[3220/342] 1994

SCOTTISH CERTIFICATE OF EDUCATION

PHYSICS (REVISED)

Higher Grade—PAPER II

Friday, 13th May—1.30 p.m. to 4.00 p.m.

READ CAREFULLY

1. **All questions should be attempted.**
2. **Enter the question number clearly in the margin beside each question.**
3. **Any necessary data will be found in the Data Sheet on page two.**
4. **Care should be taken not to give an unreasonable number of significant figures in the final answers to calculations.**
5. **Square-ruled paper (if used) should be placed inside the front cover of the answer book for return to the Examination Board.**

ES 3220/342 6/3/20610

DATA SHEET

COMMON PHYSICAL QUANTITIES

Quantity	*Symbol*	*Value*	*Quantity*	*Symbol*	*Value*
Speed of light in vacuum	c	$3{\cdot}0 \times 10^{8}\,\mathrm{m\,s^{-1}}$	Mass of electron	m_e	$9{\cdot}11 \times 10^{-31}\,\mathrm{kg}$
Charge on electron	e	$-1{\cdot}60 \times 10^{-19}\,\mathrm{C}$	Mass of neutron	m_n	$1{\cdot}675 \times 10^{-27}\,\mathrm{kg}$
Gravitational acceleration	g	$9{\cdot}8\,\mathrm{m\,s^{-2}}$	Mass of proton	m_p	$1{\cdot}673 \times 10^{-27}\,\mathrm{kg}$
Planck's constant	h	$6{\cdot}63 \times 10^{-34}\,\mathrm{J\,s}$			

REFRACTIVE INDICES

The refractive indices refer to sodium light of wavelength 589 nm and to substances at a temperature of 273 K.

Substance	*Refractive index*	*Substance*	*Refractive index*
Diamond	2·42	Glycerol	1·47
Glass	1·51	Water	1·33
Ice	1·31	Air	1·00
Perspex	1·49		

SPECTRAL LINES

Element	*Wavelength/nm*	*Colour*	*Element*	*Wavelength/nm*	*Colour*
Hydrogen	656	Red	Cadmium	644	Red
	486	Blue-green		509	Green
	434	Blue-violet		480	Blue
	410	Violet			
	397	Ultraviolet			
	389	Ultraviolet			
Sodium	589	Yellow			

Lasers

Element	*Wavelength/nm*	*Colour*
Carbon dioxide	9550, 10590	Infra-red
Helium-neon	633	Red

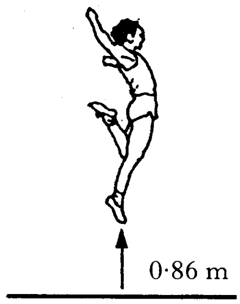
PROPERTIES OF SELECTED MATERIALS

Substance	*Density/* $\mathrm{kg\,m^{-3}}$	*Melting Point/* K	*Boiling Point/* K	*Specific Heat Capacity/* $\mathrm{J\,kg^{-1}\,K^{-1}}$	*Specific Latent Heat of Fusion/* $\mathrm{J\,kg^{-1}}$	*Specific Latent Heat of Vaporisation/* $\mathrm{J\,kg^{-1}}$
Aluminium	$2{\cdot}70 \times 10^{3}$	933	2623	$9{\cdot}02 \times 10^{2}$	$3{\cdot}95 \times 10^{5}$	....
Copper	$8{\cdot}96 \times 10^{3}$	1357	2853	$3{\cdot}86 \times 10^{2}$	$2{\cdot}05 \times 10^{5}$	....
Glass	$2{\cdot}60 \times 10^{3}$	1400	....	$6{\cdot}70 \times 10^{2}$	....	....
Ice	$9{\cdot}20 \times 10^{2}$	273	....	$2{\cdot}10 \times 10^{3}$	$3{\cdot}34 \times 10^{5}$	....
Glycerol	$1{\cdot}26 \times 10^{3}$	291	563	$2{\cdot}43 \times 10^{3}$	$1{\cdot}81 \times 10^{5}$	$8{\cdot}30 \times 10^{5}$
Methanol	$7{\cdot}91 \times 10^{2}$	175	338	$2{\cdot}52 \times 10^{3}$	$9{\cdot}9 \times 10^{4}$	$1{\cdot}12 \times 10^{6}$
Sea Water	$1{\cdot}02 \times 10^{3}$	264	377	$3{\cdot}93 \times 10^{3}$	....	....
Water	$1{\cdot}00 \times 10^{3}$	273	373	$4{\cdot}19 \times 10^{3}$	$3{\cdot}34 \times 10^{5}$	$2{\cdot}26 \times 10^{6}$
Air	1·29	....	....	....	....	....
Hydrogen	$9{\cdot}0 \times 10^{-2}$	14	20	$1{\cdot}43 \times 10^{4}$	....	$4{\cdot}50 \times 10^{5}$
Nitrogen	1·25	63	77	$1{\cdot}04 \times 10^{3}$	....	$2{\cdot}00 \times 10^{5}$
Oxygen	1·43	55	90	$9{\cdot}18 \times 10^{2}$	....	$2{\cdot}40 \times 10^{5}$

The gas densities refer to a temperature of 273 K and a pressure of $1{\cdot}01 \times 10^{5}$ Pa.

1. (*a*) A long jumper devises a method for estimating the horizontal component of his velocity during a jump.

