[3220/435] 1993

SCOTTISH CERTIFICATE OF EDUCATION

PHYSICS (REVISED)

Higher Grade—PAPER II

Wednesday, 19th 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.**

UCP 3220/435 6/3/19860

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*
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

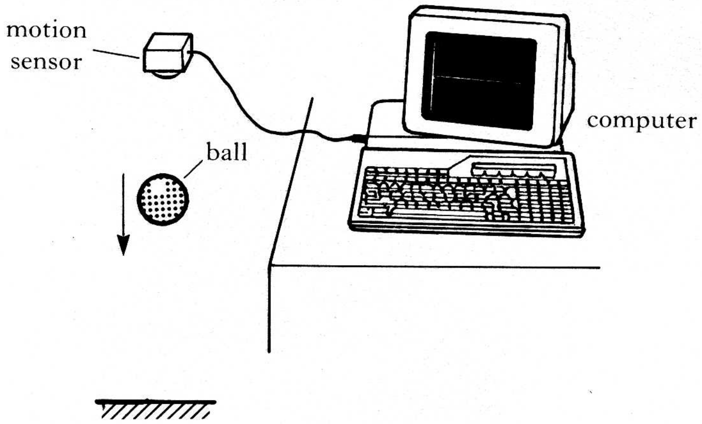
Element	*Wavelength/nm*	*Colour*
Carbon dioxide	9550 } 10590 }	Infra-red
Helium-neon	633	Red

PROPERTIES OF SELECTED MATERIALS

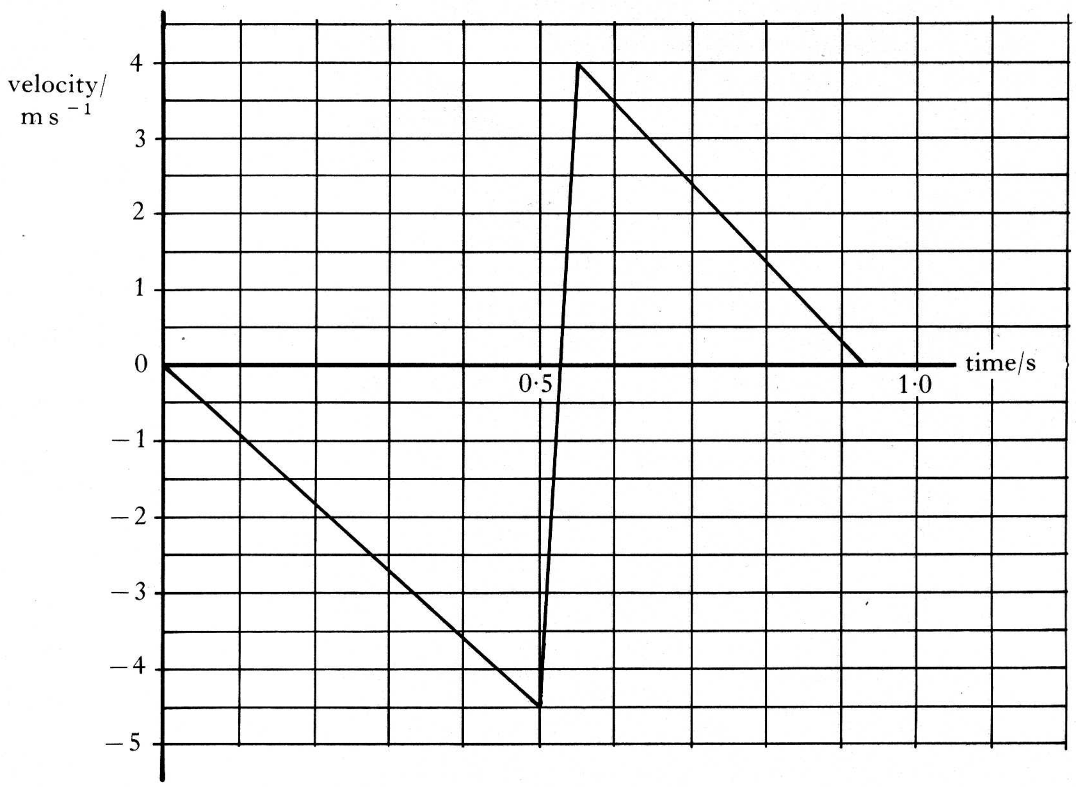
Substance	*Density/* $\mathrm{kg\,m^{-3}}$	*Melting Point/* K	*Boiling Point/* K	*Specific Heat Capacity/* $\mathrm{J\,kg^{-1}\,K^{-1}}$	*Specific Latent Heat of Fusion/* $\mathrm{J\,kg^{-1}}$	*Specific Latent Heat of Vaporisation/* $\mathrm{J\,kg^{-1}}$
Aluminium	$2{\cdot}70 \times 10^{3}$	933	2623	$9{\cdot}02 \times 10^{2}$	$3{\cdot}95 \times 10^{5}$	....
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. The velocity–time graph for one bounce of a ball is obtained using a motion sensor connected to a computer as shown.



