X069/12/02

NATIONAL QUALIFICATIONS 2015

TUESDAY, 5 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 31)

11 Answer the questions numbered 21 to 31 in the answer book provided.

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

Diagrams and graphs should be drawn in pencil.

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 31.

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.

DATA SHEET

COMMON PHYSICAL QUANTITIES

Quantity	*Symbol*	*Value*	*Quantity*	*Symbol*	*Value*
Speed of light in vacuum	c	$3{\cdot}00 \times 10^{8}\ \mathrm{m\,s^{-1}}$	Mass of electron	m_e	$9{\cdot}11 \times 10^{-31}\ \mathrm{kg}$
Magnitude of the charge on an 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 on Earth	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	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

Element	*Wavelength*/nm	*Colour*
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

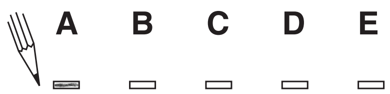
B ampere

C watt

D coulomb

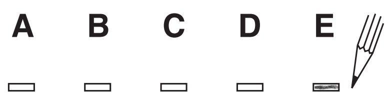
E volt.

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 of the following contains one scalar quantity and one vector quantity?

A acceleration; displacement

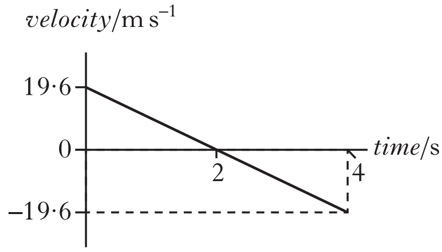
B kinetic energy; speed

C momentum; velocity

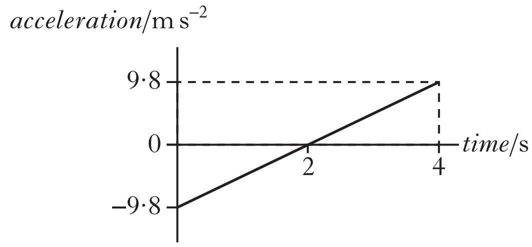
D potential energy; work

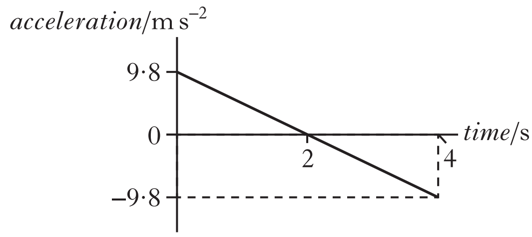
E power; weight

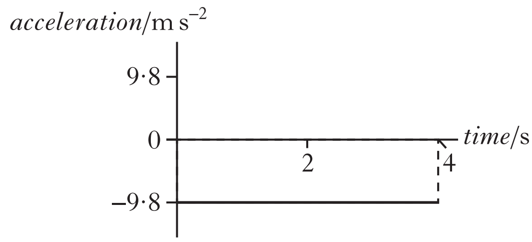
2. The following velocity-time graph represents the vertical motion of a ball.

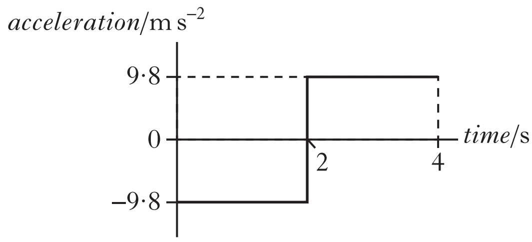


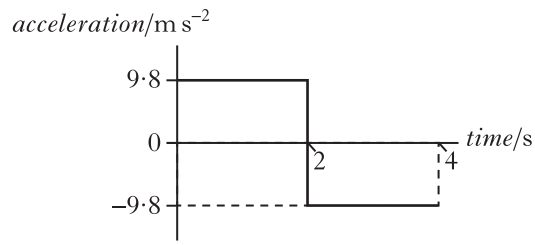
Which of the following acceleration-time graphs represents the same motion?

A


B


C


D


E


3. The mass of a car is 900 kg. The car is being towed at a steady speed of $4{\cdot}0\,m\,s^{-1}$. The tow rope breaks and the car travels a further 6·0 m in a straight line before coming to rest.

The magnitude of the average unbalanced force acting on the car while coming to rest is

A 600 N

B 1200 N

C 1350 N

D 3600 N

E 5400 N.