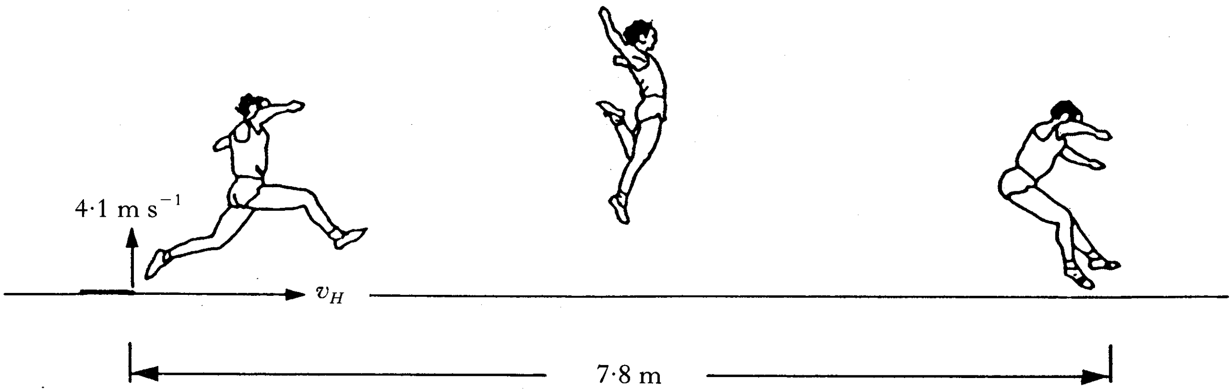
His method involves first finding out how high he can jump **vertically**.



He finds that the maximum height he can jump is 0·86 m.

(i) Show that his initial vertical velocity is 4·1 m s^{-1}.

He now assumes that when he is long jumping, the initial vertical component of his velocity at take-off is 4·1 m s^{-1}.



The length of his long jump is 7·8 m.

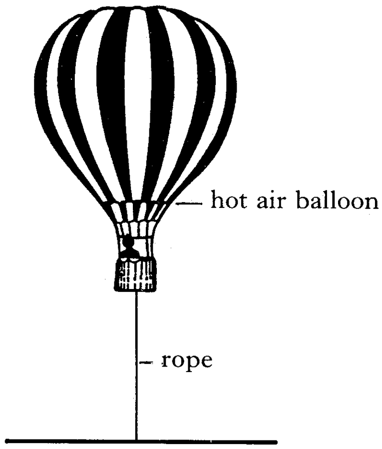
(ii) Calculate the value that he should obtain for the horizontal component of his velocity, v_H. **5**

(*b*) His coach tells him that, during the 7·8 m jump, his maximum height above the ground was less than 0·86 m. Ignoring air resistance, state whether his actual horizontal component of velocity was greater or less than the value calculated in part (*a*) (ii). You must justify your answer. **2**

(7)

[Turn over

2. (*a*) A hot air balloon, of total mass 500 kg, is held stationary by a single vertical rope.

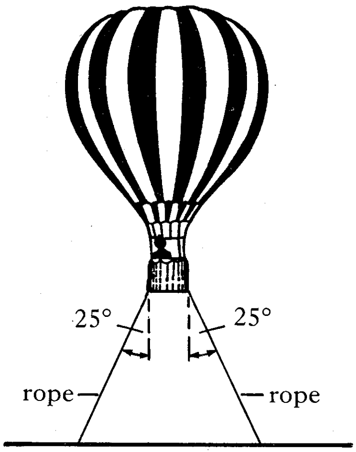


(i) Draw a sketch of the balloon. On your sketch, mark and label all the forces acting on the balloon.

(ii) When the rope is released, the balloon initially accelerates vertically upwards at $1{\cdot}5\ \mathrm{m\,s^{-2}}$. Find the magnitude of the buoyancy force.

(iii) Calculate the tension in the rope **before** it is released. **5**

(*b*) An identical balloon is moored using two ropes, each of which makes an angle of 25° to the vertical, as shown below.



By using a scale diagram, or otherwise, calculate the tension in each rope. **2**

(*c*) During a flight, when a hot air balloon is travelling vertically upwards with constant velocity, some hot air is released. This allows cooler air to enter through the bottom of the balloon.

Describe **and** explain the effect of this on the motion of the balloon. You may assume that the volume of the balloon does not change. **3**

(10)

Marks

3. A water rocket consists of a plastic bottle, partly filled with water. Air is pumped in through the water as shown in Figure 1. When the pressure inside the bottle is sufficiently high, water is forced out at the nozzle and the rocket accelerates vertically upwards as shown in Figure 2.