The ball is dropped from a position below the motion sensor and measurement starts at the same instant as the ball is released. The graph obtained is shown below.



(*a*) Calculate the acceleration of the falling ball. **2**

(*b*) The ball loses 1·7 joules of kinetic energy during the bounce. Show that the mass of the ball is 0·80 kg. **3**

(*c*) The momentum of the ball is changed by the bounce. What is the magnitude of this change? **2**

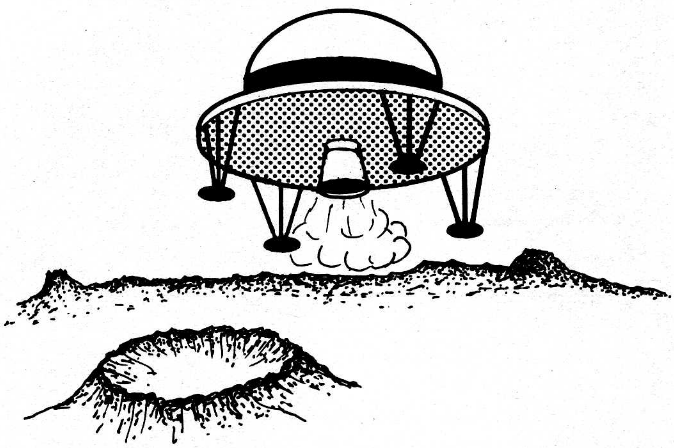
(*d*) The ball is in contact with the ground for 50 milliseconds. Calculate the magnitude of the average force exerted by the ball on the ground during the bounce. **2**

(9)

Marks

2. A lunar landing craft descends vertically towards the surface of the Moon with a constant speed of $2{\cdot}0\,\text{m s}^{-1}$. The craft and crew have a total mass of 15 000 kg.

Assume that the gravitational field strength on the Moon is $1{\cdot}6\,\text{N kg}^{-1}$.



(*a*) During the first part of the descent the upward thrust of the rocket engine is 24 000 N.

Show that this results in the craft moving with a constant speed. **2**

(*b*) The upward thrust of the engine is increased to 25 500 N for the last 18 seconds of the descent.

(i) Calculate the deceleration of the craft during this time.

(ii) What is the speed of the craft just before it lands?

(iii) How far is the craft above the surface of the Moon when the engine thrust is increased to 25 500 N? **7**

(9)

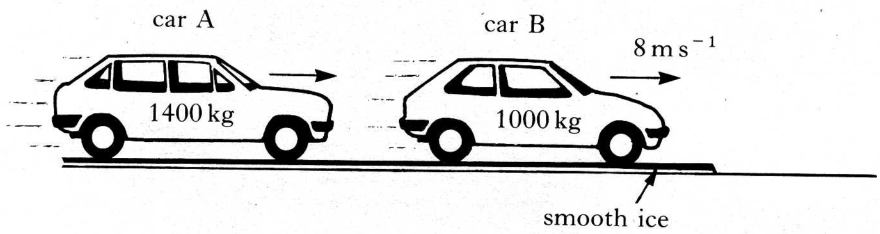
Marks

3. (*a*) State the law of conservation of linear momentum as it applies to a collision between two objects. 1

(*b*) Two cars, travelling in the same direction, skid on a patch of smooth, level ice.

Car A, of mass 1400 kg, skids straight into the back of car B, of mass 1000 kg.

The two cars become entangled after the impact and continue to move in the same straight line.



Immediately before the impact, car B is moving with a speed of $8\,m\,s^{-1}$.

Immediately after the impact, both cars are moving with a speed of $15\,m\,s^{-1}$.

(i) Calculate the speed of car A just before the collision takes place.

