3220/202

SCOTTISH
CERTIFICATE OF
EDUCATION
1998

FRIDAY, 15 MAY
1.00 PM – 3.30 PM

PHYSICS
HIGHER GRADE
Paper II

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 Scottish Qualifications Authority.

SCOTTISH
QUALIFICATIONS
AUTHORITY

DATA SHEET

COMMON PHYSICAL QUANTITIES

Quantity	*Symbol*	*Value*	*Quantity*	*Symbol*	*Value*
Speed of light in vacuum	c	$3{\cdot}00 \times 10^{8}$ m s^{-1}	Mass of electron	m_e	$9{\cdot}11 \times 10^{-31}$ kg
Charge on electron	e	$-1{\cdot}60 \times 10^{-19}$ C	Mass of neutron	m_n	$1{\cdot}675 \times 10^{-27}$ kg
Gravitational acceleration	g	$9{\cdot}8$ m s^{-2}	Mass of proton	m_p	$1{\cdot}673 \times 10^{-27}$ kg
Planck's constant	h	$6{\cdot}63 \times 10^{-34}$ 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
Crown glass	1·50	Water	1·33
Ice	1·31	Air	1·00
Perspex	1·49		

SPECTRAL LINES

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

Element	*Wavelength*/nm	*Colour*
Cadmium	644	Red
	509	Green
	480	Blue

Lasers

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

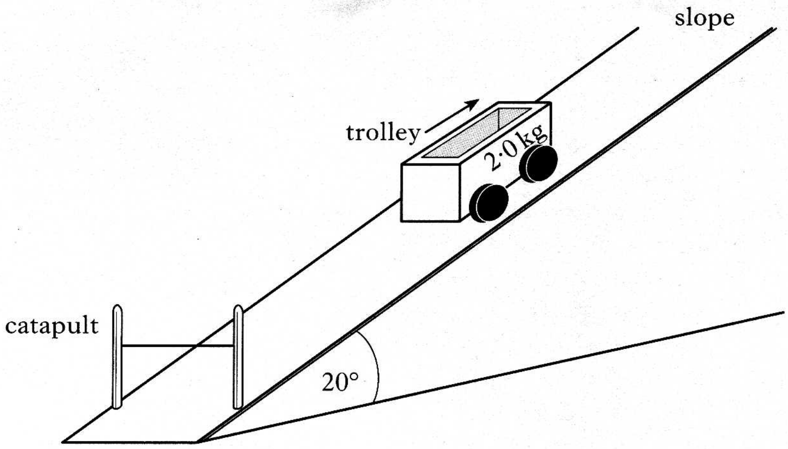
PROPERTIES OF SELECTED MATERIALS

Substance	*Density*/ kg m^{-3}	*Melting Point*/ K	*Boiling Point*/ K	*Specific Heat Capacity*/ J kg^{-1} K^{-1}	*Specific Latent Heat of Fusion*/ J kg^{-1}	*Specific Latent Heat of Vaporisation*/ 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.

Marks

1. A trolley of mass 2·0 kg is catapulted up a slope. The slope is at an angle of 20° to the horizontal as shown in the diagram below. The speed of the trolley when it loses contact with the catapult is 3·0 m s^{-1}.



The size of the force of friction acting on the trolley as it moves up the slope is 1·3 N.

(*a*) (i) Calculate the component of the weight of the trolley acting parallel to the slope.

(ii) Draw a diagram to show the forces acting on the trolley as it moves **up the slope** and is no longer in contact with the catapult.

Show only forces or components of forces acting parallel to the slope. Name the forces.

(iii) Show that, as the trolley moves up the slope, it has a deceleration of magnitude 4·0 m s^{-2}.

(iv) Calculate the time taken for the trolley to reach its furthest point up the slope.

(v) Calculate the maximum distance the trolley travels along the slope. **9**

The trolley now moves back down the slope.

(*b*) (i) Draw a diagram to show the forces acting on the trolley as it moves **down the slope**.