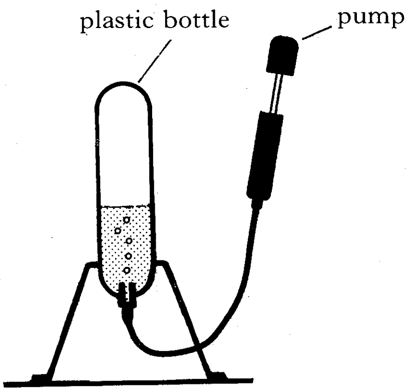


Figure 1

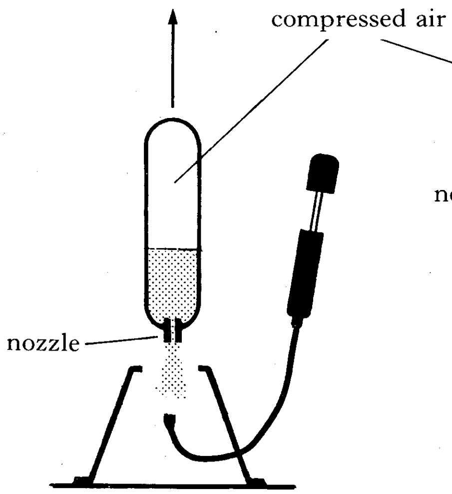


Figure 2

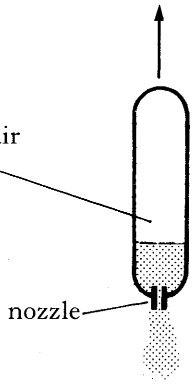


Figure 3

(*a*) (i) At take-off, the volume of air in the bottle is $750\,cm^3$ at a pressure of $1{\cdot}76 \times 10^5$ Pa.

Figure 3 shows the rocket at a later stage in its flight, when the volume of the air in the bottle has increased to $900\,cm^3$.

Calculate the new pressure of the compressed air at this later stage in its flight.

(ii) The area of the water surface which is in contact with the compressed air in the bottle is $5{\cdot}0 \times 10^{-3}\,m^2$.

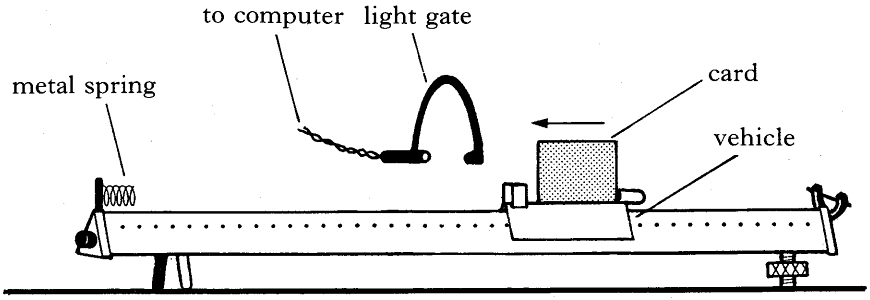
Calculate the force exerted on the water by the compressed air at the new pressure. **4**

(*b*) Explain fully why the rocket rises as the water is forced out at the nozzle. **2**

(6)

[Turn over

4. A student uses a linear air track to investigate collisions. In one experiment a vehicle, mass 0·50 kg, moves along and rebounds from a metal spring mounted at one end of the level track as shown below.



By using a light gate connected to a computer, she obtains values for the speed of the vehicle before and after it collides with the spring.

She then repeats this procedure, replacing the metal spring first with the block of polyurethane foam and then with the rubber band catapult. She records the results of each experiment in a table as shown below.

	Metal spring	Polyurethane block	Rubber band
Speed before collision/m s^{-1}	0·55	0·55	0·55
Speed after collision/m s^{-1}	0·49	0·33	0·43
Kinetic energy before collision/J	0·076	0·076	0·076
Kinetic energy after collision/J	0·060		

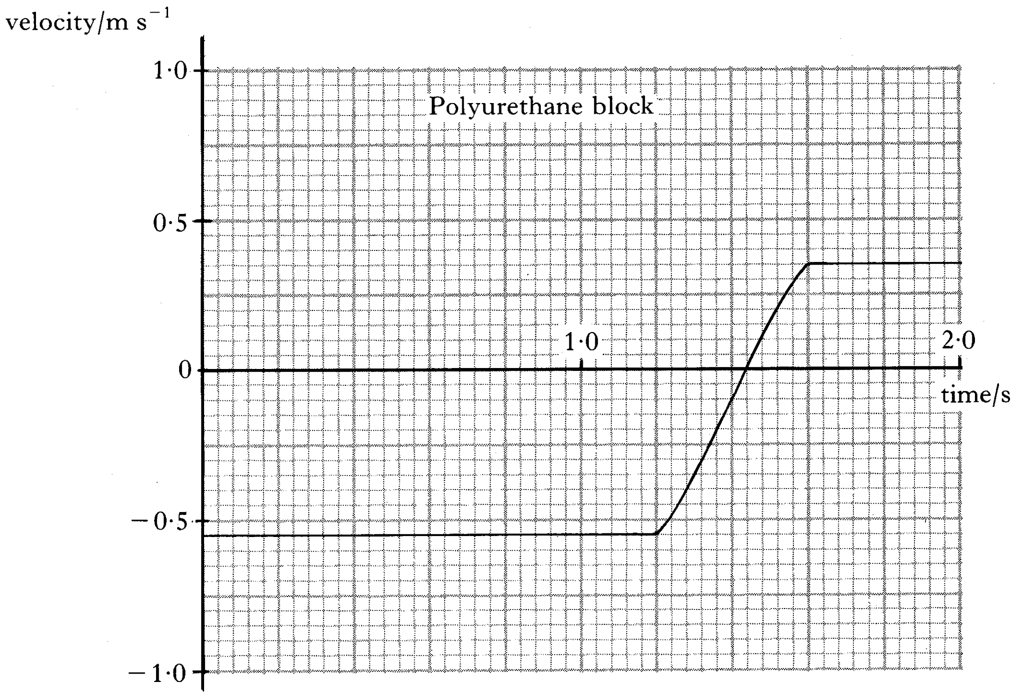
(*a*) Calculate values of kinetic energy to complete the last row of the table. **2**

(*b*) For which experiment is the collision most nearly elastic? You must justify your answer. **1**

(*c*) Describe a method she could use to give the vehicle the same initial speed each time. **1**

4. (continued)

(*d*) In order to analyse a collision in more detail, she now uses a motion sensor. This enables the computer to display a velocity–time graph of the motion.



