[3220/469] 1992

SCOTTISH CERTIFICATE OF EDUCATION

PHYSICS (REVISED)

Higher Grade—PAPER II

Thursday, 14th 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. **Use the approximation $g = 10\,\mathrm{m\,s^{-2}}$ or $g = 10\,\mathrm{N\,kg^{-1}}$.**

   Any other data required will be found in the Science Data Booklet (1982 edition) provided.

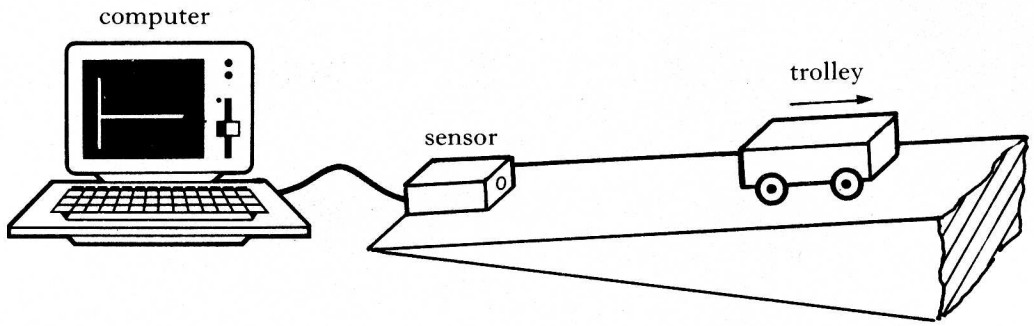
4. **Care should be taken not to give an unreasonable number of significant figures in the final answers to calculations.**

5. **Square-ruled paper (if used) should be placed inside the front cover of the answer book for return to the Examination Board.**

UCP 3220/469 6/3/16560

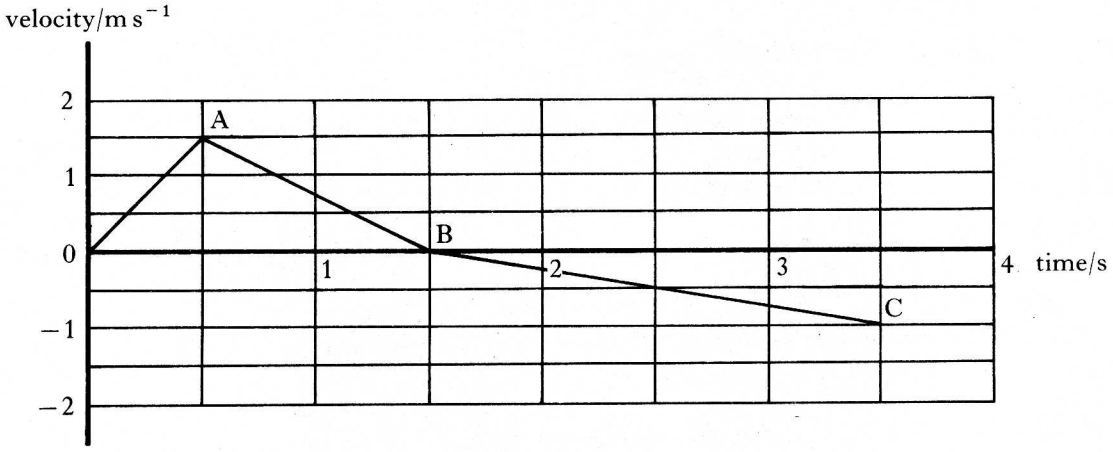
Marks

1. The velocity of a trolley on a slope can be investigated using a computer and a sensor as shown below.



The sensor emits ultrasound pulses which are reflected from the trolley. The computer measures the time between emitted and reflected pulses and uses this information to calculate the velocity at regular times.

In an investigation, the trolley is given a sharp push **up** the slope and then released. The graph below shows the resulting velocity-time graph as displayed on the screen.



Point A on the graph corresponds to the instant at which the trolley is released.

(*a*) At what time is the trolley at its maximum displacement from the sensor? You must justify your answer. **2**

(*b*) On the square-ruled paper provided, draw the corresponding acceleration-time graph of the motion. **3**