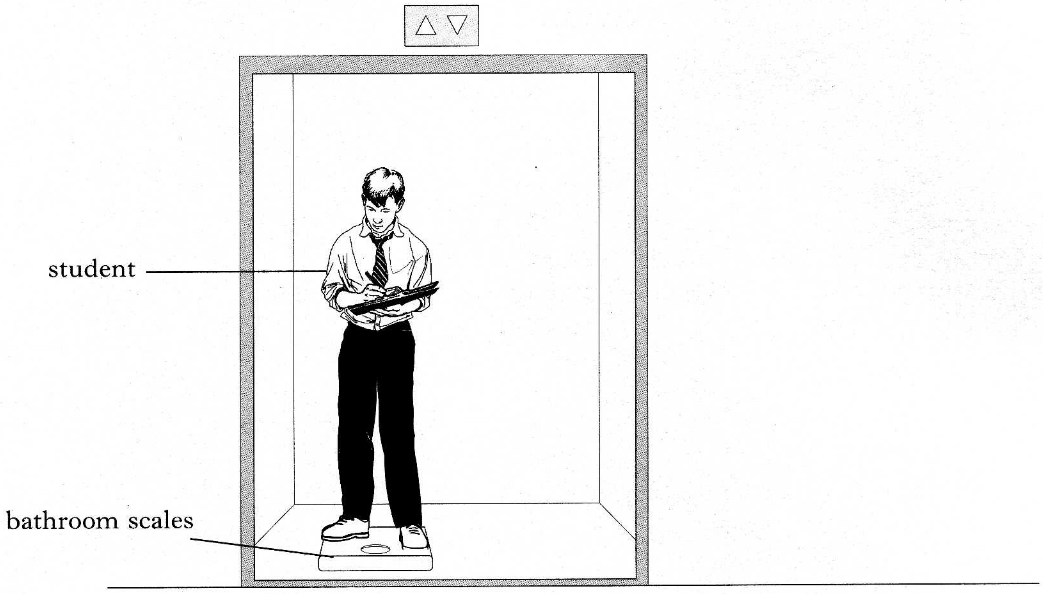
Show only forces or components of forces acting parallel to the slope. Name the forces.

(ii) The magnitude of the deceleration of the trolley is 4·0 m s^{-2} as it moves up the slope. Explain why the magnitude of the acceleration is not 4·0 m s^{-2} when the trolley moves down the slope. **2**

(11)

[Turn over

2. A student performs an experiment to study the motion of the school lift as it moves upwards.



The student stands on bathroom scales during the lift's journey upwards.

The student records the reading on the scales at different parts of the lift's journey as follows.

Part of journey	*Reading on scales*
At the start (while the lift is accelerating)	678 N
In the middle (while the lift is moving at a steady speed)	588 N
At the end (while the lift is decelerating)	498 N

(*a*) Show that the mass of the student is 60 kg. **2**

(*b*) Calculate the initial acceleration of the lift. **2**

(*c*) Calculate the deceleration of the lift. **1**

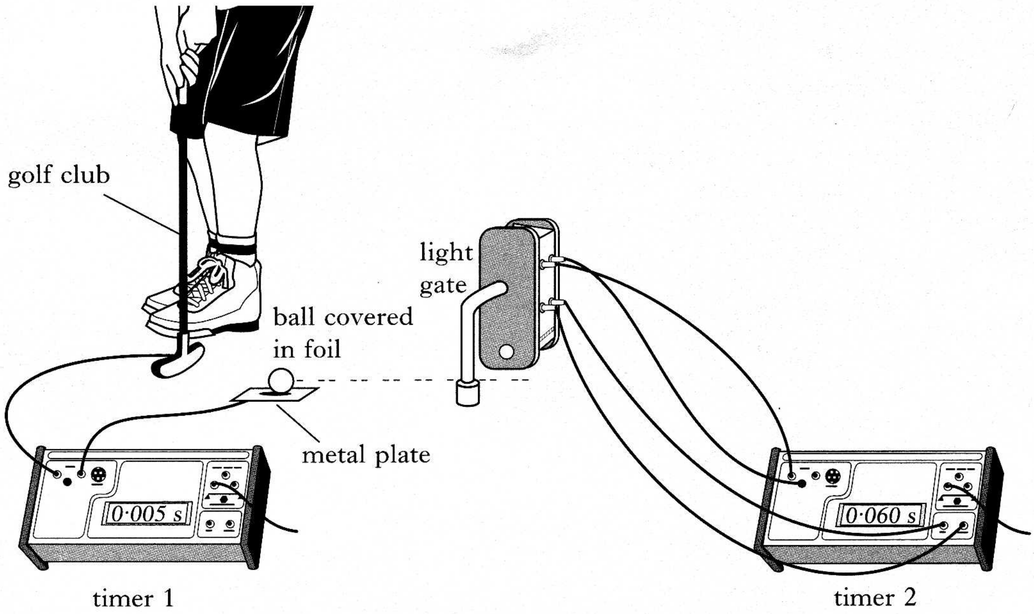
(*d*) During the journey, the lift accelerates for 1·0 s, moves at a steady speed for 3·0 s and decelerates for a further 1·0 s before coming to rest.

Sketch the acceleration-time graph for this journey. **2**

(7)

Marks

3. The apparatus in the diagram is being used to investigate the average force exerted by a golf club on a ball.



The club hits the stationary ball. Timer 1 records the time of contact between the club and the ball. Timer 2 records the time taken for the ball to pass through the light gate beam.

The mass of the ball is 45·00 ± 0·01 g.

The time of the contact between club and ball is 0·005 ± 0·001 s.

The time for the ball to pass through the light gate beam is 0·060 ± 0·001 s.

The diameter of the ball is 24 ± 1 mm.

(*a*) (i) Calculate the speed of the ball as it passes through the light gate.

(ii) Calculate the average force exerted on the ball by the golf club. **3**

(*b*) (i) Show by calculation which measurement contributes the largest percentage error in the final value of the average force on the ball.