(ii) After the collision, the cars leave the patch of ice and continue skidding along the road. They come to rest in a distance of 20 metres after leaving the ice.

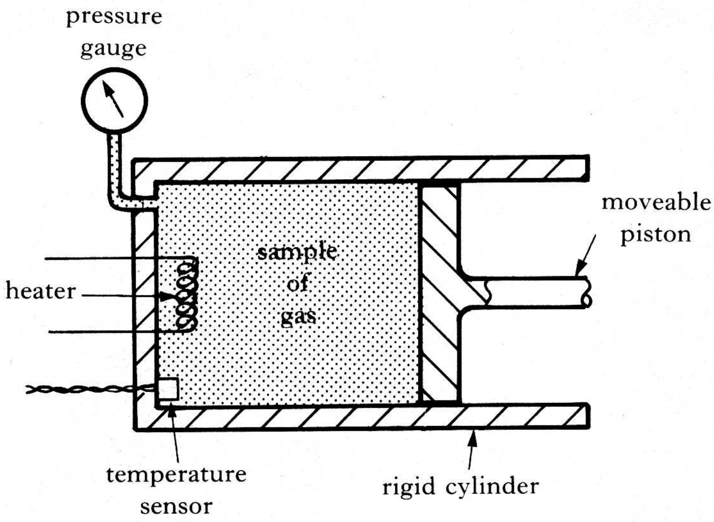
Calculate the average frictional force acting on the cars as they come to rest.

(iii) State what happens to the kinetic energy of the cars after they leave the ice. 7

(8)

[Turn over

4. A pupil uses the apparatus below to investigate properties of a sample of gas.

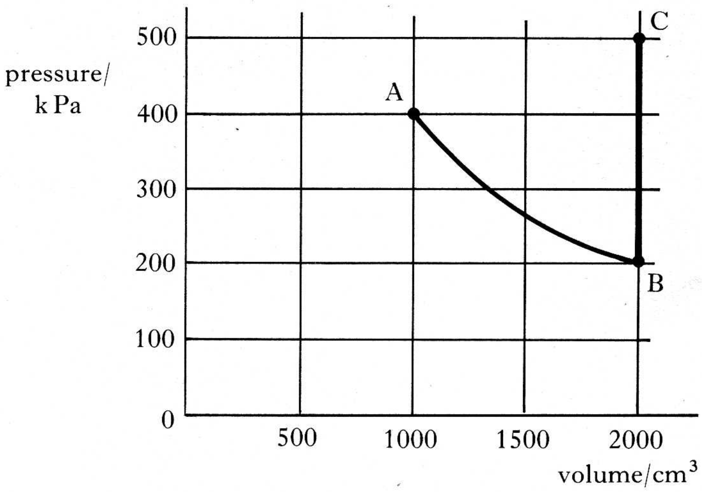


The volume of the sample of gas can be changed by moving the piston.

The temperature of the sample of gas can be increased by using the heater.

At the start, the pressure of the gas is 400 kPa and its volume is 1000 cm^3.

During the investigation, the pressure and volume of the gas change as indicated by sections AB and BC on the graph below.



During section AB, the temperature of the gas is constant at 300 K.

(*a*) **Calculate** the volume of the gas when its pressure is 250 kPa during stage AB. **2**

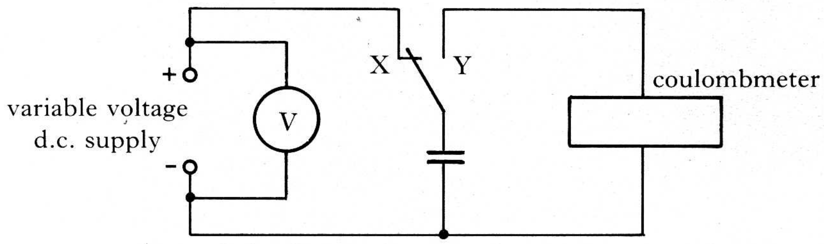
(*b*) State what happens to the pressure, volume and temperature of the gas over the section of the graph which starts at B and finishes at C. **2**

(*c*) What is the temperature of the gas, in kelvin, corresponding to point C on the graph? **2**

(6)

Marks

5. (*a*) The circuit shown below is used to find the capacitance of a capacitor.



With the switch in position X, the capacitor charges up to the supply voltage.

The reading on the voltmeter is noted and the switch is moved to position Y.