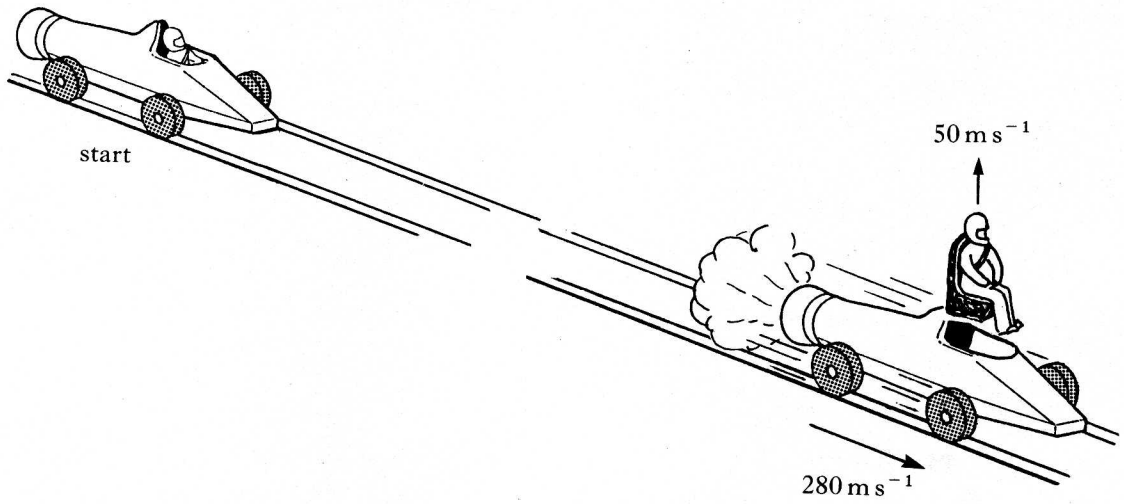
(*c*) Draw a diagram to show the forces acting on the trolley as it moves **up** the slope after the push is removed. Show only forces or components of forces acting parallel to the slope. **1**

(*d*) Explain, in terms of the forces acting on the trolley, why the magnitude of the acceleration from A to B differs from the magnitude of the acceleration from B to C. **2**

(8)

Marks

2. A rocket-propelled vehicle carrying a dummy is used at a research centre to test the ejection seat for a jet aircraft as shown in the diagram.



The vehicle and dummy have a combined mass of 500 kg. The rocket engines increase the kinetic energy of the vehicle by $2{\cdot}80 \times 10^7$ J for each kilogram of fuel used.

In a test run, the vehicle accelerates **from rest** along the track until 0·70 kg of fuel is used up.

(*a*) (i) Show that the maximum possible speed reached by the vehicle is 280 m s^{-1}. You may ignore the effect of friction.

(ii) The dummy is ejected when the vehicle reaches a speed of 280 m s^{-1} after 8·0 s.

Calculate how far the vehicle is from the start when the dummy is ejected. Assume that the acceleration of the vehicle is constant during the 8·0 s test run. **5**

(*b*) The dummy is ejected at the instant the vehicle reaches a horizontal velocity of 280 m s^{-1}. The ejection seat being tested projects the dummy upwards with an initial vertical velocity of 50 m s^{-1}.

(i) Describe and explain the path taken by the dummy after its ejection from the vehicle.

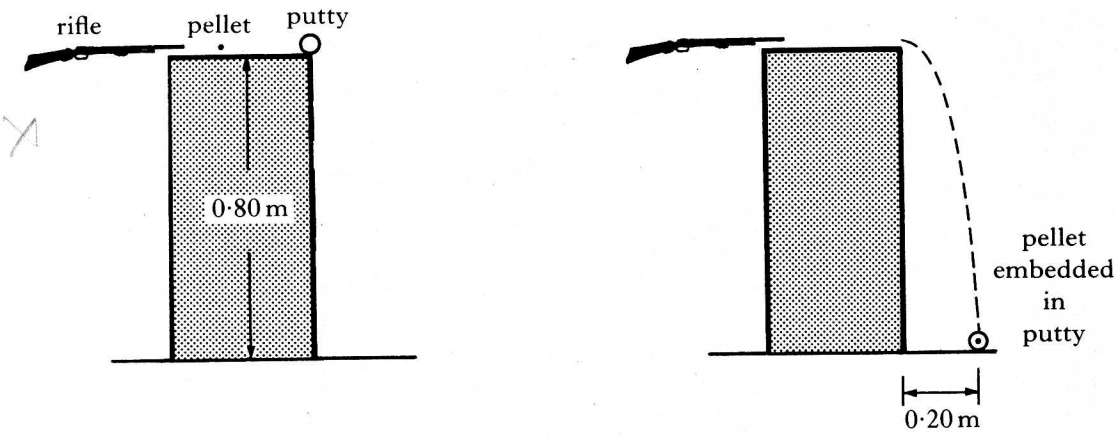
(ii) Calculate the maximum height reached by the dummy. You may ignore the effect of friction. **4**

(9)

[Turn over

Marks

3. The diagrams below illustrate an experimental method which can be used to measure the speed of an air rifle pellet.



A lump of putty, of mass 0·10 kg, is resting on the edge of a bench of height 0·80 m. The pellet, of mass $5{\cdot}0 \times 10^{-4}$ kg, is fired at the lump of putty.

The putty, with the pellet embedded in it, lands 0·20 m from the foot of the bench as shown.