(ii) Express your numerical answer to (*a*)(ii) in the form

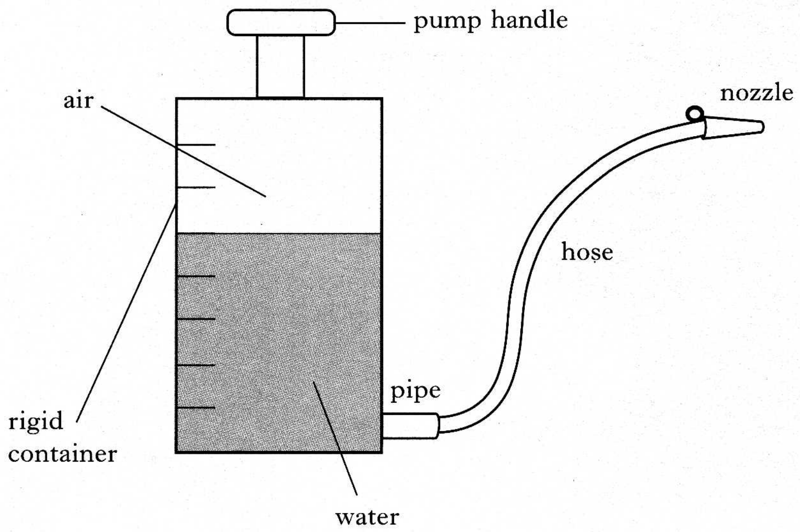
final value ± absolute error. **3**

(6)

[Turn over

4. The rigid container of a garden sprayer has a total volume of 8·0 litres (8×10^{-3} m^3).

A gardener pours 5·0 litres (5×10^{-3} m^3) of water into the container. The pressure of the air inside the container is $1{\cdot}01 \times 10^5$ Pa.



(*a*) Calculate the mass of air in the sprayer. Use information from the data sheet. **3**

(*b*) The gardener now pumps air into the container until the pressure of the air inside it becomes $3{\cdot}0 \times 10^5$ Pa.

(i) The area of the water surface in contact with the compressed air is $7{\cdot}0 \times 10^{-3}$ m^2.

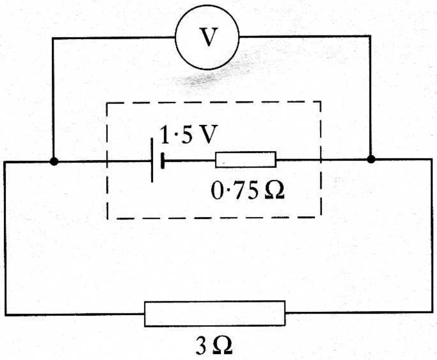
Calculate the force which the compressed air exerts on the water.

(ii) Water is now released through the nozzle. Calculate the final pressure of the air inside the sprayer when the volume of water falls from 5·0 litres (5×10^{-3} m^3) to 2·0 litres (2×10^{-3} m^3).

Assume the temperature of the compressed air remains constant. **4**

(7)

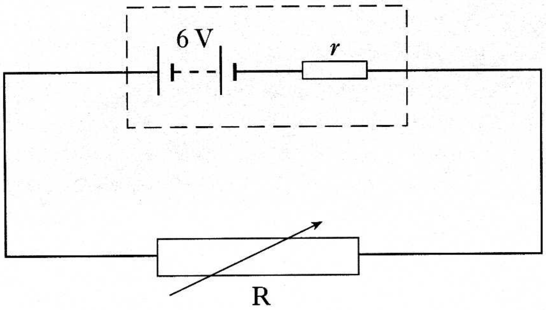
5. (*a*) A cell of e.m.f. 1·5 V and internal resistance 0·75 Ω is connected as shown in the following circuit.



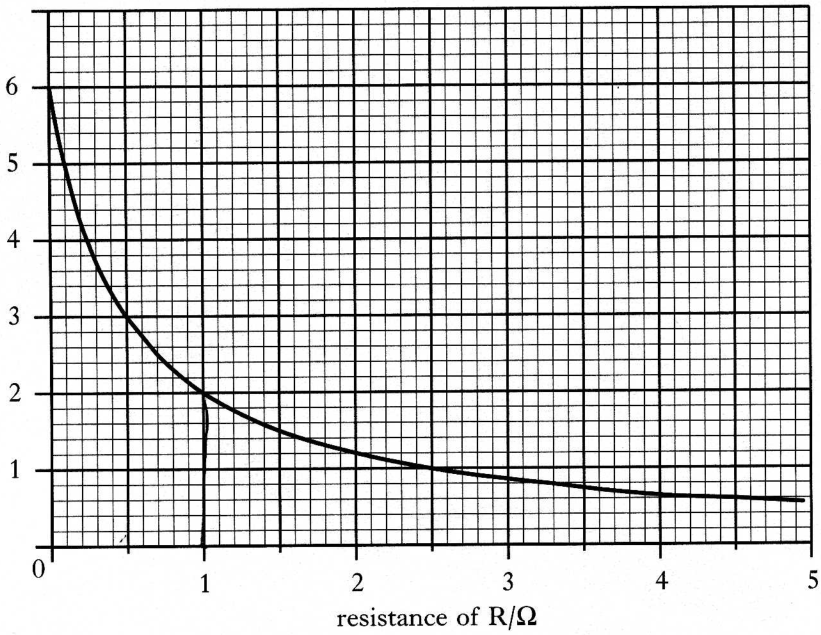
(i) Calculate the value of the reading on the voltmeter.

