X069/301

NATIONAL QUALIFICATIONS 2008

FRIDAY, 23 MAY
1.00 PM – 3.30 PM

PHYSICS
HIGHER

Read Carefully

Reference may be made to the Physics Data Booklet.

1 All questions should be attempted.

Section A (questions 1 to 20)

2 Check that the answer sheet is for Physics Higher (Section A).

3 For this section of the examination you must use an **HB pencil** and, where necessary, an eraser.

4 Check that the answer sheet you have been given has **your name**, **date of birth**, **SCN** (Scottish Candidate Number) and **Centre Name** printed on it.

Do not change any of these details.

5 If any of this information is wrong, tell the Invigilator immediately.

6 If this information is correct, **print** your name and seat number in the boxes provided.

7 There is **only one correct** answer to each question.

8 Any rough working should be done on the question paper or the rough working sheet, **not** on your answer sheet.

9 At the end of the exam, put the **answer sheet for Section A inside the front cover of your answer book**.

10 Instructions as to how to record your answers to questions 1–20 are given on page three.

Section B (questions 21 to 30)

11 Answer the questions numbered 21 to 30 in the answer book provided.

12 **All answers must be written clearly and legibly in ink**.

13 Fill in the details on the front of the answer book.

14 Enter the question number clearly in the margin of the answer book beside each of your answers to questions 21 to 30.

15 Care should be taken to give an appropriate number of significant figures in the final answers to calculations.

16 Where additional paper, eg square ruled paper, is used, write your name and SCN (Scottish Candidate Number) on it and place it inside the front cover of your answer booklet.

SA X069/301 6/15570

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
Magnitude of the charge on an electron	e	$1{\cdot}60 \times 10^{-19}$ C	Mass of neutron	m_n	$1{\cdot}675 \times 10^{-27}$ kg
Gravitational acceleration on Earth	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	Water	1·33
Crown glass	1·50	Air	1·00

SPECTRAL LINES

Element	*Wavelength*/nm	*Colour*
Hydrogen	656 486 434 410 397 389	Red Blue-green Blue-violet Violet Ultraviolet Ultraviolet
Sodium	589	Yellow
Cadmium	644 509 480	Red Green 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
Aluminium	$2{\cdot}70 \times 10^{3}$	933	2623
Copper	$8{\cdot}96 \times 10^{3}$	1357	2853
Ice	$9{\cdot}20 \times 10^{2}$	273	. . . .
Sea Water	$1{\cdot}02 \times 10^{3}$	264	377
Water	$1{\cdot}00 \times 10^{3}$	273	373
Air	1·29	. . . .	. . . .
Hydrogen	$9{\cdot}0 \times 10^{-2}$	14	20

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

SECTION A

For questions 1 to 20 in this section of the paper the answer to each question is either A, B, C, D or E. Decide what your answer is, then, using your pencil, put a horizontal line in the space provided—see the example below.

EXAMPLE

The energy unit measured by the electricity meter in your home is the

A kilowatt-hour

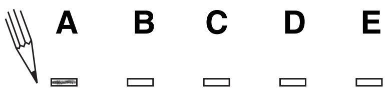
B ampere

C watt

D coulomb

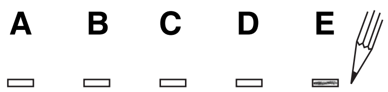
E volt.

The correct answer is **A—**kilowatt-hour. The answer **A** has been clearly marked in **pencil** with a horizontal line (see below).



Changing an answer

If you decide to change your answer, carefully erase your first answer and, using your pencil, fill in the answer you want. The answer below has been changed to **E**.



[Turn over

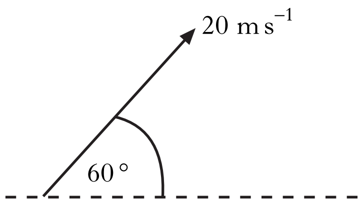
SECTION A

Answer questions 1–20 on the answer sheet.

1. Which row in the table is correct?

	Scalar	*Vector*
A	distance	work
B	weight	acceleration
C	velocity	displacement
D	mass	momentum
E	speed	time

2. A javelin is thrown at 60° to the horizontal with a speed of 20 m s^{-1}.



The javelin is in flight for 3·5 s.
Air resistance is negligible.
The horizontal distance the javelin travels is

A 35·0 m

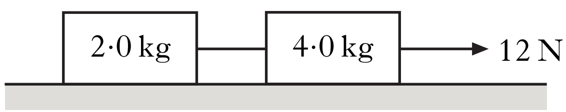
B 60·6 m

C 70·0 m

D 121 m

E 140 m.

3. Two boxes on a frictionless horizontal surface are joined together by a string. A constant horizontal force of 12 N is applied as shown.



The tension in the string joining the two boxes is

A 2·0 N

B 4·0 N

C 6·0 N

D 8·0 N

E 12 N.

4. The total mass of a motorcycle and rider is 250 kg. During braking, they are brought to rest from a speed of 16·0 m s^{-1} in a time of 10·0 s.

The maximum energy which could be converted to heat in the brakes is

A 2000 J

B 4000 J

C 32 000 J

D 40 000 J

E 64 000 J.

5. A shell of mass 5·0 kg is travelling horizontally with a speed of 200 m s^{-1}. It explodes into two parts. One part of mass 3·0 kg continues in the original direction with a speed of 100 m s^{-1}.

The other part also continues in this same direction. Its speed is

A 150 m s^{-1}

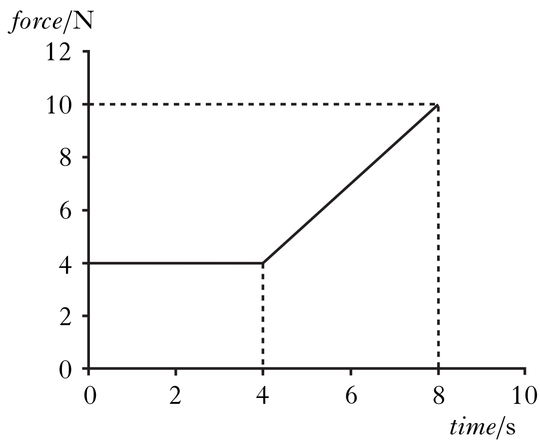
B 200 m s^{-1}

C 300 m s^{-1}

D 350 m s^{-1}

E 700 m s^{-1}.

