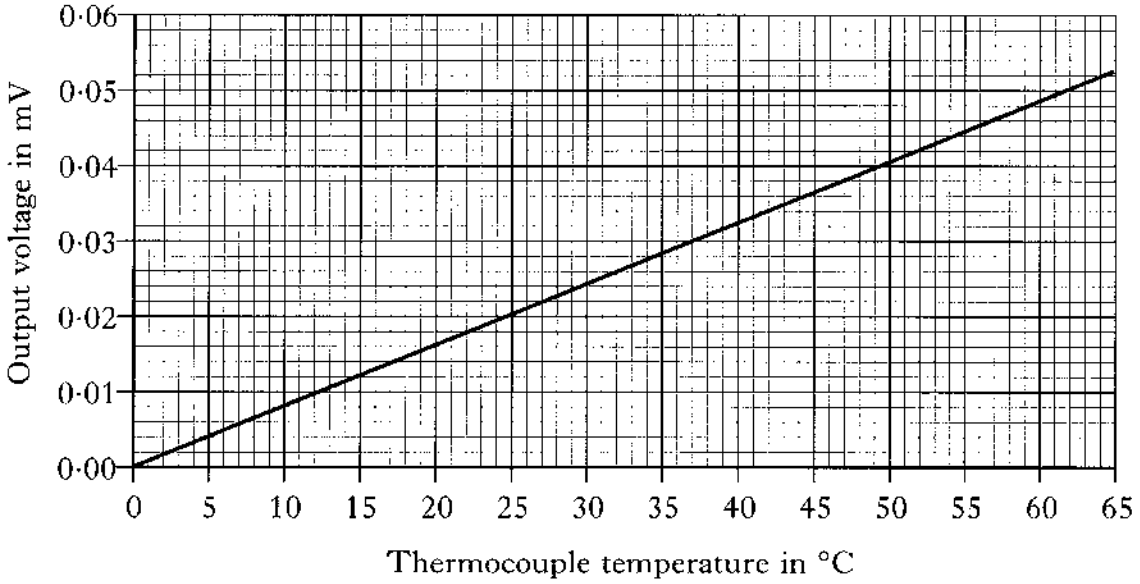
Marks | K&U | PS

6. (continued)

(*b*) State the energy transformation that takes place in a thermocouple.

..... **1**

(*c*) The following graph shows how the output voltage from the thermocouple varies over a certain temperature range.



(i) What is the voltage produced by the thermocouple at 37 °C?

..... **1**

(ii) The thermocouple is inserted inside the body of a patient who has a fever.

Suggest a value for the voltage produced by the thermocouple.

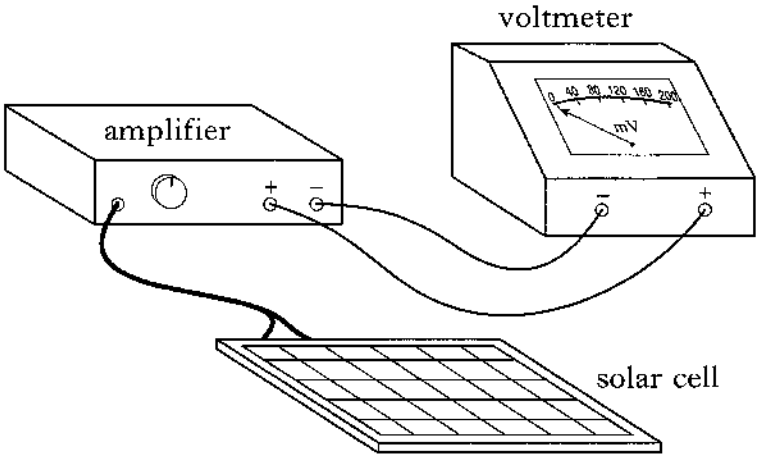
..... **1**

[Turn over

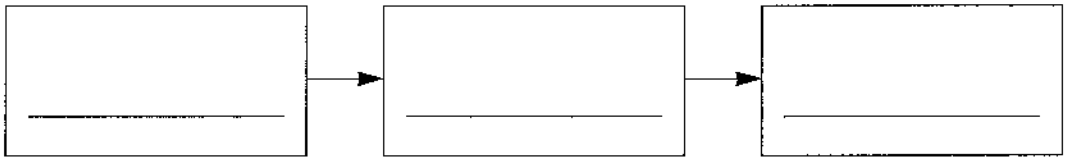
DO NOT WRITE IN THIS MARGIN

Marks | K&U | PS

7. The electronic system shown is used as a light meter. A voltage is generated when light falls on the solar cell. This voltage is amplified and the output voltage is displayed on the voltmeter.