(ii) What is the value of the "lost volts" in this circuit? **5**

(*b*) A battery of e.m.f. 6 V and internal resistance, r, is connected to a variable resistor R as shown in the following circuit diagram.



The graph below shows how the "lost volts" of this battery changes as the resistance of R increases.



(i) Use information from the graph to calculate the p.d. across the terminals of the battery (t.p.d.) when the resistance of R is 1 Ω.

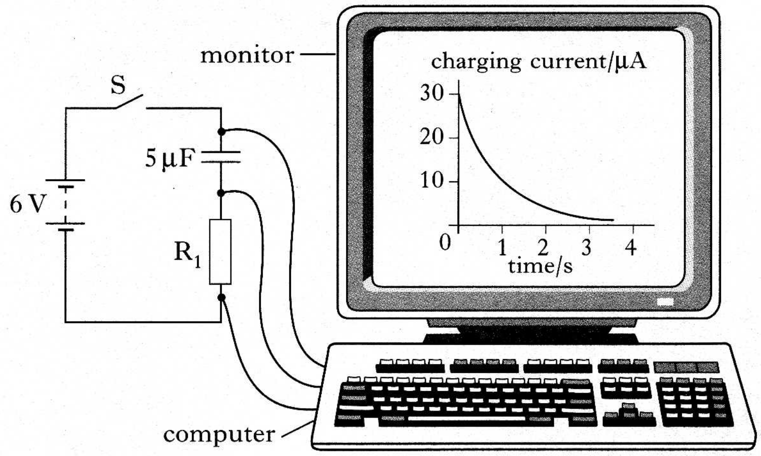
(ii) Calculate the internal resistance, r, of the battery. **4**

(9)

Marks

6. (a) A capacitor has a value of $5\,\mu F$. Explain in terms of electric charge what this means. **1**

(b) The $5\,\mu F$ capacitor shown in the circuit below is initially uncharged. The circuit is connected to a computer and switch S is closed. The monitor of the computer displays a graph of current against time as the capacitor charges.



The battery has negligible internal resistance.

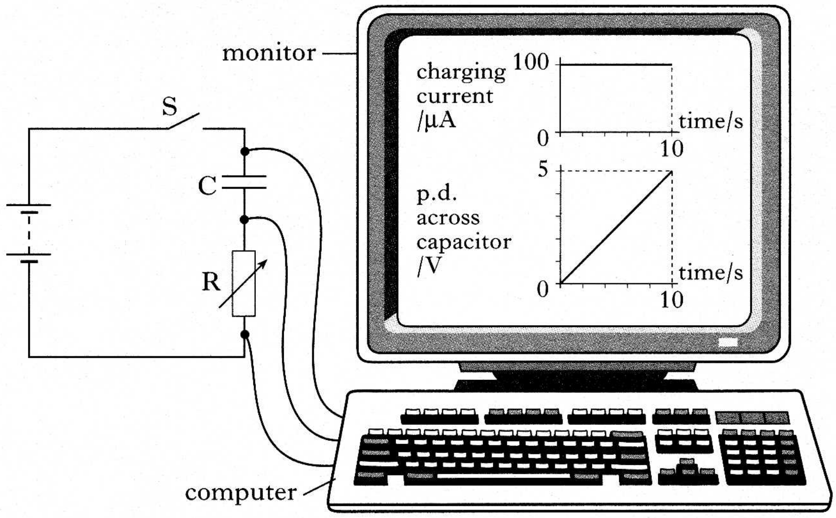
(i) Calculate the resistance of R_1.

(ii) The resistor R_1 is replaced by another resistor R_2. The resistance of R_2 is half that of R_1.

The capacitor is discharged and the experiment repeated.

Sketch the graph of charging current against time when R_2 is used. Include values on the axes. **3**

(c) In the following circuit a variable resistor R is used to keep the current constant as a different capacitor charges. The graphs on the monitor show how the charging current and p.d. across the capacitor vary with time after switch S is closed.