(*a*) Show that the horizontal velocity of the putty after the impact of the pellet is $0{\cdot}5\ \text{m s}^{-1}$. **3**

(*b*) (i) State the principle of conservation of momentum.

(ii) Using this principle, calculate the velocity of the pellet just before it strikes the putty. **3**

(*c*) Using only the apparatus above, suggest one way of improving the accuracy of this experiment. **1**

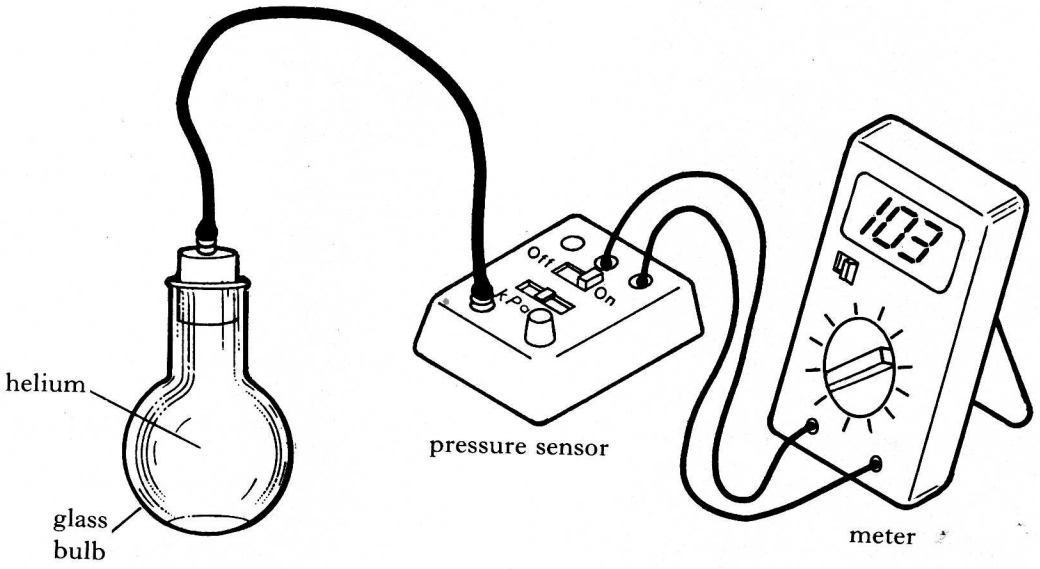
(7)

Marks

4. The apparatus shown below can be used as a type of thermometer.

It consists of a bulb containing helium gas, the pressure of which can be monitored.

The volume of the bulb is considered to be constant over the range of temperature measured by the thermometer.



The following results for the temperature and pressure of the gas were obtained while calibrating the thermometer.

Pressure/kPa	89	96	103	110	117
Temperature/°C	−20	0	20	40	60
Temperature/K					

(*a*) (i) Copy the above table. Complete the table, giving the temperature in kelvin.

(ii) Use the data from your completed table to establish the relationship between the pressure and temperature of the gas.

(iii) Explain this change of pressure with temperature in terms of the movement of the helium molecules. **5**

(*b*) When the bulb is immersed in a sample of liquid nitrogen, the meter gives a reading of 24 kPa for the pressure of the helium gas.

Find the temperature of the liquid nitrogen sample. **2**

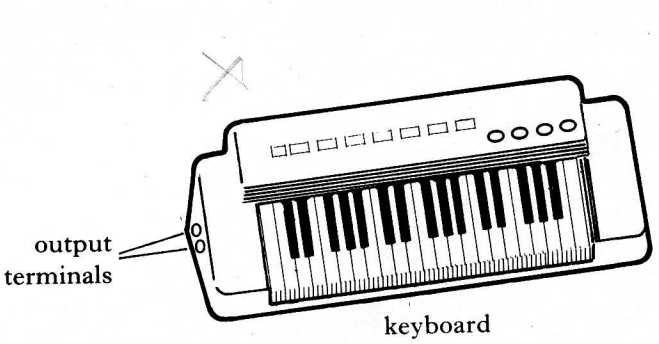
(7)

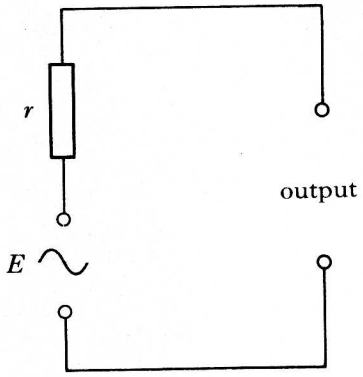
[Turn over

Marks

5. (*a*) An electronic keyboard contains an audio amplifier with output terminals which can be connected to a loudspeaker.

When a key is pressed, the amplifier may be considered as a source of e.m.f. E and internal resistance r in series, as shown below.