The coulombmeter then indicates the charge stored by the capacitor.

(i) One set of results is recorded below.

Voltmeter reading = 1·5 V
Coulombmeter reading = 24 μC.

Use these results to calculate a value for the capacitance of the capacitor.

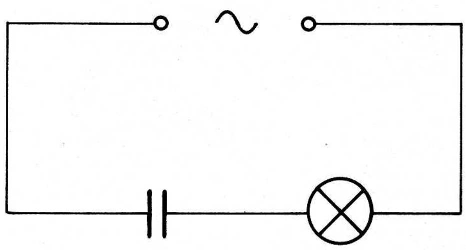
(ii) The experiment is repeated with the **same** capacitor for five different values of the supply voltage, giving the following values for the capacitance.

Capacitance in μF = 16, 18, 20, 16, 15.

Using these five results, calculate the mean value for the capacitance **and** the approximate random error in this value.

(iii) How could the approximate random error in the mean value of the capacitance be reduced? **6**

(*b*) The circuit below shows a capacitor connected to a lamp and a signal generator.



When the frequency of the signal generator is set at 100 Hz, the lamp glows.

The frequency of the signal generator is now altered while the amplitude is kept constant. The lamp glows more brightly.

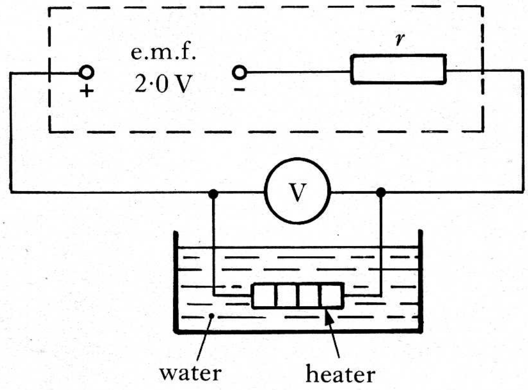
Explain this effect. **2**

(8)

[Turn over

Marks

6. A heater of resistance 0·32 ohms is connected to a power supply of e.m.f. 2·0 volts and internal resistance r as shown below.



(*a*) State what is meant by the term electromotive force (e.m.f.). **1**

(*b*) The power output of the **heater** is 8·0 watts.

Calculate:

(i) the current in the heater;

(ii) the reading on the voltmeter;

(iii) the internal resistance of the power supply. **5**

(*c*) Another identical heater is now placed in the water and connected in parallel with the original heater.

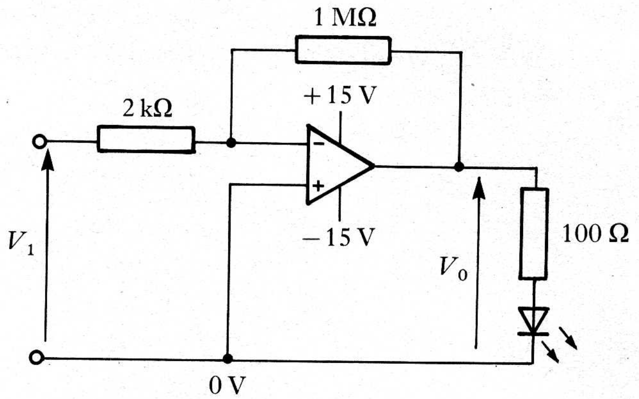
The rest of the circuit is unaltered.

How does this affect the rate at which heat is supplied to the water?

Justify your answer by calculation. **3**

(9)

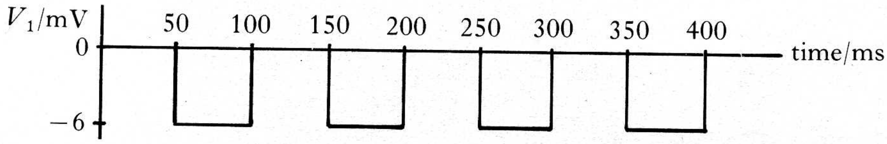
7. (*a*) A pupil connects an op-amp as in the circuit shown below.



(i) In which mode is this op-amp working?

(ii) Calculate the gain of the op-amp in this mode.