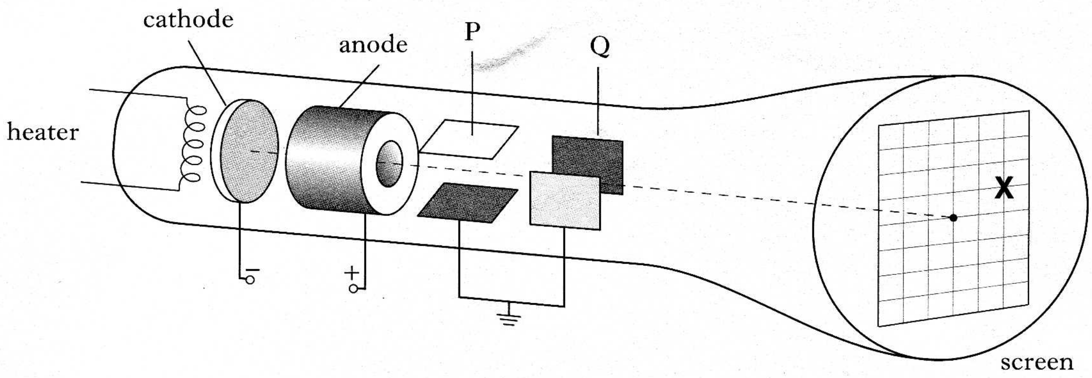
(i) What adjustment must be made to the variable resistor R so that a constant charging current is produced?

(ii) Show by calculation that 10 seconds after switch S is closed, the charge on the capacitor is 1mC.

(iii) Calculate the capacitance of C. **4**

(8)

7. The diagram below shows a cathode ray tube used in an oscilloscope.



The electrons which are emitted from the cathode start from rest and reach the anode with a speed of $4{\cdot}2 \times 10^7$ m s^{-1}.

(*a*) (i) Calculate the kinetic energy in joules of each electron just before is reaches the anode.

(ii) Calculate the p.d. between the anode and the cathode. **4**

(*b*) Describe how the spot at the centre of the screen produced by the electrons can be moved to position **X**.

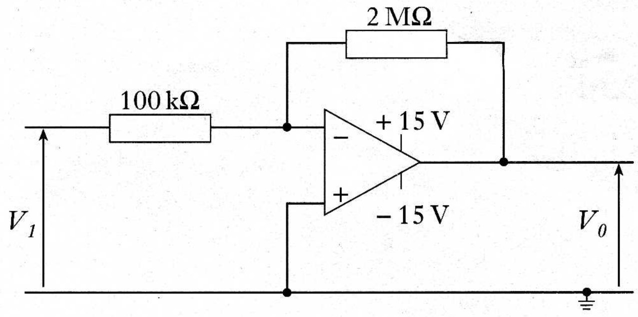
Your answer must make reference to the relative sizes and polarity (signs) of the voltages applied to plates P and Q. **2**

(6)

[Turn over

Marks

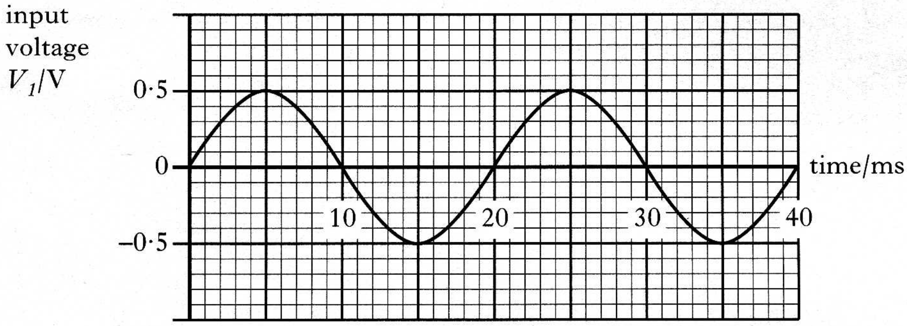
8. An op-amp is connected in an amplifier circuit as shown below.



(*a*) (i) State the mode in which the op-amp is working.

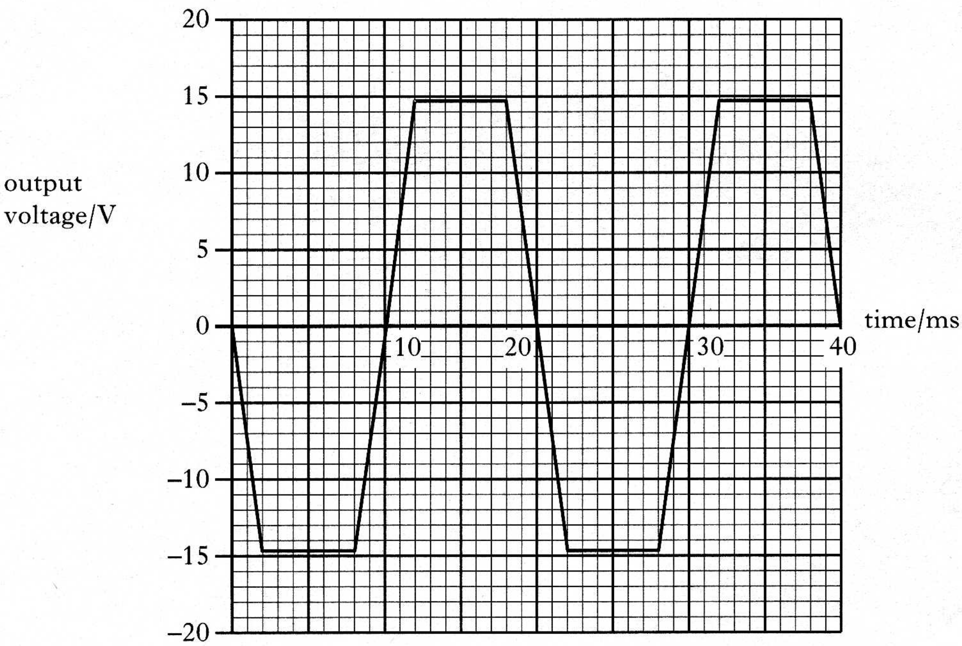
(ii) Calculate the gain of this amplifier circuit.