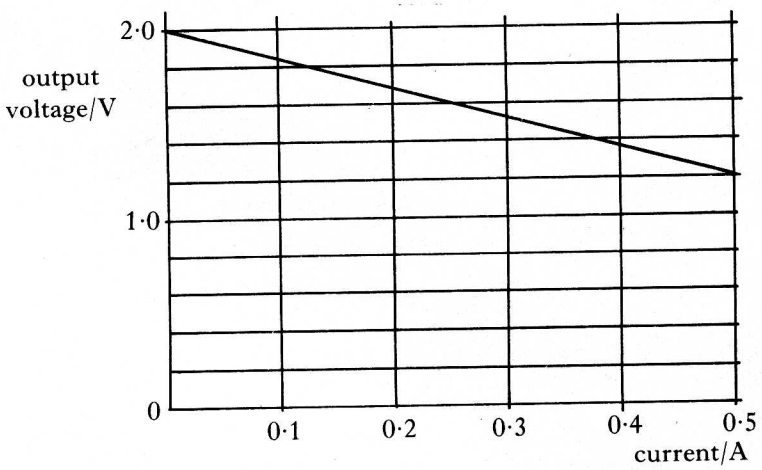




In an experiment to measure the internal resistance of the amplifier, the following equipment is used:

keyboard
a.c. ammeter
a.c. voltmeter
variable resistor.

The graph below displays the results of the experiment.



(i) Describe how the apparatus is used to obtain the data for this graph. Your answer must include a circuit diagram.

(ii) Calculate the value of the internal resistance of the amplifier.

(iii) A loudspeaker of resistance 4·0 Ω is now connected across the output terminals of the amplifier and a key is pressed.

What is the output voltage across the loudspeaker? **7**

5. (continued)

(*b*) The internal resistance of a power supply can be measured with a voltmeter and a **calibrated** variable resistor.

First, the e.m.f. of the power supply is measured using the voltmeter as shown in Figure 1.

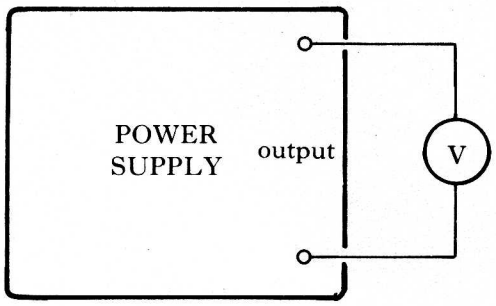


Figure 1

The variable resistor is then connected, as in Figure 2, and adjusted until the output p.d. is equal to half the e.m.f.

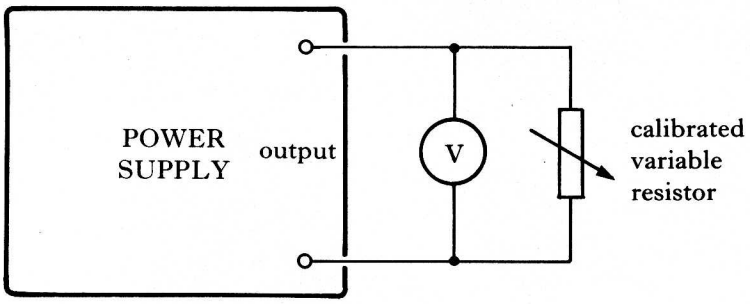


Figure 2

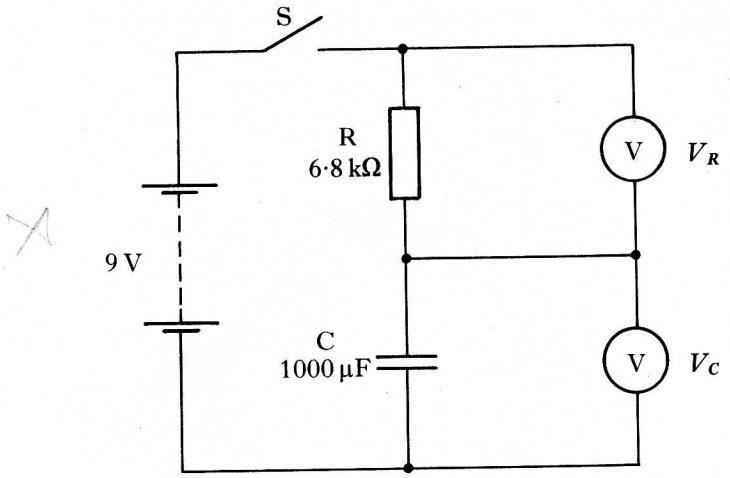
Explain how these measurements can be used to obtain the value of the internal resistance of the power supply. **2**

(9)