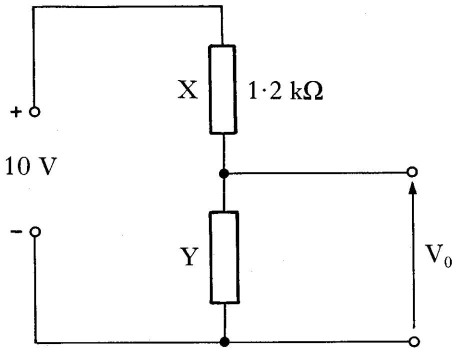
(i) Use information from this graph to calculate the average force exerted by the polyurethane block on the vehicle, mass 0·50 kg, during the time that they are in contact.

(ii) Describe the motion of the vehicle during the time that it is in contact with the polyurethane block. **4**

(8)

[Turn over

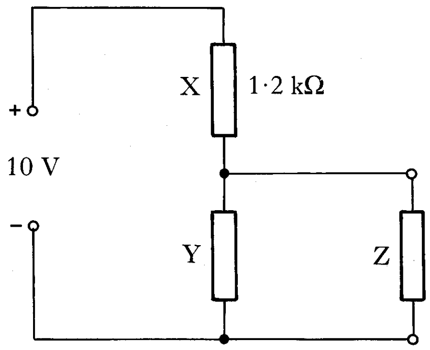
5. (*a*) A potential divider is used to provide an output voltage V_0 from a 10 V supply as shown below. The supply has negligible internal resistance.



(i) The resistance of resistor X is 1·2 kΩ and the output voltage required is 6·0 V.

Calculate the resistance of resistor Y.

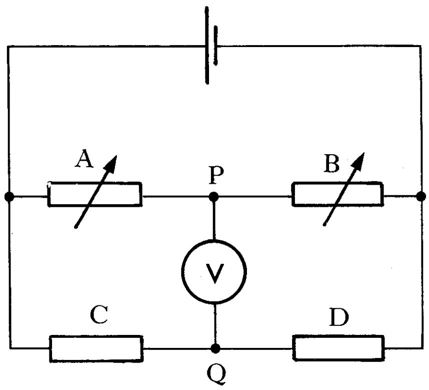
(ii) A load resistor Z is now connected across the output as shown below.



Explain why the voltage across Z is less than 6·0 V.

(iii) Calculate the voltage across resistor Z when its resistance is 4·7 kΩ. **6**

(*b*) A Wheatstone bridge circuit is shown below.



(i) How are the resistances of A, B, C and D related when the bridge is balanced?

5. (continued)

(ii) C and D are fixed resistors, each of value 120 Ω. The resistors A and B are variable and each is initially set at 120 Ω. The voltmeter is used to measure the p.d. between the points P and Q.

Small changes are made to the resistances of A and B, and the various values are shown in the table below.

Resistance of A/Ω	Resistance of B/Ω	Voltmeter reading/mV
120	120	
121	120	−21
121	121	
121	122	
121	119	

Copy and complete the last column of the table to show the voltmeter readings (including sign) that you would expect for each of the remaining sets of resistance values. **2**

(8)

[Turn over

Marks

6. (*a*) A rechargeable cell is rated at 0·50 A h (ampere hour). This means that, for example, it can supply a constant current of 0·50 A for a period of 1 hour. The cell then requires to be recharged.

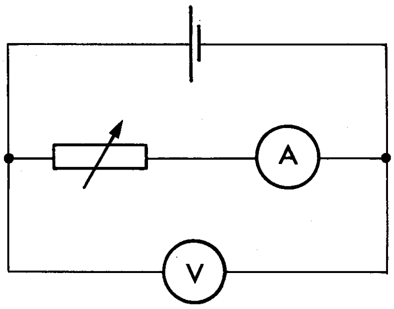
(i) What charge, in coulombs, is available from a fully charged cell?

(ii) A fully charged cell is connected to a load resistor and left until the cell requires recharging. During this time, the p.d. across the terminals of the cell remains constant at 1·2 V.