(iii) The following graph shows how the input voltage V_1 varies with time.



Sketch a graph to show how the output voltage V_0 varies with time. **5**

(*b*) The amplifier circuit above is modified to give the following output voltage.

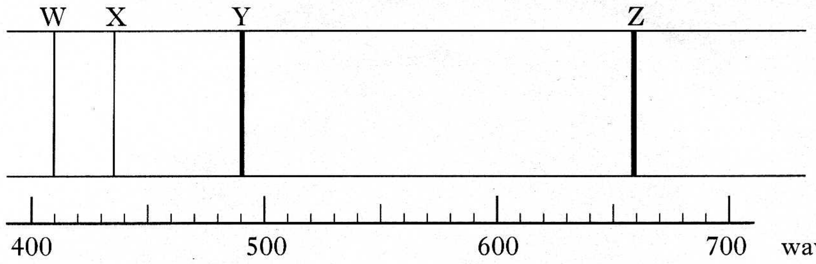


(i) Explain the shape of the output voltage graph between 2 ms and 8 ms.

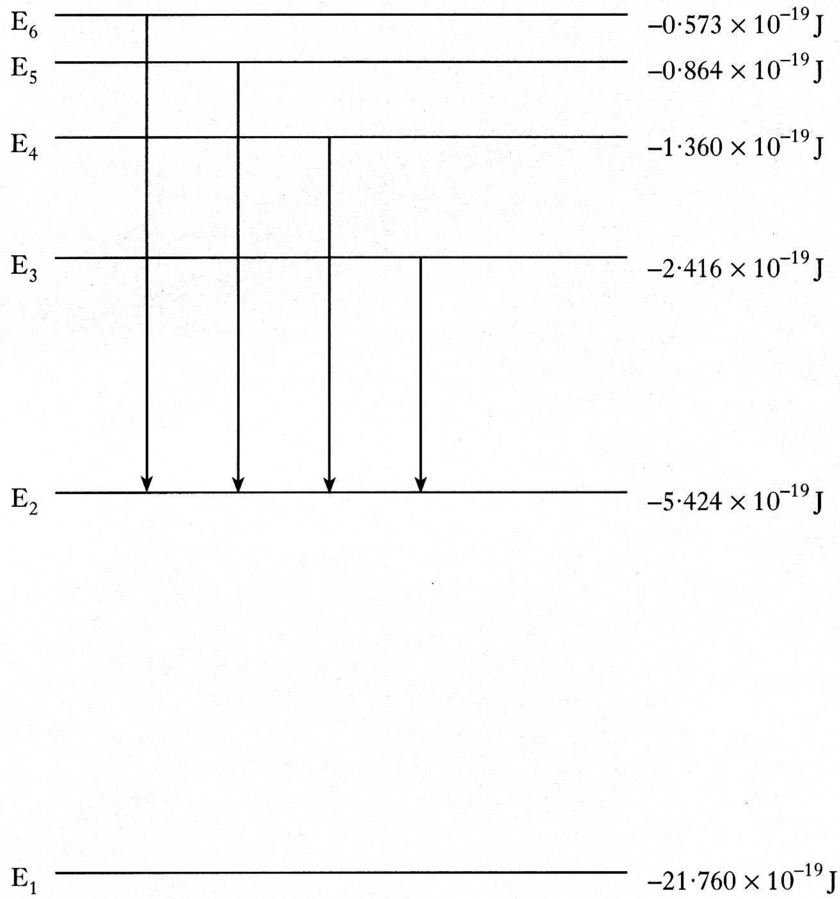
(ii) Describe **two** alterations which could be made to the circuit above to give this output voltage. **3**

(8)

9. The line emission spectrum of hydrogen has four lines in the visible spectrum as shown in the following diagram.



These four lines are caused by electron transitions in a hydrogen atom from high energy levels to a low energy level E_2 as shown below.



(*a*) From the information above, state which spectral line W, X, Y or Z is produced by an electron transition from E_3 to E_2. **1**

(*b*) Explain why lines Y and Z in the line emission spectrum are brighter than the other two lines. **1**

(*c*) Infrared radiation of frequency $7{\cdot}48 \times 10^{13}$ Hz is emitted from a hydrogen atom.

(i) Calculate the energy of one photon of this radiation.