[Turn over

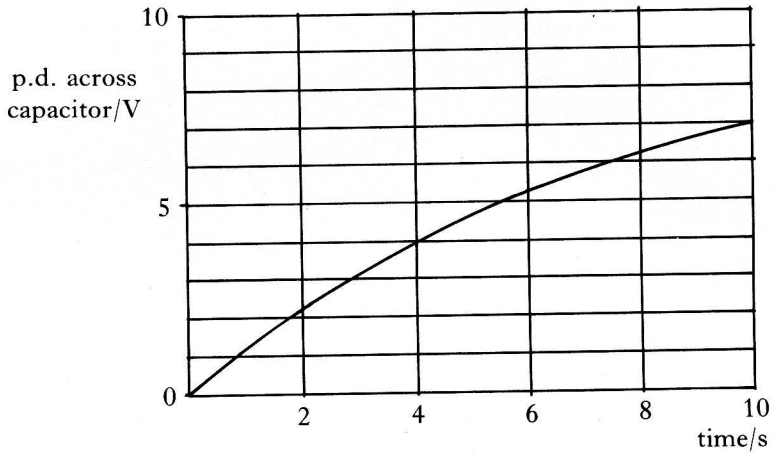
Marks

6. The following circuit is set up to investigate the charging of a capacitor.



At the start of the experiment the capacitor is uncharged.

(*a*) The graph below shows how the p.d. V_C across the capacitor varies with time from the instant the switch S is closed.



Sketch a graph showing how the p.d. V_R across the resistor varies with time during the first 10 s of charging. **2**

(*b*) Calculate the current in the circuit at the instant the p.d. across the capacitor is 6·0 V. **2**

(*c*) (i) When the capacitor is fully charged, it is removed from the circuit and connected across a 10 Ω resistor.

What is the total energy dissipated in the resistor?

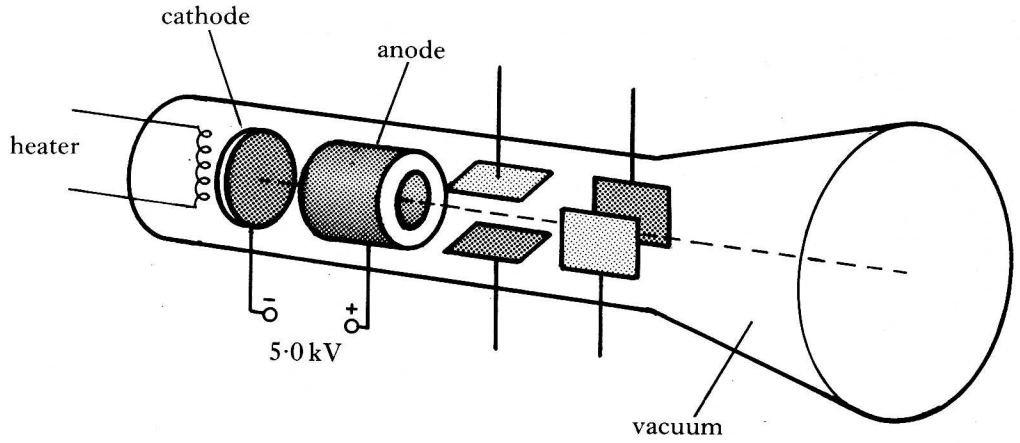
(ii) In another experiment, the fully charged capacitor is connected across a 20 Ω resistor instead of the 10 Ω resistor.

How does the energy dissipated in this resistor compare with that calculated in part (i)? You must justify your answer. **3**

(7)

Marks

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



Electrons released from the hot cathode are accelerated by a p.d. of 5·0 kV between the cathode and anode.

(*a*) (i) Assuming that an electron starts from rest at the cathode, calculate its speed just before it reaches the anode. (You may have to refer to the Science Data Booklet.)

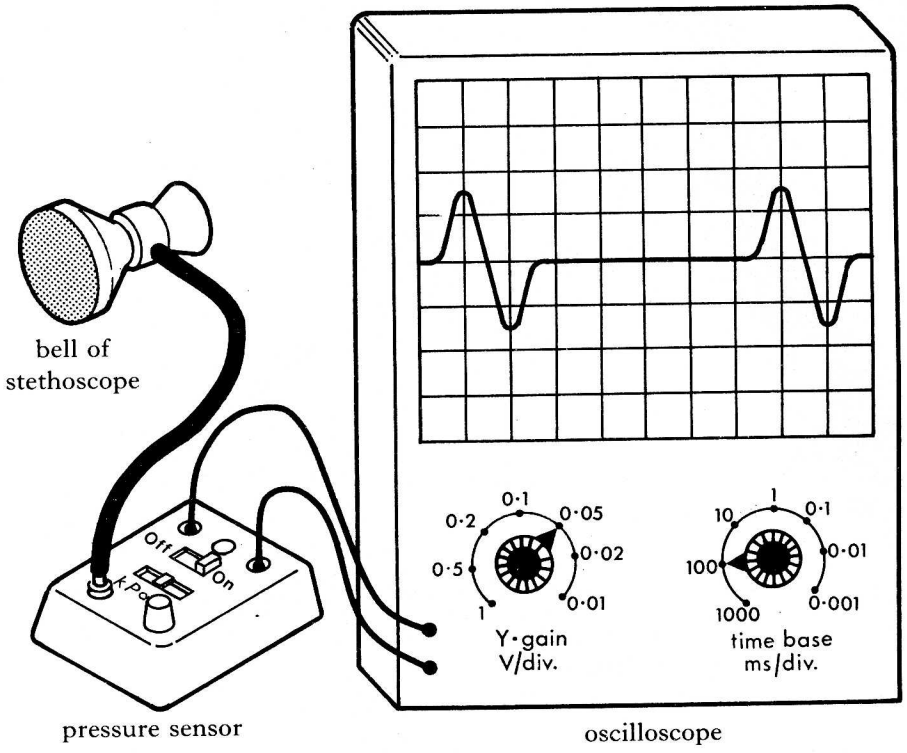
(ii) What is the effect on the speed of the electron just before it reaches the anode if the p.d. between the cathode and anode is halved? Show your reasoning. **5**