6. The graph shows the force which acts on an object over a time interval of 8 seconds.



The momentum gained by the object during this 8 seconds is

A 12 kg m s^{-1}

B 32 kg m s^{-1}

C 44 kg m s^{-1}

D 52 kg m s^{-1}

E 72 kg m s^{-1}.

7. One pascal is equivalent to

A $1\ \mathrm{N\,m}$

B $1\ \mathrm{N\,m^2}$

C $1\ \mathrm{N\,m^3}$

D $1\ \mathrm{N\,m^{-2}}$

E $1\ \mathrm{N\,m^{-3}}$.

8. An electron is accelerated from rest through a potential difference of 2·0 kV.

The kinetic energy gained by the electron is

A $8{\cdot}0 \times 10^{-23}$ J

B $8{\cdot}0 \times 10^{-20}$ J

C $3{\cdot}2 \times 10^{-19}$ J

D $1{\cdot}6 \times 10^{-16}$ J

E $3{\cdot}2 \times 10^{-16}$ J.

9. The e.m.f. of a battery is

A the total energy supplied by the battery

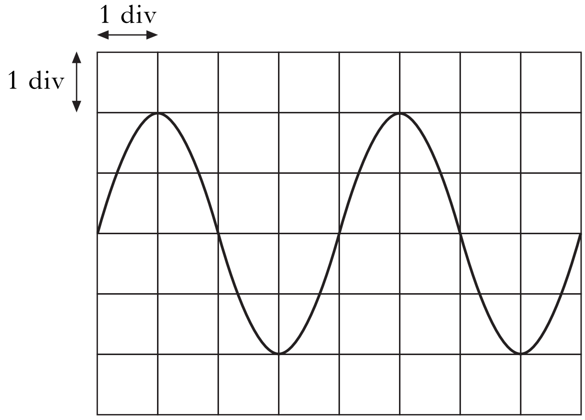
B the voltage lost due to the internal resistance of the battery

C the total charge which passes through the battery

D the number of coulombs of charge passing through the battery per second

E the energy supplied to each coulomb of charge passing through the battery.

10. The diagram shows the trace on an oscilloscope when an alternating voltage is applied to its input.



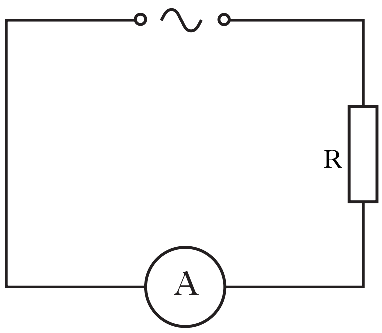
The timebase is set at 5 ms/div and the Y-gain is set at 10 V/div.

Which row in the table gives the peak voltage and the frequency of the signal?

	Peak voltage/V	*Frequency*/Hz
A	7·1	20
B	14	50
C	20	20
D	20	50
E	40	50

[Turn over

11. A resistor is connected to an a.c. supply as shown.



The supply has a constant peak voltage, but its frequency can be varied.

The frequency is steadily increased from 50 Hz to 5000 Hz.

The reading on the a.c. ammeter

A remains constant

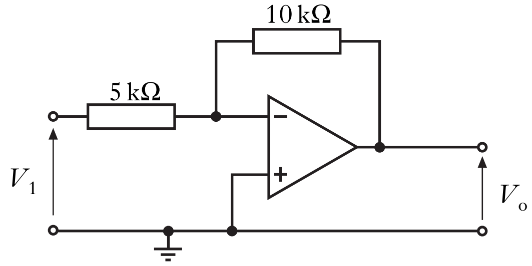
B decreases steadily

C increases steadily

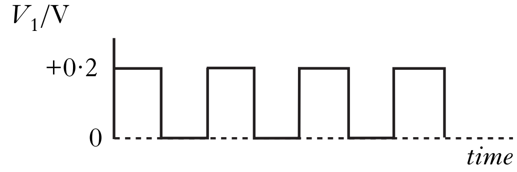
D increases then decreases

E decreases then increases.

12. An ideal op-amp is connected as shown.

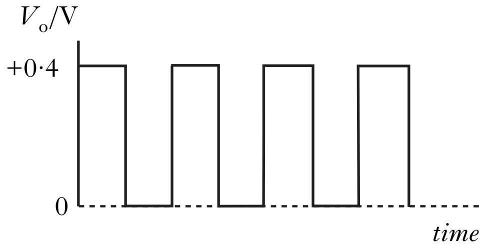


The graph shows how the input voltage, V_1, varies with time.

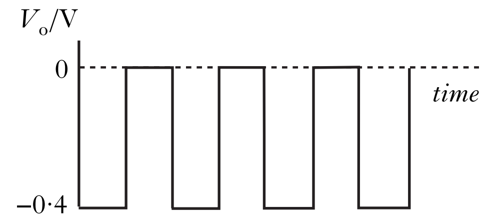


Which graph shows how the output voltage, V_o, varies with time?

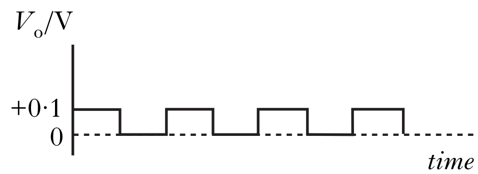
A



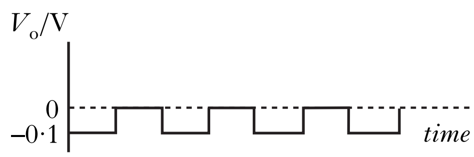
B



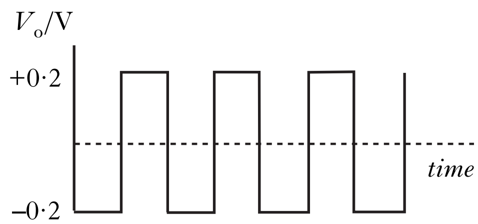
C



D



E



13. Which of the following proves that light is transmitted as waves?

A Light has a high velocity.

B Light can be reflected.

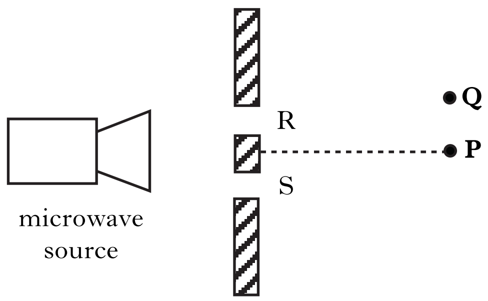
C Light irradiance reduces with distance.

D Light can be refracted.