(*a*) Enter the names of each of the three parts of this electronic system in the block diagram below.



Input Process Output **1**

(*b*) The table shows the voltage generated by the solar cell, and the output voltage of the amplifier for various values of light level. (Light level is measured in lux.)

Light level (lux)	350	400	450	500	550
Voltage generated by solar cell (mV)	0·1	0·2	0·3	0·4	0·5
Output voltage of amplifier (mV)	40	80	120	160	200

(i) Calculate the voltage gain of the amplifier.

Space for working and answer

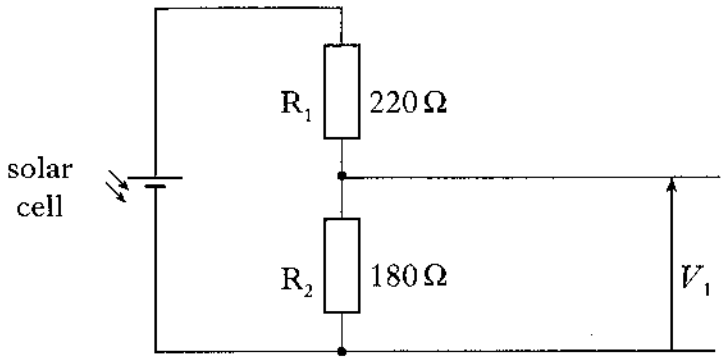
2

DO NOT WRITE IN THIS MARGIN

Marks	K&U	PS

7. (*b*) (continued)

(ii) The solar cell is connected to the amplifier as shown.



Calculate the voltage V_1 when the solar cell is in a light level of 500 lux.

Space for working and answer

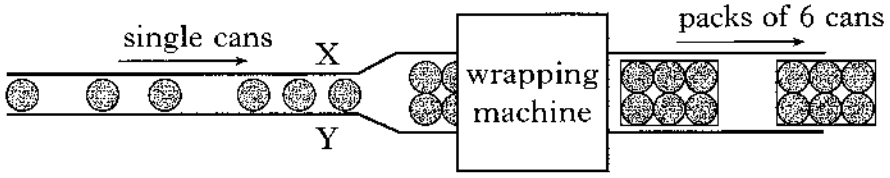
3

[Turn over

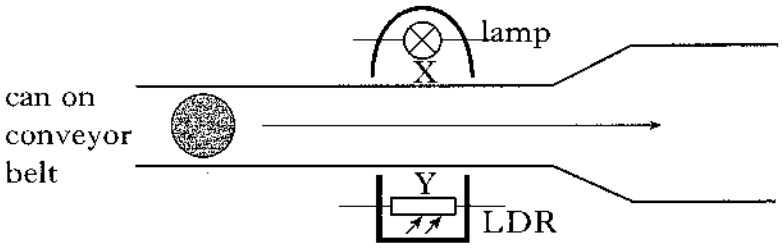
DO NOT WRITE IN THIS MARGIN

Marks | K&U | PS

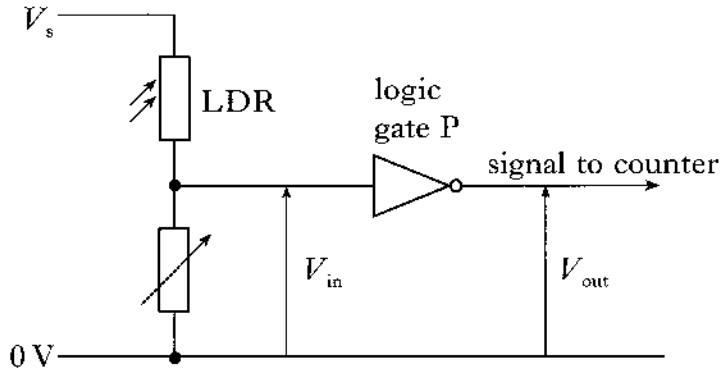
8. A factory wraps cans in packs of six. The cans travel in a single line along a conveyor belt to a wrapping machine which seals them in plastic.