(*b*) If the electron beam current is 15 mA, how many electrons leave the cathode each second? (You may have to refer to the Science Data Booklet.) **2**

(7)

[Turn over

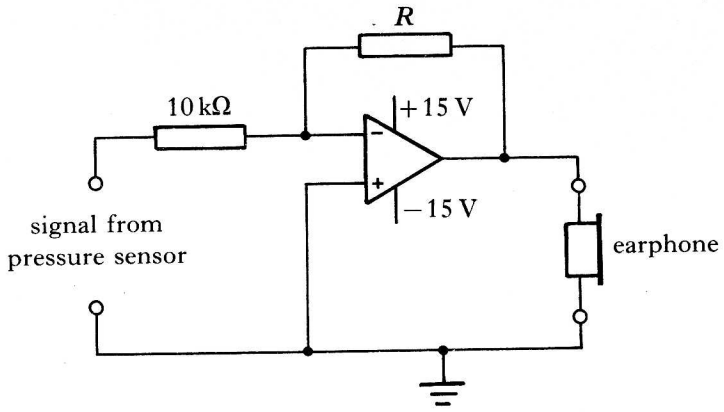
8. (*a*) A health physicist builds an electronic stethoscope system to monitor heart beats.



The trace shown is obtained when the oscilloscope has a Y-gain setting of 0·05 V/division.

(i) What is the peak voltage of the signal shown on the oscilloscope?

(ii) The following circuit is designed to amplify the signal from the electronic stethoscope to enable a doctor to hear the heart beats.

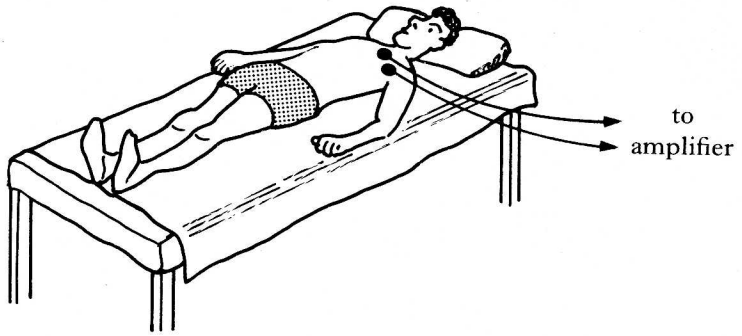


A peak output voltage of 0·90 V is required to operate the earphone.

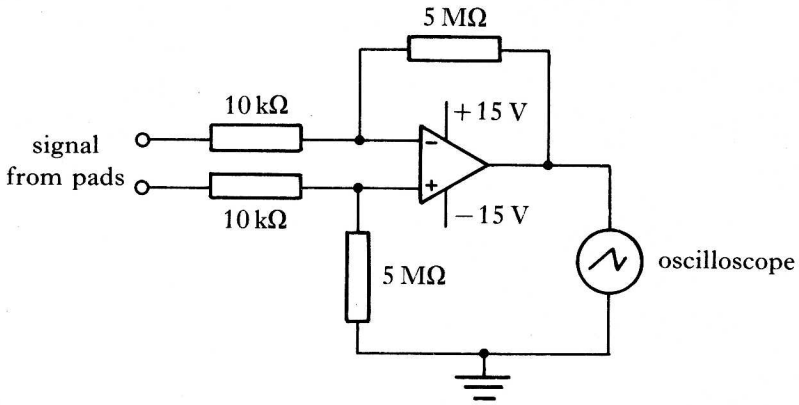
What should be the value of the resistor *R*? **2**

8. (continued)

(*b*) Two conducting pads are attached to a patient's chest to obtain further information about his heart.



The action of the heart produces a small p.d. between the two pads. This p.d. is used as an input to the amplifier shown below.