(ii) Show by calculation which electron transition produces this radiation. **4**

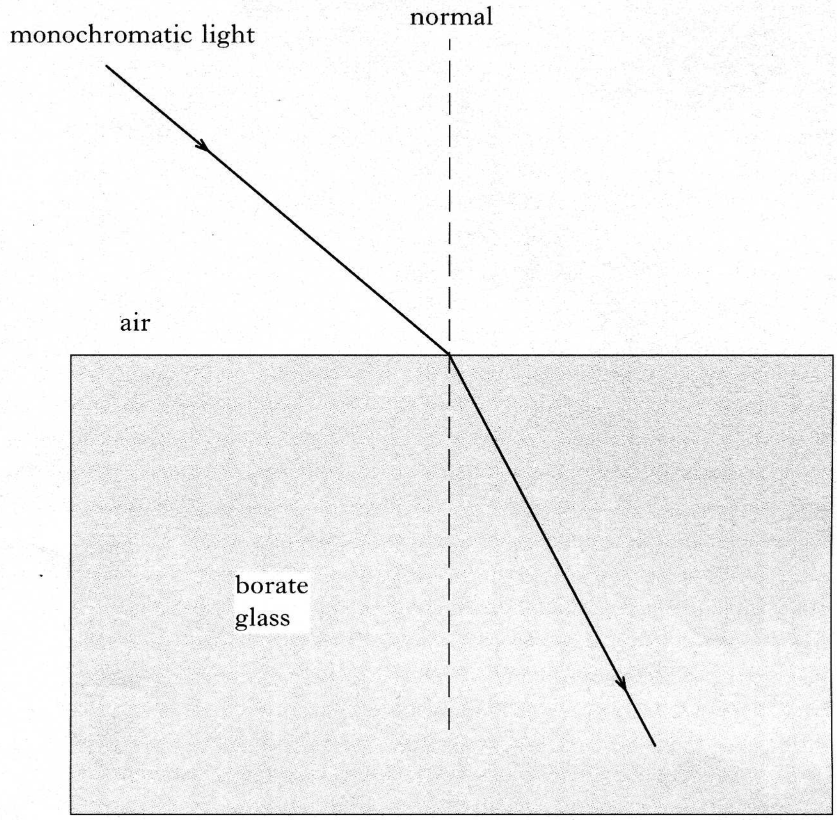
(6)

[Turn over

Marks

10. (*a*) The following diagram shows a ray of monochromatic light passing from air into a block of borate glass.

The diagram is drawn to scale.

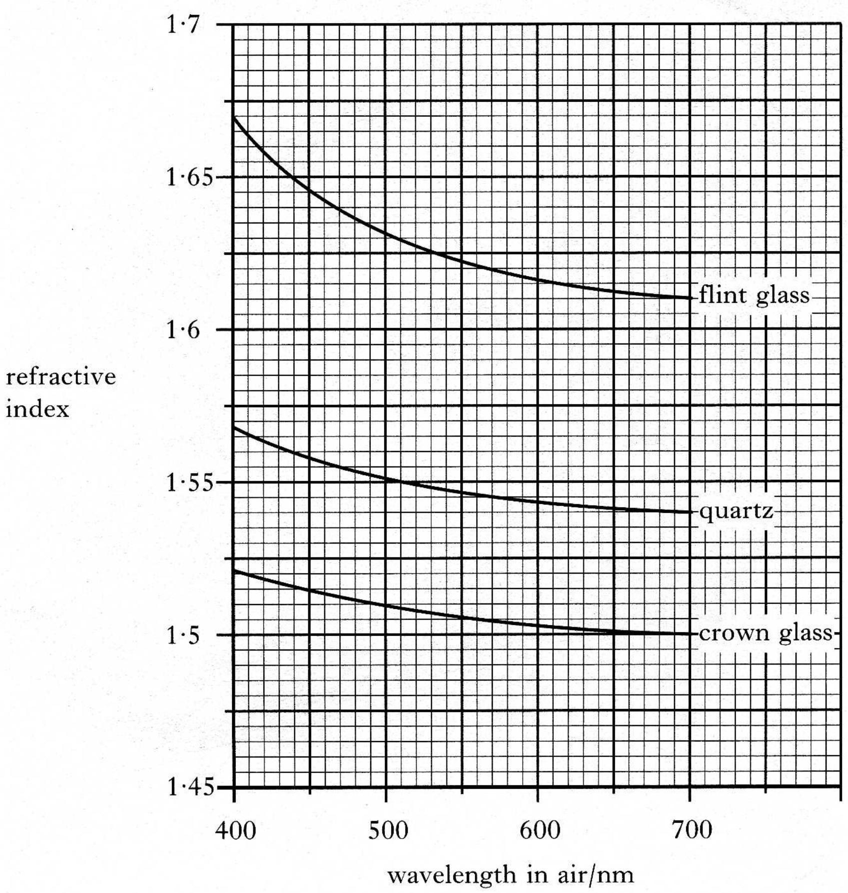


(i) Use measurements taken from the above diagram to calculate the refractive index of borate glass for this light. You will need to use a protractor.