E Light can produce interference patterns.

14. A source of microwaves of wavelength λ is placed behind two slits, R and S.

A microwave detector records a maximum when it is placed at P.



The detector is moved and the **next** maximum is recorded at Q.

The path difference (SQ – RQ) is

A 0

B $\frac{\lambda}{2}$

C λ

D $\frac{3\lambda}{2}$

E 2λ.

15. A student makes five separate measurements of the diameter of a lens.

These measurements are shown in the table.

Diameter of lens/mm	22·5	22·6	22·4	22·6	22·9

The approximate random uncertainty in the mean value of the diameter is

A 0·1 mm

B 0·2 mm

C 0·3 mm

D 0·4 mm

E 0·5 mm.

16. The value of the absolute refractive index of diamond is 2·42.

The critical angle for diamond is

A 0·413°

B 24·4°

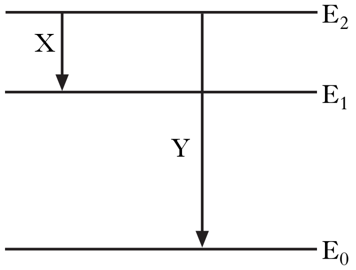
C 42·0°

D 65·6°

E 90·0°.

[Turn over

17. Part of the energy level diagram for an atom is shown.



X and Y represent two possible electron transitions.
Which of the following statements is/are correct?

I Transition Y produces photons of higher frequency than transition X.

II Transition X produces photons of longer wavelength than transition Y.

III When an electron is in the energy level E_0, the atom is ionised.

A I only

B I and II only

C I and III only

D II and III only

E I, II and III

18. The letters **X**, **Y** and **Z** represent three missing words from the following passage.

Materials can be divided into three broad categories according to their electrical resistance.

........**X**........ *have a very high resistance.*

........**Y**........ *have a high resistance in their pure form but when small amounts of certain impurities are added, the resistance decreases.*

........**Z**........ *have a low resistance.*

Which row in the table shows the missing words?

	X	**Y**	**Z**
A	conductors	insulators	semi-conductors
B	semi-conductors	insulators	conductors
C	insulators	semi-conductors	conductors
D	conductors	semi-conductors	insulators
E	insulators	conductors	semi-conductors

19. Compared with a proton, an alpha particle has

A twice the mass and twice the charge

B twice the mass and the same charge

C four times the mass and twice the charge

D four times the mass and the same charge

E twice the mass and four times the charge.

20. For the nuclear decay shown, which row of the table gives the correct values of x, y and z?

$$^{214}_{x}\text{Pb} \longrightarrow {}^{y}_{83}\text{Bi} + {}^{0}_{z}\text{e}$$

	x	y	z
A	85	214	2
B	84	214	1
C	83	210	4
D	82	214	–1
E	82	210	–1

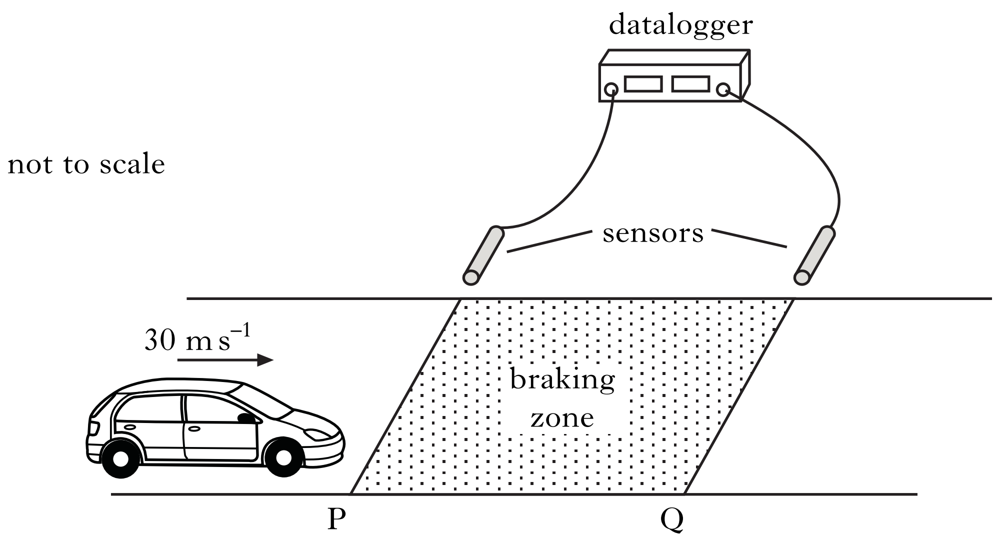
[Turn over for SECTION B on *Page ten*

SECTION B

Write your answers to questions 21 to 30 in the answer book.

Marks

21. To test the braking system of cars, a test track is set up as shown.



The sensors are connected to a datalogger which records the speed of a car at both P and Q.

A car is driven at a constant speed of $30\ m\,s^{-1}$ until it reaches the start of the braking zone at P. The brakes are then applied.

(*a*) In one test, the datalogger records the speed at P as $30\ m\,s^{-1}$ and the speed at Q as $12\ m\,s^{-1}$. The car slows down at a constant rate of $9{\cdot}0\ m\,s^{-2}$ between P and Q.

Calculate the length of the braking zone. **2**

(*b*) The test is repeated. The same car is used but now with passengers in the car. The speed at P is again recorded as $30\ m\,s^{-1}$.

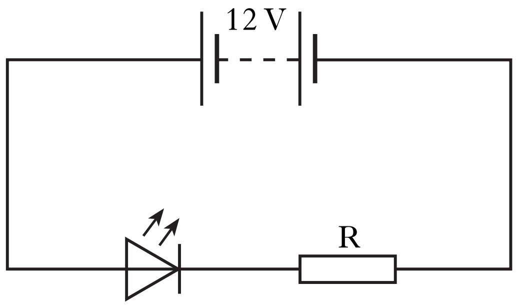
The same braking force is applied to the car as in part (*a*).

How does the speed of the car at Q compare with its speed at Q in part (*a*)? Justify your answer. **2**

21. (continued)

(*c*) The brake lights of the car consist of a number of very bright LEDs.

An LED from the brake lights is forward biased by connecting it to a 12 V car battery as shown.



The battery has negligible internal resistance.

(i) Explain, in terms of charge carriers, how the LED emits light. **1**

(ii) The LED is operating at its rated values of 5·0 V and 2·2 W.