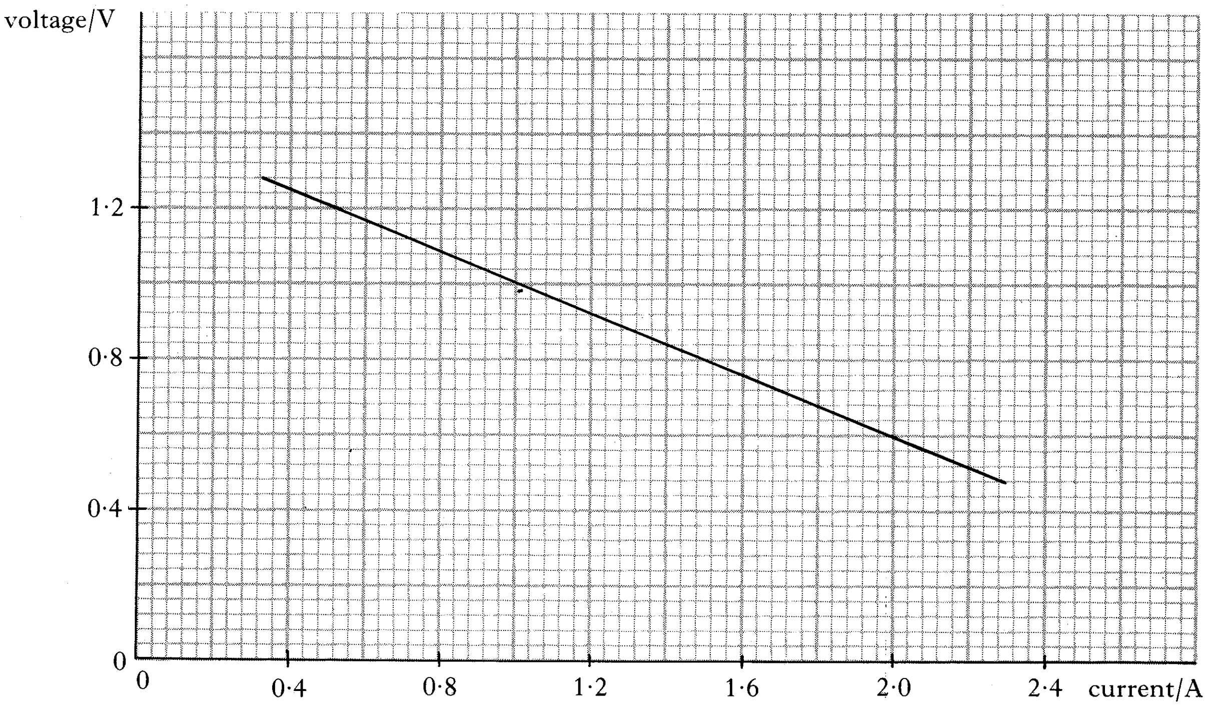
Calculate the electrical energy supplied to the load resistor in this case. **3**

(*b*) (i) State what is meant by the e.m.f. of a cell.

(ii) The circuit shown below is used in an experiment to find the e.m.f. and internal resistance of the rechargeable cell.



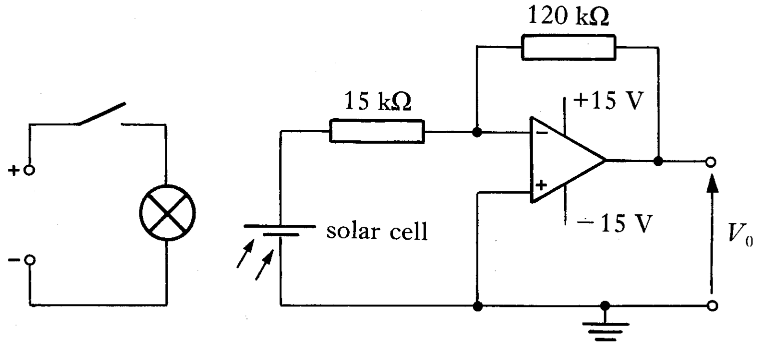
The voltmeter and ammeter readings for a range of settings of the variable resistor are used to produce the graph below.



Use the graph to find the values for the e.m.f. **and** internal resistance of the cell. **4**

(7)

7. (*a*) In order to compare the brightness of a number of low voltage lamps, a solar cell is used to detect the light from the lamps. An operational amplifier, working in the inverting mode, is used to amplify the solar cell voltage.

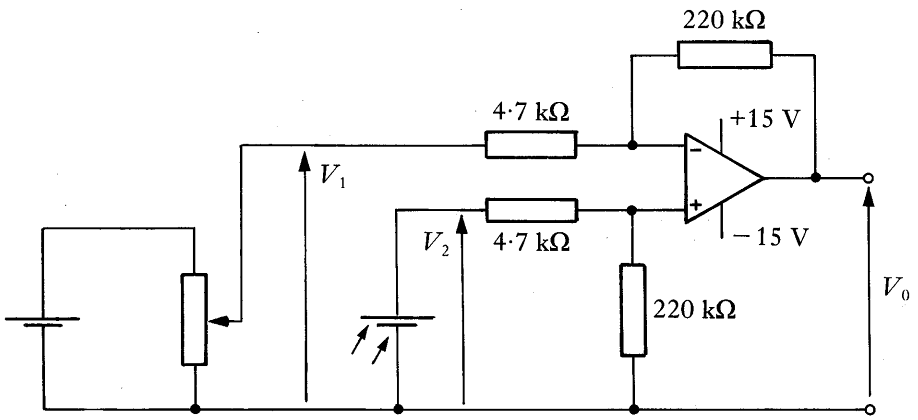


The apparatus is set up near to a window and, with the lamp switched off, there is an output voltage V_0 of $-1{\cdot}75$ V.

(i) Explain why the output voltage V_0 of the operational amplifier is not zero.

(ii) Calculate the solar cell voltage. **3**

(*b*) With the solar cell in the same position, the circuit is now altered so that the operational amplifier is working in the differential mode as shown below.



(i) With the lamp still unlit, the potentiometer setting is adjusted until the output voltage is zero.

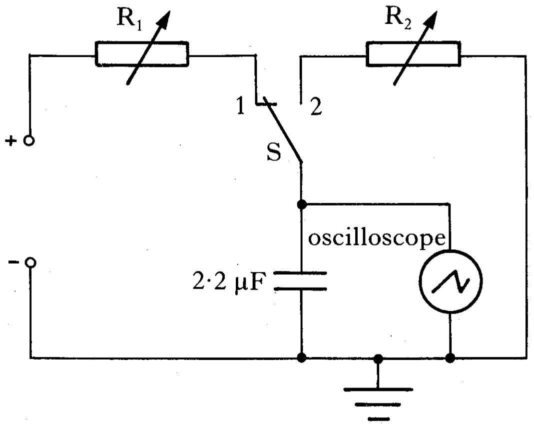
Explain how this circuit enables the output voltage to be set to zero volts.