A light beam is set up across X–Y to send a signal to a counter. This signal operates the wrapping machine after six cans are detected.



(*a*) The circuit shown produces the input signal for the counter.



(i) What type of logic gate is P?

..... 1

DO NOT WRITE IN THIS MARGIN

Marks | K&U | PS

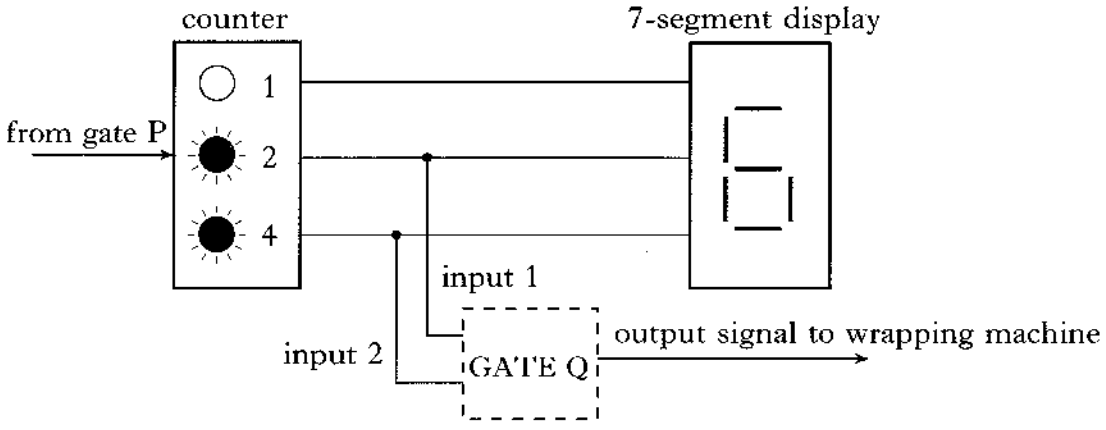
8. (*a*) (continued)

(ii) Complete the following table, writing either **high** or **low** for each entry, to show what happens as cans pass through the light beam.

	No can in light beam	*Can in light beam*
Light level at LDR		
Resistance of LDR		
V_{in}		
V_{out}		

4

(*b*) The output of gate P goes to the counter. A 7-segment display shows the number of cans at the wrapping machine. Part of this circuit is shown below.



(i) Complete each sentence below by choosing a word from the following list.

analogue **binary** **decimal**

The output of the counter circuit is .....

The output of the 7-segment display is 2

[Turn over

DO NOT WRITE IN THIS MARGIN

Marks | K&U | PS

8. (*b*) (continued)

(ii) Gate Q sends a signal to the wrapping machine when six cans have been detected.

(A) What type of logic gate is Q?

..... 1

(B) Complete the truth table for gate Q.

Input 1	*Input 2*	*Output*
0	0	
0	1	
1	0	
1	1	

2

(iii) There is a short delay to allow six cans to enter the wrapping machine before they are wrapped.

Name a suitable input device that could provide this delay.

..... 1

DO NOT WRITE IN THIS MARGIN

Marks	K&U	PS

9. On one road the speed limit is 90 km/h.

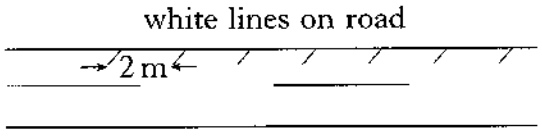
(*a*) Show by calculation that this speed limit is 25 m/s.

Space for working and answer

2

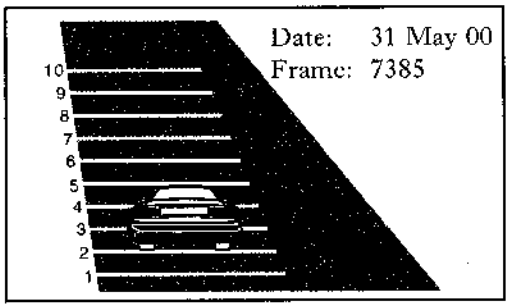
(*b*) A speed camera is used to detect motorists breaking the speed limit on this road. A section of the road in view of the camera is marked out with white lines spaced 2 m apart.