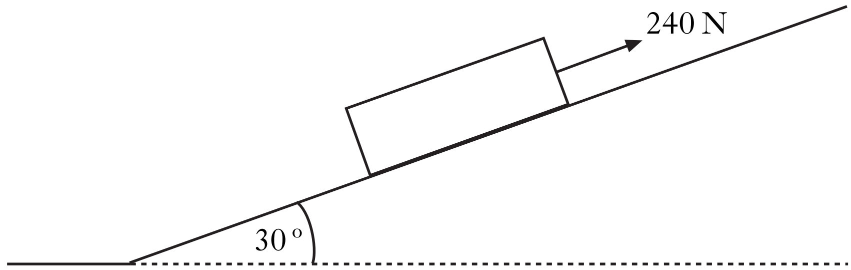
Calculate the value of resistor R. **3**

(8)

[Turn over

22. A crate of mass 40·0 kg is pulled up a slope using a rope.

The slope is at an angle of 30° to the horizontal.



A force of 240 N is applied to the crate parallel to the slope.

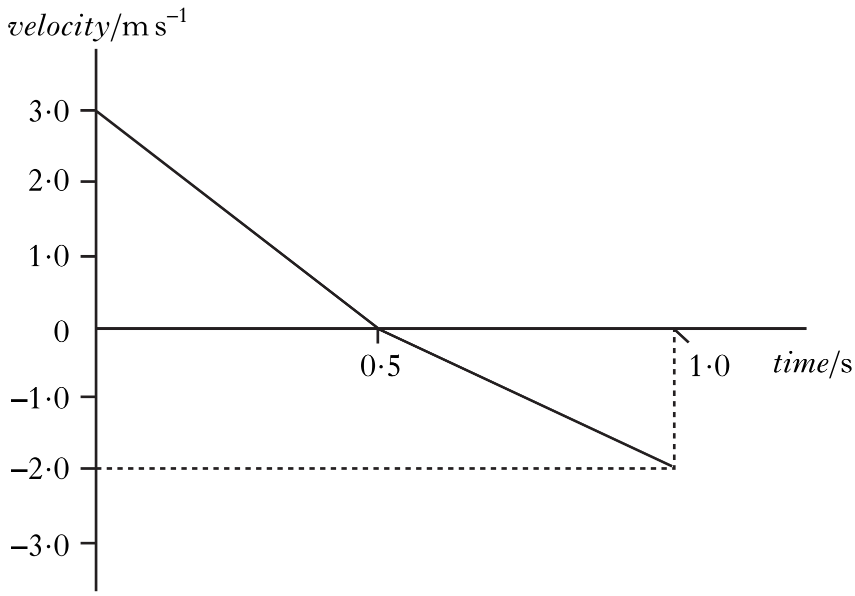
The crate moves at a constant speed of $3{\cdot}0\,\mathrm{m\,s^{-1}}$.

(*a*) (i) Calculate the component of the weight of the crate acting parallel to the slope. **2**

(ii) Calculate the frictional force acting on the crate. **2**

(*b*) As the crate is moving up the slope, the rope snaps.

The graph shows how the velocity of the crate changes from the moment the rope snaps.



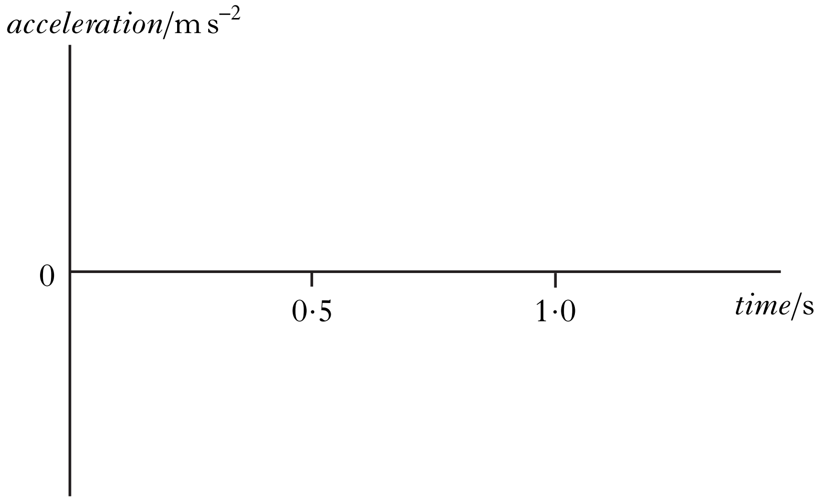
(i) Describe the motion of the crate during the first 0·5 s after the rope snaps. **1**

Marks

22. (*b*) (continued)

(ii) Copy the axes shown below and sketch the graph to show the acceleration of the crate between 0 and 1·0 s.

Appropriate numerical values are also required on the acceleration axis. **2**



(iii) Explain, in terms of the forces acting on the crate, why the magnitude of the acceleration changes at 0·5 s. **2**

(9)

[Turn over

Marks

23. A cylinder of compressed oxygen gas is in a laboratory.

(*a*) The oxygen inside the cylinder is at a pressure of $2{\cdot}82 \times 10^6$ Pa and a temperature of $19{\cdot}0\,°C$.

The cylinder is now moved to a storage room where the temperature is $5{\cdot}0\,°C$.

(i) Calculate the pressure of the oxygen inside the cylinder when its temperature is $5{\cdot}0\,°C$. **2**

(ii) What effect, if any, does this decrease in temperature have on the density of the oxygen in the cylinder?

Justify your answer. **2**

(*b*) (i) The volume of oxygen inside the cylinder is $0{\cdot}030\,m^3$.

The density of the oxygen inside the cylinder is $37{\cdot}6\,kg\,m^{-3}$.

Calculate the mass of oxygen in the cylinder. **2**

(ii) The valve on the cylinder is opened slightly so that oxygen is gradually released.

The temperature of the oxygen inside the cylinder remains constant.

Explain, in terms of particles, why the pressure of the gas inside the cylinder decreases. **1**

(iii) After a period of time, the pressure of the oxygen inside the cylinder reaches a constant value of $1{\cdot}01 \times 10^5$ Pa. The valve remains open.