(i) What is the output voltage produced by the op-amp when the p.d. between the two pads is 0·40 mV?

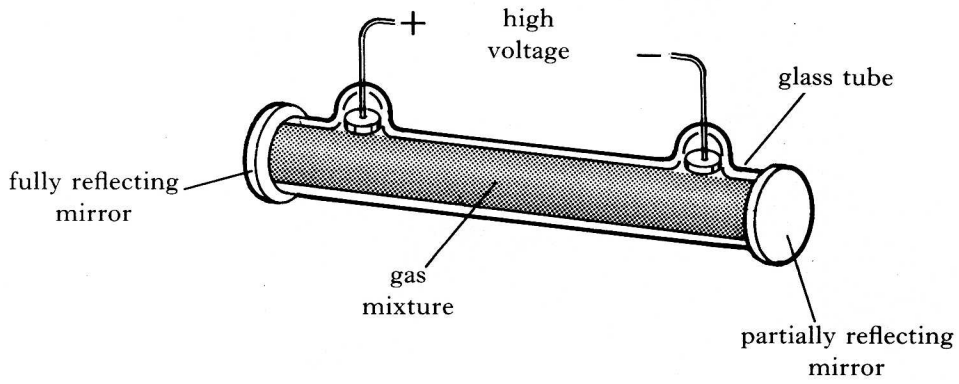
(ii) Explain why it is better to use the op-amp in this mode, rather than the mode shown in part (*a*), given that both pads pick up a 50 Hz signal from nearby mains wiring. **4**

(6)

[Turn over

Marks

9. The diagram shows a simplified view of a laser tube used in a gas laser.

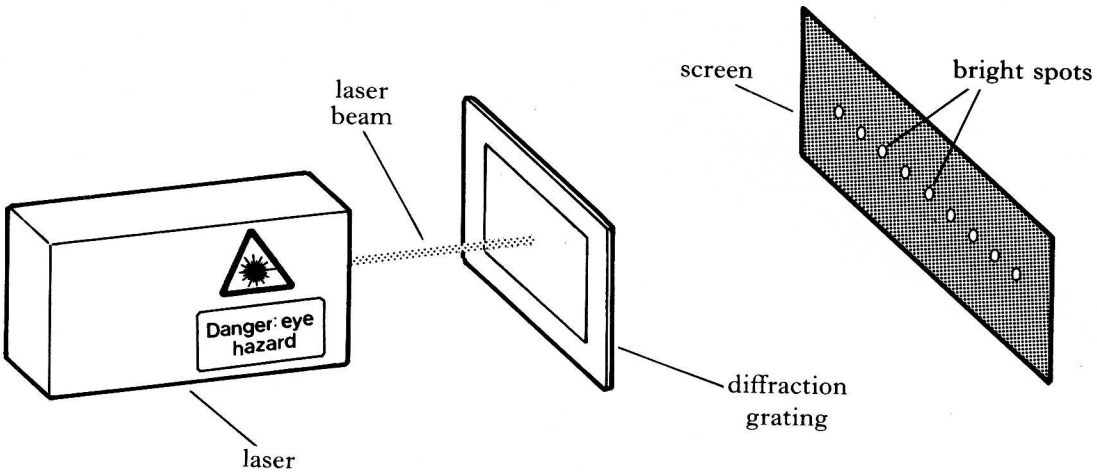


(*a*) The name LASER stands for Light Amplification by Stimulated Emission of Radiation.

(i) What is meant by "stimulated emission"?

(ii) Explain the purpose of each mirror in the laser tube. **4**

(*b*) In the experiment shown below, a laser beam is directed at a diffraction grating.



A pattern of bright spots is observed on the screen.

Explain, in terms of the wave nature of light, how this pattern is formed. **2**

Marks

9. (continued)

(*c*) The laser is marked with the warning "DANGER : EYE HAZARD".

Why does this laser, which has a power output of only 0·20 mW, present a greater potential eye hazard than a 100 W lamp? **2**

(*d*) In hospitals, pulsed lasers may be used to repair damage to the retina of the eye. The specification of a typical pulsed laser is given below:

gas used in laser	: argon
duration of pulse	: 0·50 ms
energy of one pulse	: 0·10 J
wavelengths of laser light emitted	: 488 and 514 nm.

The cross-sectional area of the laser beam at the retina is $1{\cdot}5 \times 10^{-9}\,m^2$.