(ii) Calculate the value of the critical angle for this light in the borate glass. **4**

10. (continued)

(*b*) The following graph shows how refractive index depends on the type of material and the wavelength in air of the light used.

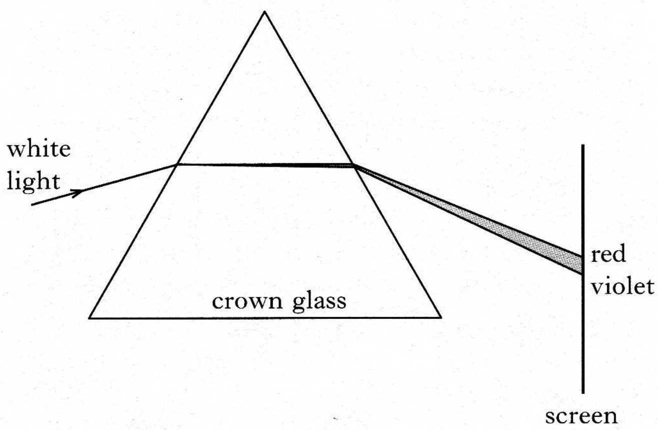


A ray of light of wavelength 510 nm in air passes into a block of quartz.

(i) Calculate the wavelength of this light in the quartz.

(ii) Explain what happens to the value of the critical angle in quartz as the wavelength of visible light increases.

(iii) A ray of white light enters a triangular prism made of crown glass, producing a visible spectrum on a screen, as shown below.



The crown glass prism is now replaced by a similar prism made from flint glass.

Describe how the visible spectrum on the screen will be different from before. **5**

(9)

 [Turn over for Question 11 on *Page fourteen*

Marks

11. (*a*) The first three stages in a radioactive decay series are shown below.

$$^{238}_{92}\text{U} \longrightarrow {}^{234}_{90}\text{Th} \longrightarrow {}^{234}_{91}\text{Pa} \longrightarrow {}^{234}_{92}\text{U}$$

(i) What particle is emitted when Thorium (Th) decays to Palladium (Pa)?

(ii) How many neutrons are in the nuclide represented by $^{238}_{92}\text{U}$?

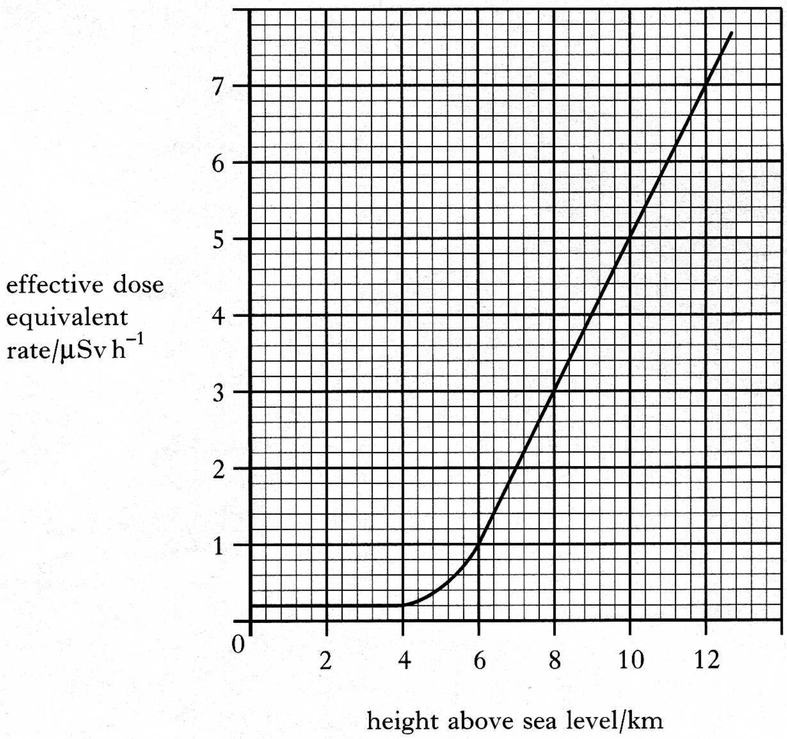
(iii) In the next stage of the above decay series, an alpha particle is emitted.

Copy and complete this stage of the radioactivity decay series shown below, giving values for a, b, c and d, and naming the element X.

$$^{234}_{92}\text{U} \longrightarrow {}^{a}_{b}\text{X} + {}^{c}_{d}\alpha$$

5

(*b*) The following graph shows how the effective dose equivalent rate due to background radiation varies with height above sea level.



(i) Name **two** sources of background radiation.

(ii) The graph shows that there is an increase in effective dose equivalent rate at altitudes greater than 4 km. Suggest a reason for this increase.

(iii) An aircraft makes a 7 hour flight at a cruising altitude of 10 km.

(A) Calculate the effective dose equivalent received by a passenger during this flight.

(B) A regular traveller makes 40 similar flights in one year and spends the rest of the year at sea level.

Calculate the effective dose equivalent of background radiation received by this traveller in that year.

8

(13)

[END OF QUESTION PAPER]