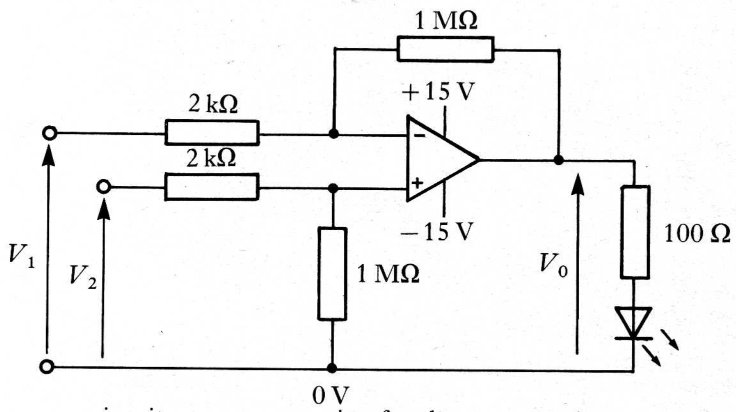
(iii) The input voltage V_1 varies with time as shown in the graph below.



Draw a graph showing how the output voltage V_0 varies with time, using the square-ruled paper provided. Numerical values must be given on both axes.

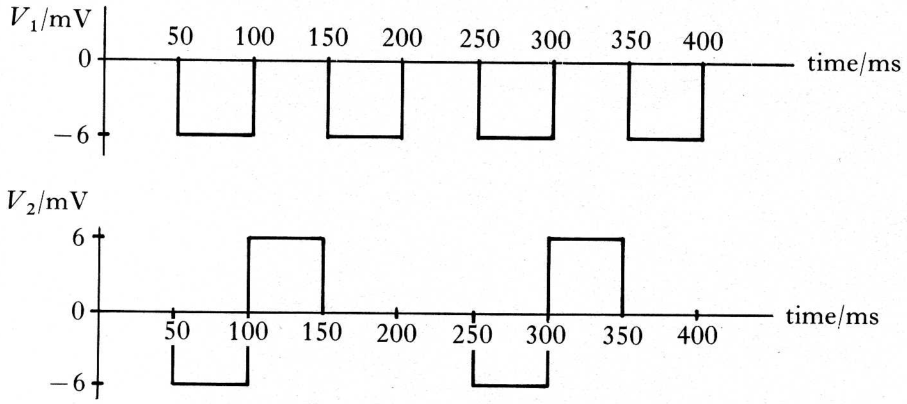
(iv) Describe fully the behaviour of the LED, in the above circuit, when supplied by this output voltage. **7**

(*b*) The op-amp is now set up in another mode as shown below.



(i) For this op-amp circuit, state an equation for the output voltage V_0 in terms of the input voltages V_1 and V_2.

(ii) The input voltages V_1 and V_2 vary with time as shown in the graphs below.

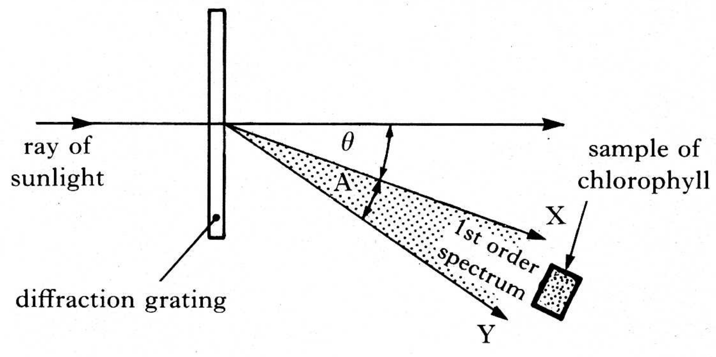


Draw a graph showing how the output voltage V_0 varies with time, giving numerical values on both axes. Use the square-ruled paper provided. **4**

(11)

8. A biologist is studying the effect of different colours of light on a sample of chlorophyll.

The biologist sets up the apparatus shown below, using a diffraction grating with $6{\cdot}0 \times 10^5$ lines per metre to produce a first order spectrum of sunlight.



(*a*) Explain briefly how a diffraction grating produces a continuous spectrum from the ray of sunlight. **2**

(*b*) (i) The wavelength of the light at the end X of the spectrum is 410 nm. Calculate the value of the angle θ.

(ii) The angle A, in the diagram above, is 9°. Calculate the wavelength at end Y of the spectrum. **5**

(*c*) The biologist now uses a triangular glass prism to produce a continuous spectrum from a ray of sunlight.