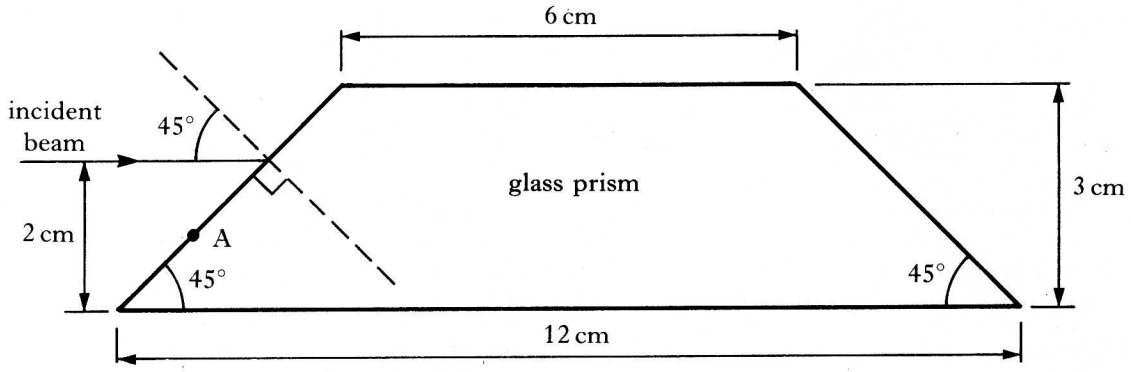
Calculate the light intensity produced at the retina during a pulse of light from this laser. **3**

(11)

[Turn over

Marks

10. A pupil finds a glass prism of the shape shown below when she dismantles an old optical instrument.



To investigate the optical properties of the prism, she directs a narrow beam of red light towards the prism as shown.

The glass prism has a refractive index of 1·52 for this red light.

(*a*) (i) Calculate the value of the critical angle for this light in the glass prism.

(ii) On the square-ruled paper provided, draw the prism with the dimensions stated in the diagram.

On your diagram, show the passage of the light beam until after it emerges from the prism.

Mark on your diagram the values of all relevant angles.

(iii) A second beam of light, parallel to the first and of the same wavelength, is now directed onto the prism at A.

Add to your diagram the complete path of this beam through the prism. **7**

(*b*) How would a distant object appear when viewed through the prism when it is held as shown below?

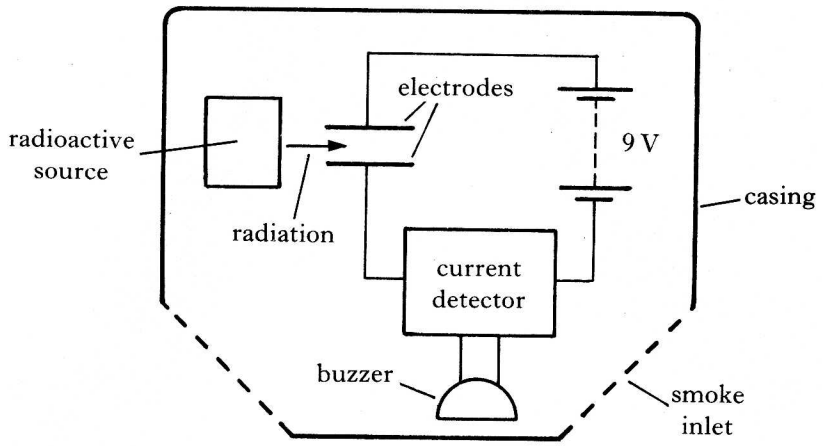
1

(8)

Marks

11. Smoke detectors are important in giving early warning of fire starting in the home.

(*a*) The simplified layout of one type of smoke detector is illustrated below.



The following is an extract from the manufacturer's data sheet.

"The detector uses a low energy source of ionising radiation, 30 kBq Americium 241, which causes ionisation of the air molecules, and hence a small current between the electrodes. When smoke particles enter the space between the electrodes, they impede the flow of ions and the current is reduced. When the current falls below a certain value, the buzzer sounds."

(i) The symbol for the radioactive source used is $^{241}_{95}\text{Am}$.

What information is given by the numbers 95 and 241?

(ii) What is meant by "30 kBq"?

(iii) Explain what is meant by "ionising radiation".

(iv) The equation for the decay of this source is

$$^{241}_{95}\text{Am} \longrightarrow {}^{237}_{93}\text{Np} + \text{radiation}$$

Identify the type of radiation emitted in this decay and explain why this particular type of radiation is used in the smoke detector.

(v) The half-life of Americium 241 is 458 years.

Discuss the advantage of using this source compared to one with a half-life of 5 years. **7**

(*b*) The workers in the factory assembling this type of smoke detector will experience a higher radiation dose equivalent than that due to background radiation alone.

(i) State one factor contributing to background radiation.

(ii) It is recommended that the workers assembling the smoke detectors should not receive a dose equivalent rate greater than 5·0 mSv per year above the background level.

A worker in a factory making smoke detectors assembles 15 000 detectors in a year.

An absorbed dose of $1{\cdot}2 \times 10^{-8}$ Gy is received by the worker in assembling one detector and the quality factor of the radiation is 20.

Show, by calculation, whether the permissible level of 5·0 mSv per year will be exceeded for the worker. **4**

(11)

[END OF QUESTION PAPER]