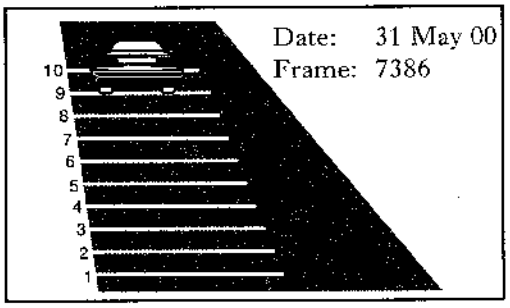
speed camera



The camera unit is fitted with a radar speed sensor. When a passing vehicle breaks the speed limit, the camera takes a pair of photographs 0·4 s apart.

When the speed camera film is later analysed, the following pair of photographs is obtained.





Calculate how much **faster** than the speed limit of 25 m/s this car was travelling.

Space for working and answer

3

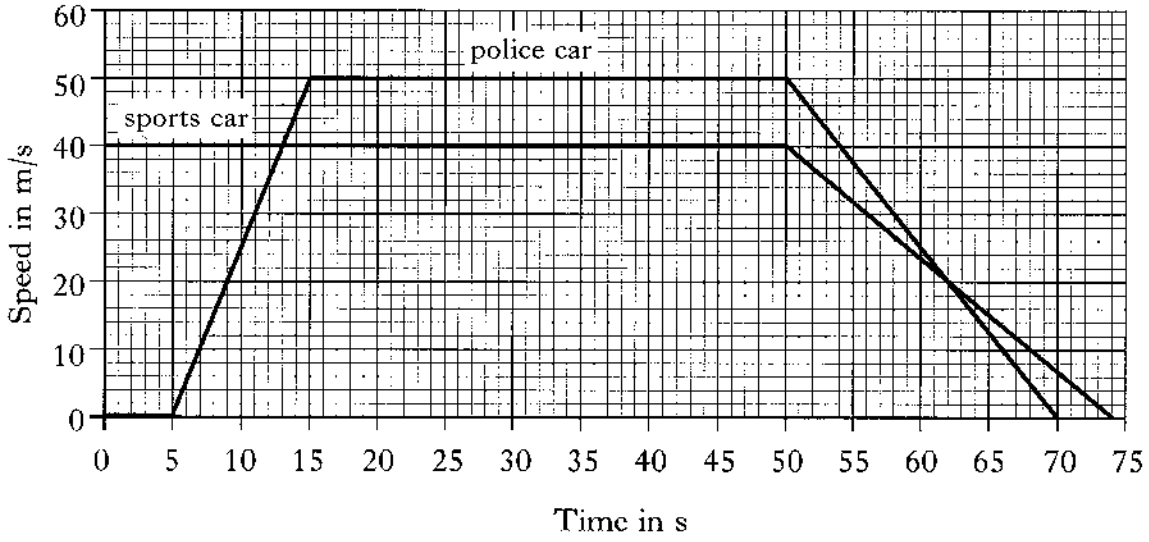
DO NOT WRITE IN THIS MARGIN

Marks | K&U | PS

9. (continued)

(*c*) Further along the road, a sports car travelling at a constant speed of 40 m/s passes a police car which is parked in a lay-by. The police car follows the sports car.

The speed-time graph shows the motion of both cars from the time the sports car passes the parked police car.



(i) How long does it take for the police car to start to move?

..... 1

(ii) Calculate the acceleration of the police car when it sets off.

Space for working and answer

2

DO NOT WRITE IN THIS MARGIN

Marks | K&U | PS

9. (c) (continued)

(iii) Fifty seconds (50 s) after being passed by the sports car, the police car has travelled 2000 m.

Show by calculation that the cars are side by side at this time.

Space for working and answer

2

(iv) By calculating the distance travelled by each car while decelerating, show which car stops in front **and** the distance between them when both cars are stopped.

Space for working and answer

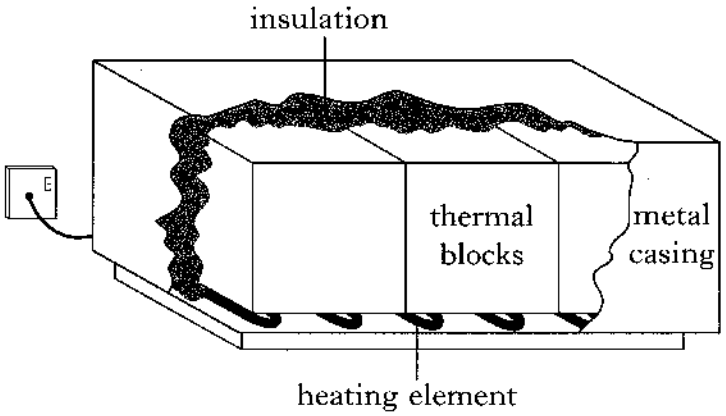
3

[Turn over

DO NOT WRITE IN THIS MARGIN

Marks	K&U	PS

10. An electric storage heater contains a heating element, thermal blocks and insulation as shown in the diagram.



The heating element heats the thermal blocks during the night.