(ii) With V_1 unchanged, the lamp is switched on and the output voltage V_0 is now $1{\cdot}50$ V. Calculate the voltage which the solar cell now produces. **4**

(7)

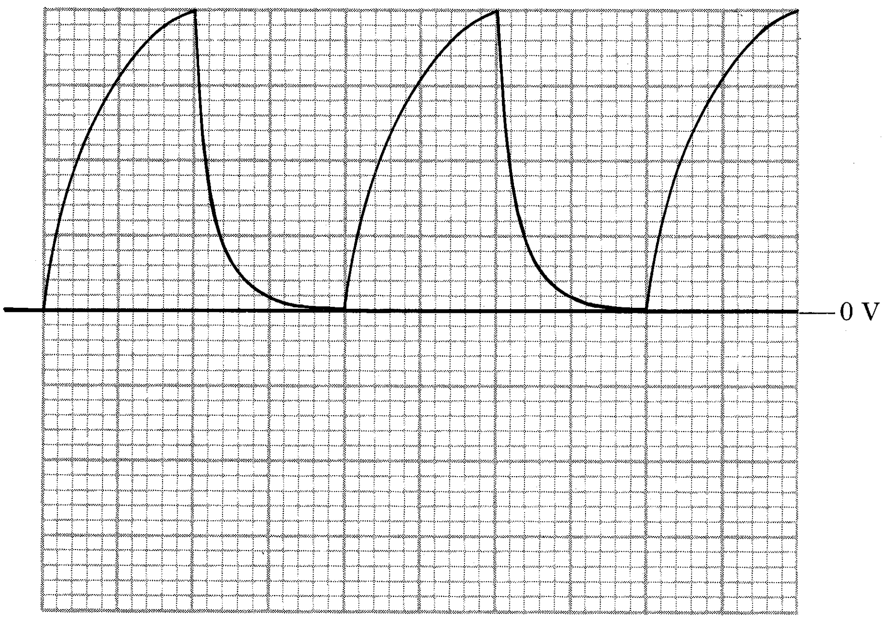
[Turn over

8. The circuit shown below is used to investigate the charging and discharging of a capacitor.



The capacitor is repeatedly charged and discharged by switching S between contacts 1 and 2.

(*a*) For one setting of R_1 and R_2 the following trace is obtained on the oscilloscope.

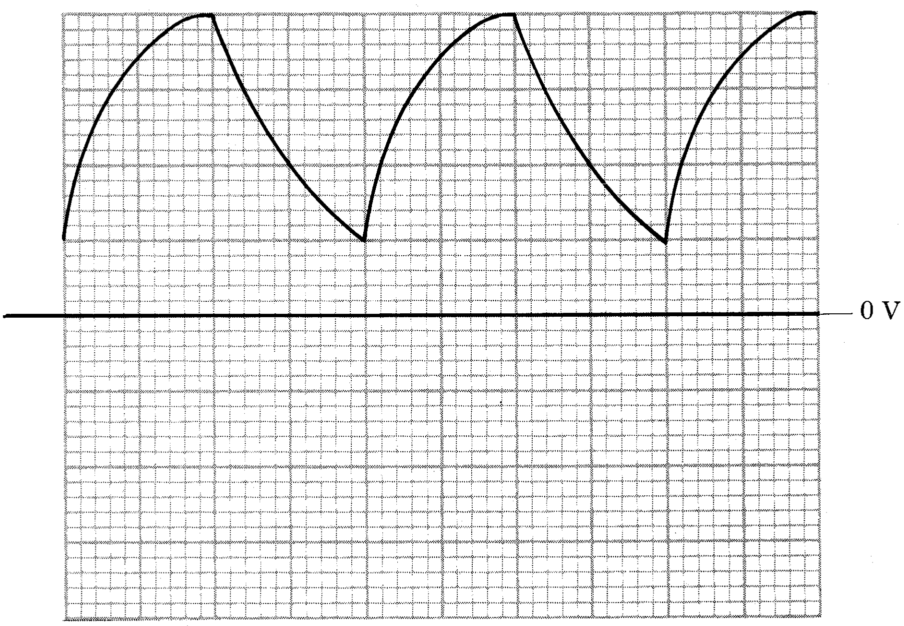


The time base of the oscilloscope is set at 5 m s per centimetre and the Y gain is set at 2 V per centimetre.

Calculate the frequency of the vibrating switch. **2**

8. (continued)

(*b*) With the settings of the oscilloscope unaltered, a new trace is produced when the resistance of one of the variable resistors is changed.



(i) State which one of the variable resistors was changed and whether its resistance was increased or decreased. Justify your answer.