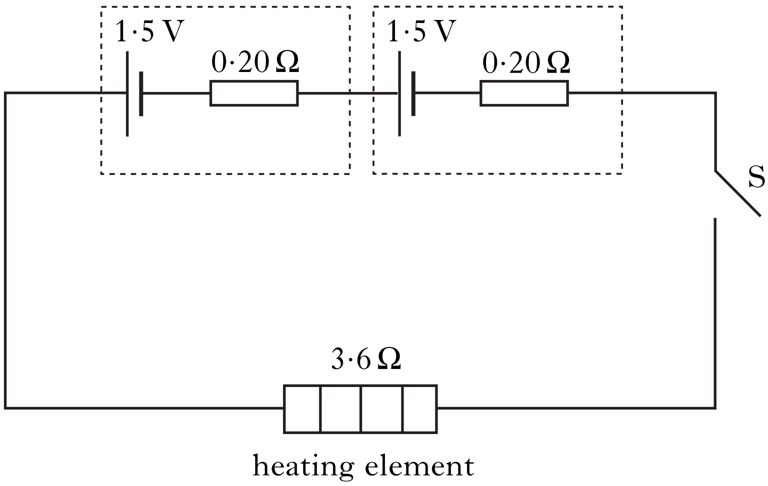
Explain why the pressure does not decrease below this value. **1**

(8)

24. Electrically heated gloves are used by skiers and climbers to provide extra warmth.

(*a*) Each glove has a heating element of resistance $3{\cdot}6\,\Omega$.

Two cells, each of e.m.f. $1{\cdot}5\,V$ and internal resistance $0{\cdot}20\,\Omega$, are used to operate the heating element.



Switch S is closed.

(i) Determine the value of the total circuit resistance. **1**

(ii) Calculate the current in the heating element. **2**

(iii) Calculate the power output of the heating element. **2**

(*b*) When in use, the internal resistance of each cell gradually increases.

What effect, if any, does this have on the power output of the heating element?

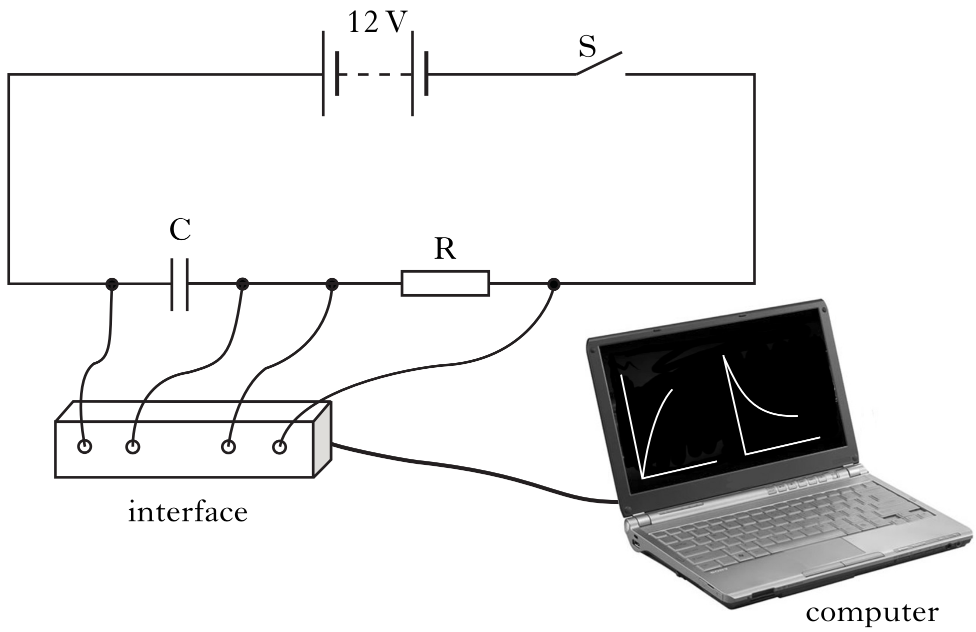
Justify your answer. **2**

(7)

[Turn over

25. (*a*) State what is meant by the term *capacitance*. **1**

(*b*) An uncharged capacitor, C, is connected in a circuit as shown.



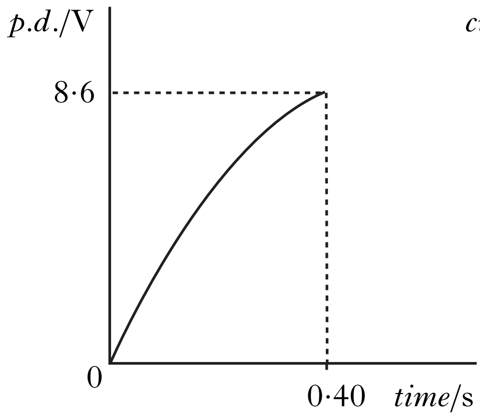
The 12 V battery has negligible internal resistance.

Switch S is closed and the capacitor begins to charge.

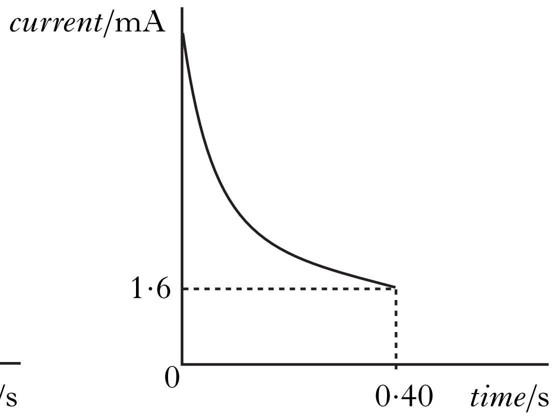
The interface measures the current in the circuit and the potential difference (p.d.) across the capacitor. These measurements are displayed as graphs on the computer.

Graph 1 shows the p.d. across the capacitor for the first 0·40 s of charging.

Graph 2 shows the current in the circuit for the first 0·40 s of charging.



Graph 1



Graph 2

25. (*b*) (continued)

(i) Determine the p.d. **across resistor R** at 0·40 s. **1**

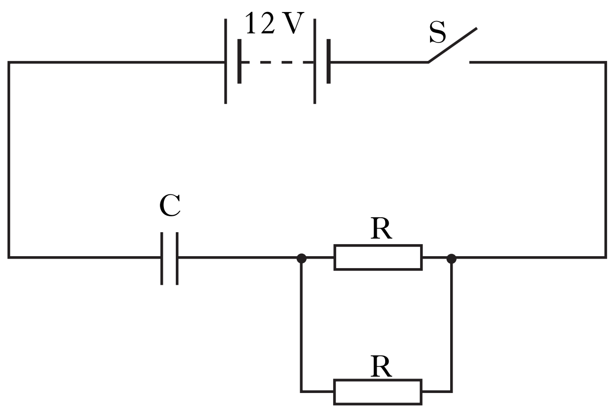
(ii) Calculate the resistance of R. **2**

(iii) The capacitor takes 2·2 seconds to charge fully.