(*a*) Between midnight and 6.00 am, $8{\cdot}64 \times 10^7$ J of energy are supplied to the heating element.

(i) Calculate the power rating of the heating element.

Space for working and answer

2

(ii) The total mass of the thermal blocks in the heater is 144 kg and the specific heat capacity of the thermal blocks is 2625 J/kg °C.

Calculate the maximum possible rise in the temperature of the thermal blocks between midnight and 6.00 am.

Space for working and answer

2

DO NOT WRITE IN THIS MARGIN

	Marks	K&U	PS

10. (*a*) (continued)

(iii) Explain why the actual temperature rise of the blocks is less than the value calculated in (*a*)(ii).

.....

..... **1**

(*b*) Why is there insulation between the thermal blocks and the outer casing of the heater?

.....

.....

..... **1**

(*c*) During the day, heat energy stored in the heater is released into the room. State **one** way in which heat is transferred to the surroundings from this heater.

.....

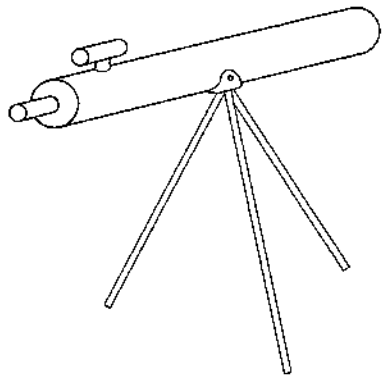
..... **1**

[Turn over

DO NOT WRITE IN THIS MARGIN

Marks	K&U	PS

11. A refracting telescope has an objective lens which has a focal length of 800 mm and a diameter of 50 mm.



The telescope can be fitted with any one of three eyepiece lenses Q, R or S. Information on these lenses is shown in the table.

Lens	*Focal length* (mm)	*Diameter* (mm)
Q	10	5
R	20	5
S	40	5

(*a*) Why is it important to make the diameter of the **objective** lens as large as possible?

.....

..... **1**

DO NOT WRITE IN THIS MARGIN

Marks | K&U | PS

11. (continued)

(*b*) (i) Calculate the power of lens R.

Space for working and answer

2

(ii) Which of the three eyepiece lenses has the greatest power?

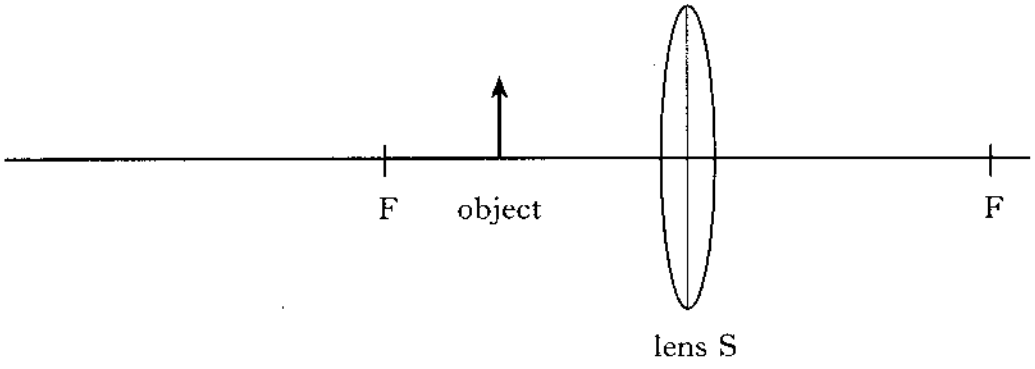
.....

1

(*c*) Each eyepiece lens can be used on its own as a magnifying glass.

Complete the diagram below to show how lens S can be used to form a magnified image of an object.