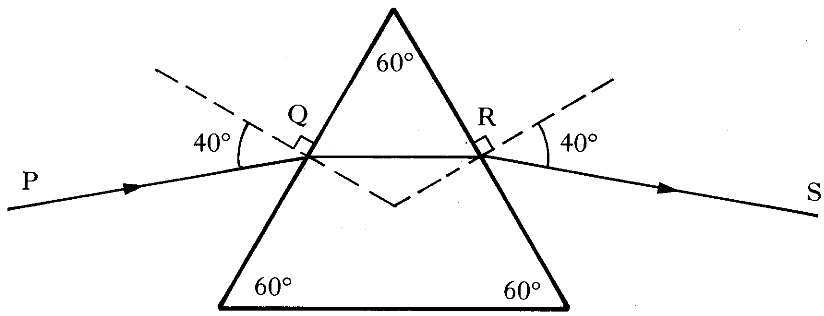
(ii) Calculate the charge lost by the capacitor each time the switch is in the discharge position. **6**

(8)

[Turn over

Marks

9. (*a*) The diagram below shows the path of a monochromatic beam of light through a triangular plastic prism.



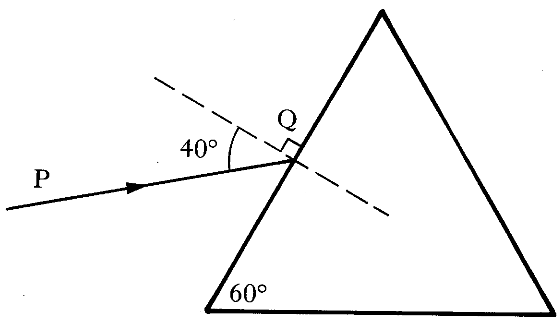
plastic prism

(i) Calculate the refractive index of the plastic.

(ii) Sketch a copy of the above diagram with ray PQRS clearly labelled. (Sizes of angles need not be shown.)

Add to your drawing the path which the ray PQ would take from Q if the prism were made of a plastic with a **slightly higher** refractive index. **3**

(*b*) The original prism is now replaced with one of the same size and shape but made from glass of refractive index 1·80.



glass prism

(i) Calculate the critical angle for this glass.

(ii) Draw an accurate diagram, showing the passage of the ray PQ through this prism until after it emerges into the air.

Mark on your diagram the values of all relevant angles. **5**

(8)

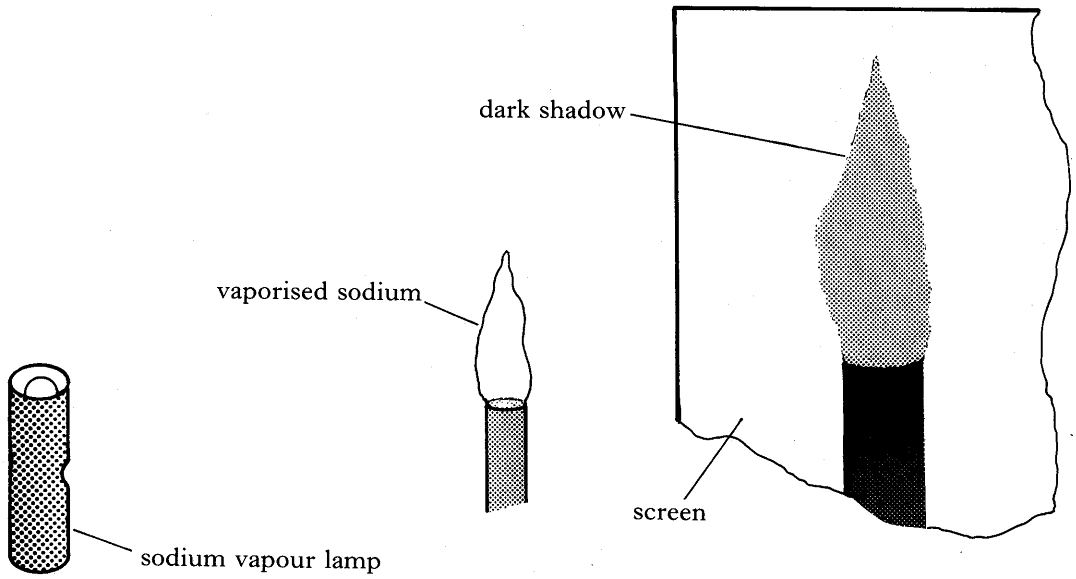
Marks

10. (*a*) A sodium vapour lamp emits bright yellow light when electrons make transitions from one energy level to another within the sodium atoms.

(i) State whether electrons are moving to higher or lower energy levels when the light is emitted.

(ii) Using information provided in the data sheet, calculate the energy difference between these two electron energy levels in the sodium atom. **4**

(*b*) A Bunsen flame containing vaporised sodium is placed between a sodium vapour lamp and a screen as shown.



(i) Explain why a dark shadow of the flame is seen on the screen.

(ii) The sodium vapour lamp is replaced with a cadmium vapour lamp.

Explain why there is now no dark shadow of the flame on the screen. **2**

(6)

[Turn over

Marks

11. A nuclear medicine laboratory contains a small radioactive source in a sealed container. The following information is displayed on the label.

> Radionuclide : ^{131}I
> Date : 23rd Feb. '93 (12 noon)
> Activity : 300 MBq
> Half-life : 8 days
> Radiation emitted : gamma (quality factor 1)
> Dose equivalent rate at a distance of 1 m : 16 μSv h^{-1}
> Half value thickness of lead : 3·3 mm

(*a*) When the source has the activity stated on the label, how many nuclei decay in one minute? **1**

(*b*) A technician needs to work at a distance of 1 m from a freshly prepared source.