At that time it stores 10·8 mJ of energy.

Calculate the capacitance of the capacitor. **3**

(*c*) The capacitor is now discharged.
A second, identical resistor is connected in the circuit as shown.



Switch S is closed.

Is the time taken for the capacitor to fully charge less than, equal to, or greater than the time taken to fully charge in part (*b*)?

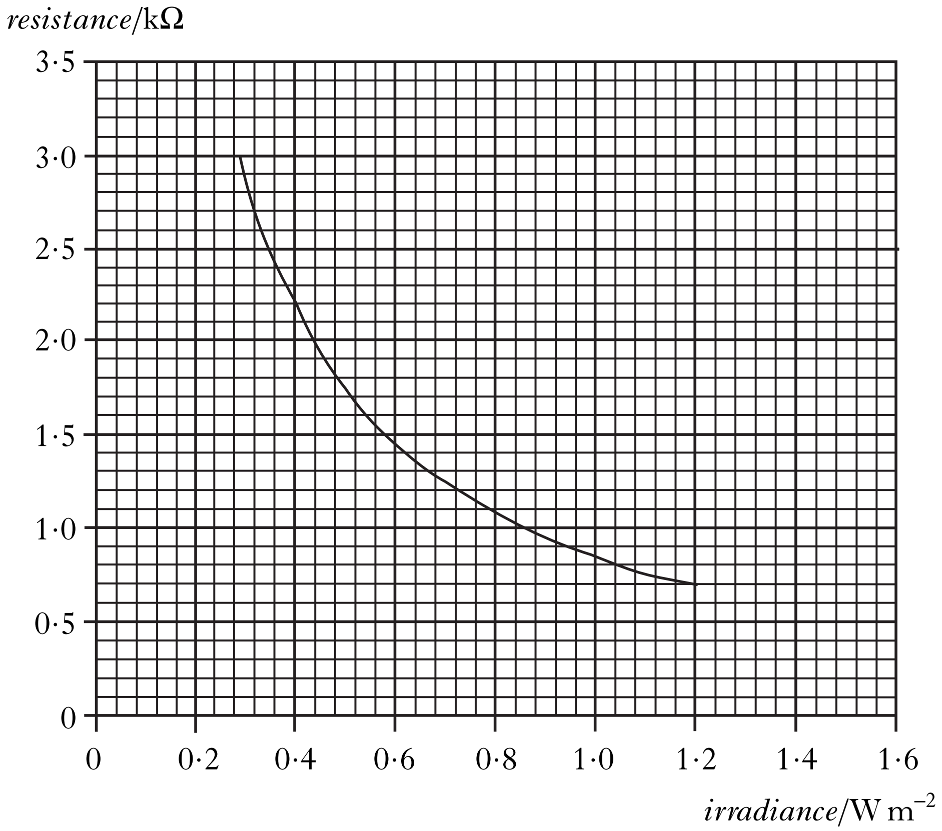
Justify your answer. **2**

(9)

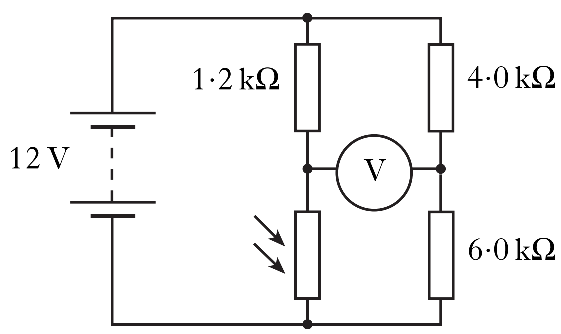
[Turn over

Marks

26. The graph shows how the resistance of an LDR changes with the irradiance of light incident on it.



(*a*) The LDR is connected in the following bridge circuit.

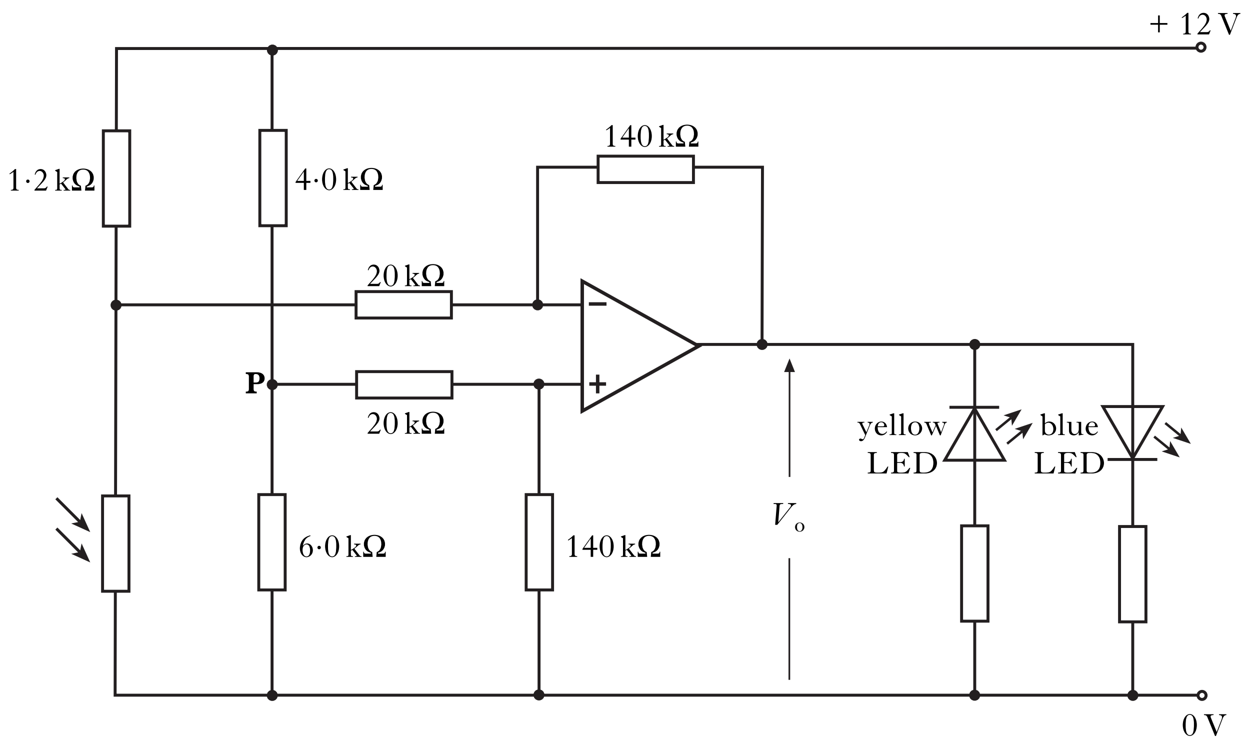


Determine the value of irradiance at which the bridge is balanced.