State **two** differences between this spectrum and the spectrum produced by the grating. **2**

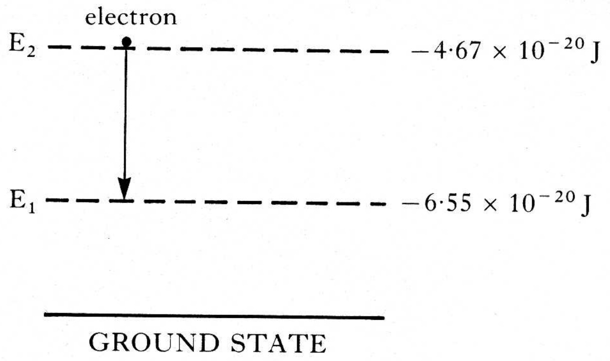
(9)

Marks

9. (*a*) Laser light is *monochromatic* and *coherent*.

Briefly explain the meaning of the terms *monochromatic* and *coherent*. **2**

(*b*) A laser radiates energy when electrons are stimulated to fall from energy level E_2 to energy level E_1 as shown in the diagram.



(i) What are the frequency and wavelength of the radiation emitted?

(ii) Name the section of the electromagnetic spectrum in which the radiation occurs. **5**

(*c*) The beam of light from a laser is very intense.

Give **two** reasons for this. **2**

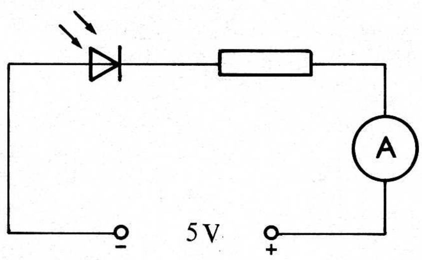
(9)

[Turn over

Marks

10. The circuit below shows a photodiode connected in series with a resistor and an ammeter.

The power supply has an output voltage of 5 V and negligible internal resistance.



In a darkened room, there is no current in the circuit.

When light strikes the photodiode, there is a current in the circuit.

(*a*) Describe the effect of light on the material of which the photodiode is made. **1**

(*b*) In which mode is the photodiode operating? **1**

(*c*) When the photodiode is placed 1·0 m from a small lamp, the current in the circuit is 3·0 μA.

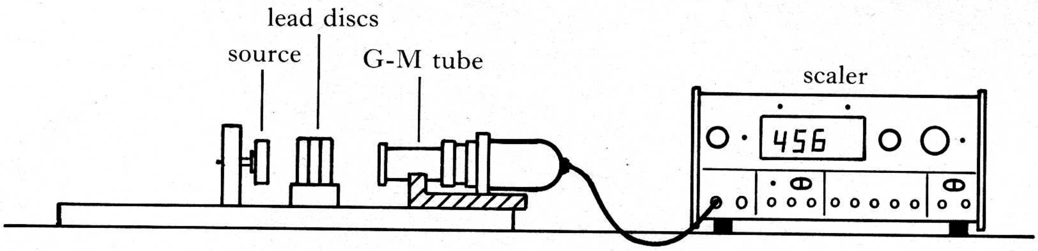
What is the current in the circuit when the photodiode is placed 75 cm from the same lamp? **3**

(5)

11. (*a*) A certain radioactive source emits only gamma radiation.

A technician is asked to determine the half-value thickness of lead for the radiation from this source.

The technician sets up the apparatus shown below and keeps the distance between the source and the gamma ray detector the same throughout the experiment.



The technician measures the count rate several times for a certain thickness of lead sheet, and obtains an average value for the count rate.

The measurements are repeated with several different thicknesses of lead sheet and also with no lead present.

The source and the lead are then removed and the background count rate is measured.

The technician corrects each average count rate for background and records the results as shown in the table.

Thickness of lead sheet in mm	*Corrected average count rate in counts/minute*
0	520
5	390
10	280
15	200
20	145
25	110

(i) Draw a graph of corrected average count rate against thickness of lead sheet, using the square-ruled paper provided.

Find the half-value thickness of lead for this source.

(ii) On the same axes, sketch a graph which might be obtained if the average count rate was not corrected for background radiation. **5**

(*b*) 21 years later, another technician repeats the experiment with the same source.

The gamma ray source has a half-life of 5·25 years.

What corrected average count rate would be recorded with no lead sheet between the source and the detector? **2**

(7)

[*END OF QUESTION PAPER*]