For what period of time can the technician work at this distance so that the absorbed dose does not exceed 50 μGy? **2**

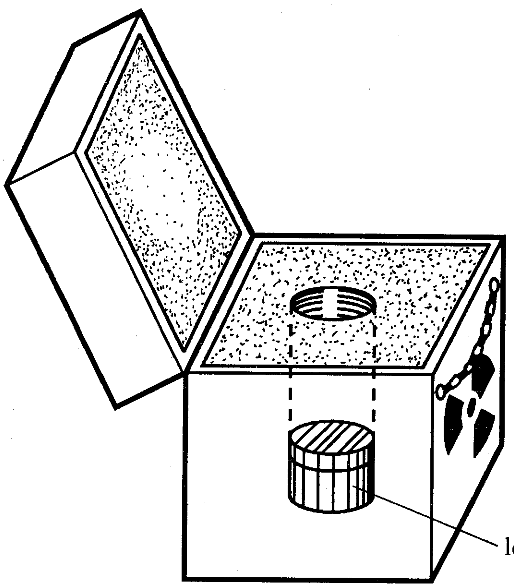
(*c*) Lead shielding is used around the source to reduce the dose equivalent rate at a distance of 1 m to 2·5 μSv h^{-1}.

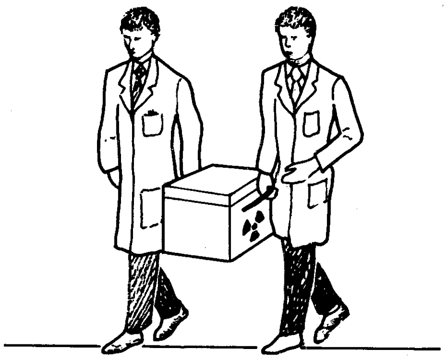
(i) On the square ruled paper provided, draw a graph to show how the dose equivalent rate at a distance of one metre varies with the thickness of lead shielding.

(ii) Use your graph to estimate the thickness of lead needed to provide the required level of shielding. **3**

11. (continued)

(*d*) A gamma ray source is often transported in a cardboard container carried by two porters. The source is inside a small lead pot surrounded by a large volume of polystyrene packaging.





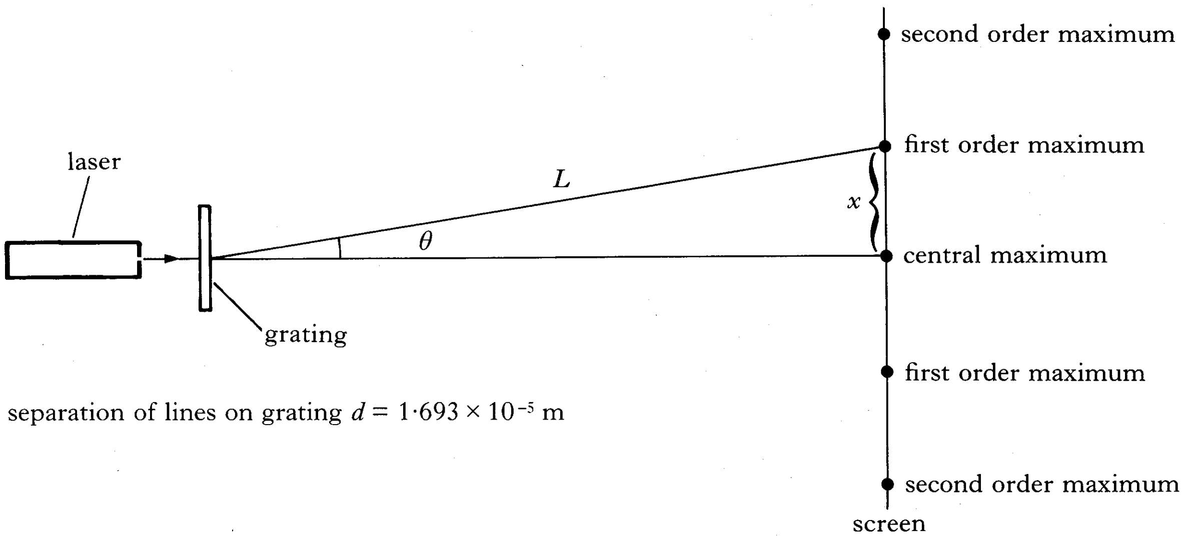
The lead pot provides shielding.

What other feature of this packaging system reduces the dose equivalent rate for the porters? Give a reason for your answer. **1**

(7)

[Turn over

12. The apparatus shown below is set up to determine the wavelength of light from a laser.



separation of lines on grating $d = 1{\cdot}693 \times 10^{-5}$ m

The wavelength of the light is calculated using the equations

$$\lambda = d \sin \theta \quad \text{and} \quad \sin \theta = \frac{x}{L}$$

where angle θ and distances x and L are as shown in the diagram.

(*a*) Seven students measure the distance L with a tape measure.

Their results are as follows.

2·402 m 2·399 m 2·412 m 2·408 m

2·388 m 2·383 m 2·415 m

Calculate the mean value for L **and** the approximate random error in the mean. **2**

(*b*) The best estimate of the distance x is (91 ± 1) mm.

Show by calculation whether L or x has the larger percentage error. **2**

(*c*) Calculate the wavelength, in nanometres, of the laser light.

You must give your answer in the form

final value ± error. **3**

(*d*) Suggest an improvement which could be made so that a more accurate estimate of the wavelength could be made.

You must use only the same equipment and make the same number of measurements. **1**

(8)

[*END OF QUESTION PAPER*]