Show clearly how you arrive at your answer. **3**

26. (continued)

(*b*) The LDR is now mounted on the outside of a car to monitor light level. It forms part of a circuit which provides an indication for the driver to switch on the headlamps.
The circuit is shown below.



The LEDs inside the car indicate whether the headlamps should be on or off.

(i) At a particular value of irradiance the resistance of the LDR is 2·0 kΩ.

Show that the potential difference across the LDR in the circuit is 7·5 V. **1**

(ii) The potential at point P in the circuit is 7·2 V.

Calculate the output voltage, V_o, of the op-amp at this light level. **2**

(iii) Which LED(s) is/are lit at this value of output voltage?

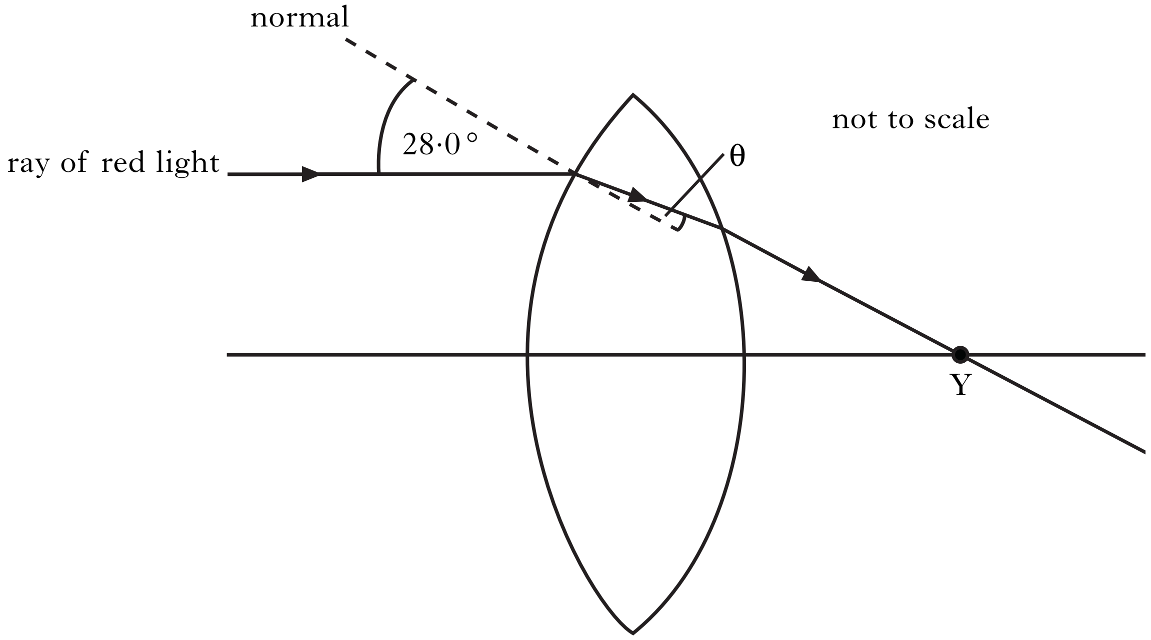
Justify your answer. **2**

(8)

[Turn over

Marks

27. (*a*) A ray of red light of frequency $4 \cdot 80 \times 10^{14}$ Hz is incident on a glass lens as shown.



The ray passes through point Y after leaving the lens.

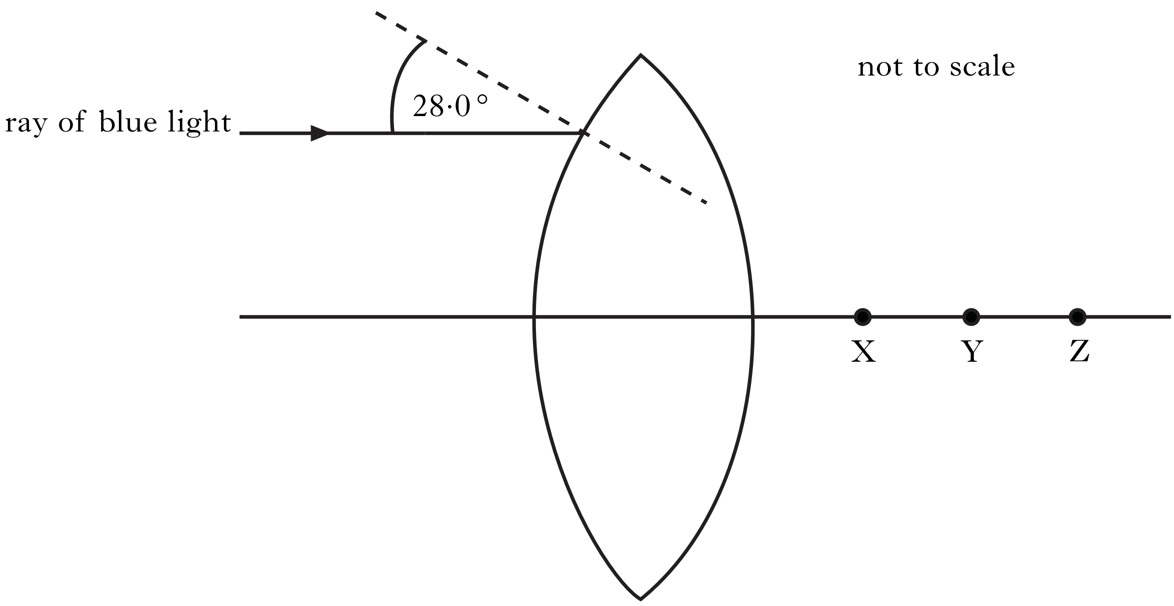
The refractive index of the glass is 1·61 for this red light.

(i) Calculate the value of the angle θ shown in the diagram. **2**

(ii) Calculate the wavelength of this light inside the lens. **3**

(*b*) The ray of red light is now replaced by a ray of blue light.