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



3

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Marks	K&U	PS

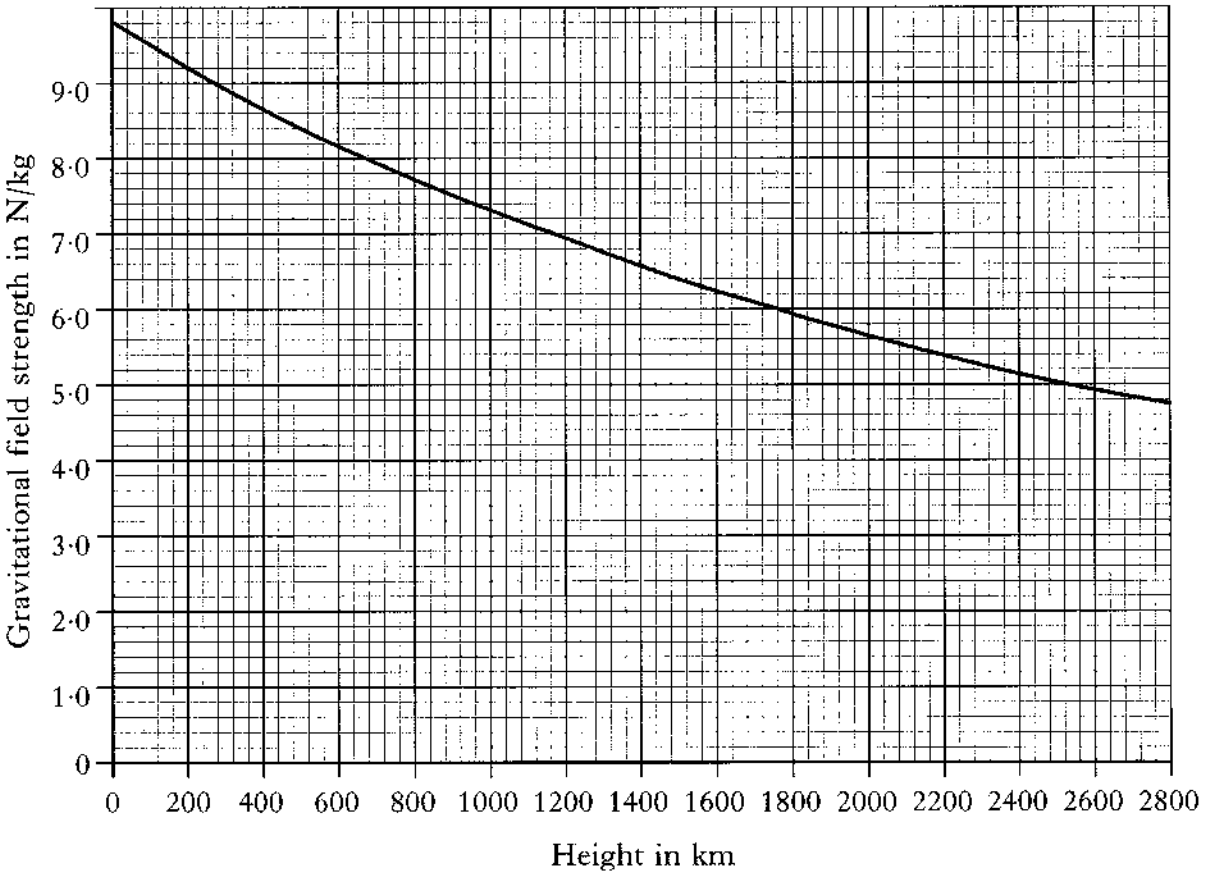
12. The International Space Station orbits Earth at a height of 360 km. The command module of the space station has a mass of 20 tonnes (20×10^3 kg).

(*a*) Masses as large as this are difficult to accelerate.

Circle the term that is used for this concept.

gravitational field strength **inertia** **thrust** **weight** 1

(*b*) The graph shows how the gravitational field strength varies with height above the surface of the Earth.



(i) What is the value of the gravitational field strength at the orbital height of the International Space Station?

..... 1

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12. (*b*) (continued)

(ii) Calculate the weight of the command module at this height.

Space for working and answer

2

(iii) As the command module is taken from Earth to its orbital height, what happens to its weight and mass?

Weight .....

Mass **2**

(*c*) The International Space Station is an artificial satellite.

Explain why it remains in orbit around the Earth.

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..... **2**

[END OF QUESTION PAPER]

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