The ray is incident on the lens at the same point as in part (*a*).



Through which point, X, Y or Z, will this ray pass after leaving the lens?

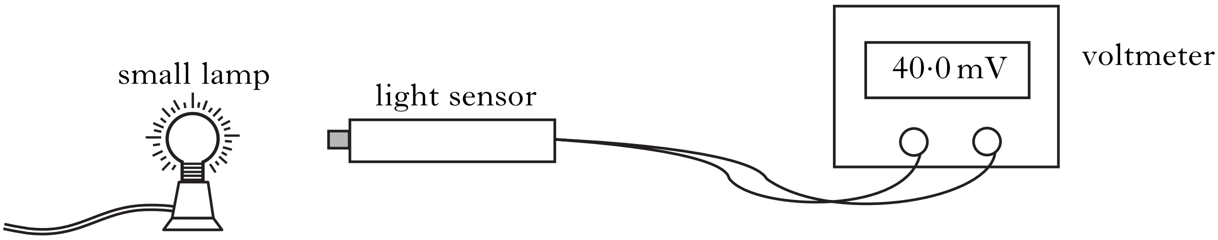
You must justify your answer. **1**

(6)

Marks

28. The diagram shows a light sensor connected to a voltmeter.

A small lamp is placed in front of the sensor.



The reading on the voltmeter is 20 mV for each 1·0 mW of power incident on the sensor.

(*a*) The reading on the voltmeter is 40·0 mV.

The area of the light sensor is $8{\cdot}0 \times 10^{-5}\,\text{m}^2$.

Calculate the irradiance of light on the sensor. **3**

(*b*) The small lamp is replaced by a different source of light.

Using this new source, a student investigates how irradiance varies with distance.

The results are shown.

Distance/m	0·5	0·7	0·9
Irradiance/W m^{-2}	1·1	0·8	0·6

Can this new source be considered to be a point source of light?

Use **all** the data to justify your answer. **2**

(5)

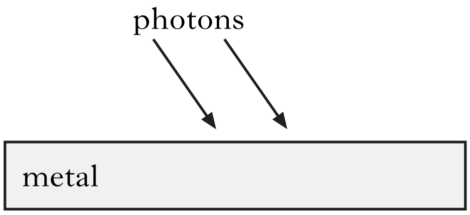
[Turn over

Marks

29. To explain the photoelectric effect, light can be considered as consisting of tiny bundles of energy. These bundles of energy are called photons.

(*a*) Sketch a graph to show the relationship between photon energy and frequency. **1**

(*b*) Photons of frequency $6{\cdot}1 \times 10^{14}$ Hz are incident on the surface of a metal.



This releases photoelectrons from the surface of the metal.

The maximum kinetic energy of any of these photoelectrons is $6{\cdot}0 \times 10^{-20}$ J.

Calculate the work function of the metal. **3**

(*c*) The irradiance due to these photons on the surface of the metal is now reduced.

Explain why the maximum kinetic energy of each photoelectron is unchanged. **1**

(5)

Marks

30. (*a*) A technician is carrying out an experiment on the absorption of gamma radiation.

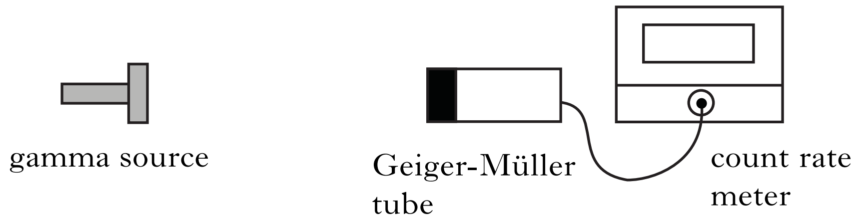
The radioactive source used has a long half-life and emits only gamma radiation. The activity of the source is 12 kBq.

(i) State what is meant by an *activity of 12 kBq*. **1**

(ii) The table shows the half-value thicknesses of aluminium and lead for gamma radiation.

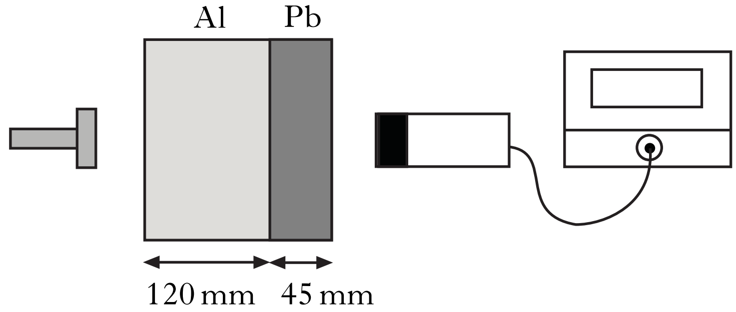
Material	*Half-value thickness*/mm
aluminium (Al)	60
lead (Pb)	15

The technician sets up the following apparatus.



The count rate, when corrected for background radiation, is 800 counts per second.

Samples of aluminium and lead are now placed between the source and detector as shown.

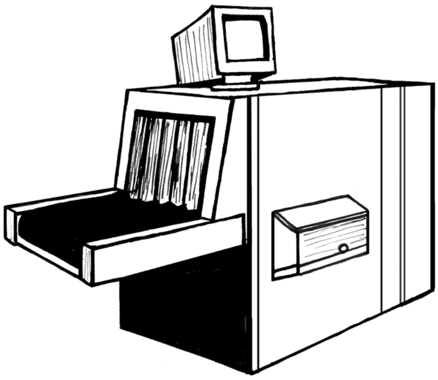


Determine the new corrected count rate. **2**

[Turn over for Question 30 (*b*) on *Page twenty-four*

30. (continued)

(*b*) X-ray scanners are used as part of airport security. A beam of X-rays scans the luggage as it passes through the scanner.



A baggage handler sometimes puts a hand inside the scanner to clear blockages.
The hand receives an average absorbed dose of 0·030 μGy each time this occurs.

The radiation weighting factor for X-rays is 1.

(i) State the average equivalent dose received by the hand on each occasion. **1**

(ii) The occupational exposure limit for a hand is 60 μSv per hour.

Calculate how many times the baggage handler would have to put a hand into the scanner in one hour to reach this limit. **1**

(5)

[*END OF QUESTION PAPER*]

ACKNOWLEDGEMENTS

Question 24—Picture of electronically heated gloves. Published by Zanier Sport GmbH. Reproduced by kind permission of Markus Zanier.