4. A student makes the following statements about elastic and inelastic collisions.

I In an elastic collision kinetic energy is conserved but momentum is not conserved.

II In an inelastic collision both kinetic energy and momentum are conserved.

III In an inelastic collision momentum is conserved but kinetic energy is not conserved.

Which of the statements is/are correct?

A I only

B II only

C III only

D I and II only

E I and III only

5. The volume of air inside a hot-air balloon is $2{\cdot}50 \times 10^3\,m^3$.

The mass of air inside the balloon is $2{\cdot}00 \times 10^3$ kg.

The density of the air inside the balloon is

A $0{\cdot}13\,kg\,m^{-3}$

B $0{\cdot}80\,kg\,m^{-3}$

C $1{\cdot}25\,kg\,m^{-3}$

D $1{\cdot}29\,kg\,m^{-3}$

E $7{\cdot}84\,kg\,m^{-3}$.

6. An aluminium cube has sides of length 0·10 m. The cube is placed on one of its faces on a table.

The pressure exerted by the cube on the table is

A $2{\cdot}7 \times 10^2$ Pa

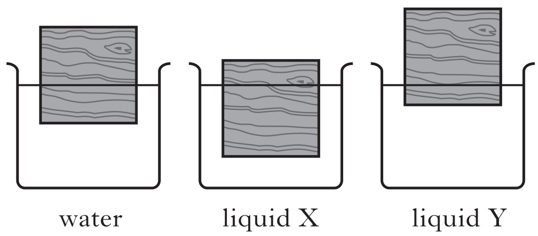
B $2{\cdot}6 \times 10^3$ Pa

C $2{\cdot}6 \times 10^4$ Pa

D $1{\cdot}0 \times 10^5$ Pa

E $2{\cdot}7 \times 10^5$ Pa.

7. Three identical blocks of wood are floating in different liquids as shown.



A student makes the following statements.

I The density of the wood is less than the density of water.

II The density of liquid X is less than the density of water.

III The density of liquid X is greater than the density of liquid Y.

Which of the statements is/are correct?

A I only

B II only

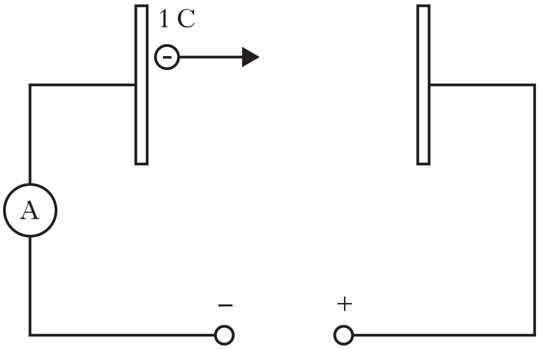
C I and II only

D I and III only

E II and III only

[Turn over

8. One joule of work is done in moving one coulomb of charge between two plates as shown.



From the information given, which of the following statements must be true?

A The distance between the plates is one metre.

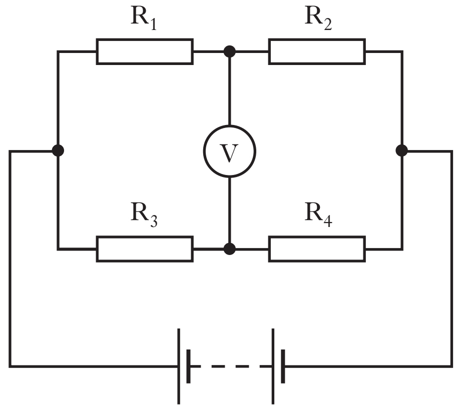
B The capacitance of the circuit is one farad.

C The current in the circuit is one ampere.

D The potential difference between the plates is one volt.

E The resistance of the circuit is one ohm.

9. A Wheatstone bridge circuit is set up as shown.



The bridge is balanced.

A student suggests three different changes to make the bridge unbalanced.

I Double the value of R_1 and double the value of R_2.

II Double the value of R_1 and double the value of R_4.

III Double the voltage of the supply.

Which of these changes would make the bridge unbalanced?

A I only

B II only

C I and II only

D II and III only

E I, II and III

10. The heating element of an electric kettle has a resistance of 30 Ω.

The kettle is connected to an a.c. power supply.

The r.m.s. voltage of the supply is 230 V.

The peak value of the current in the element is

A 0·1 A

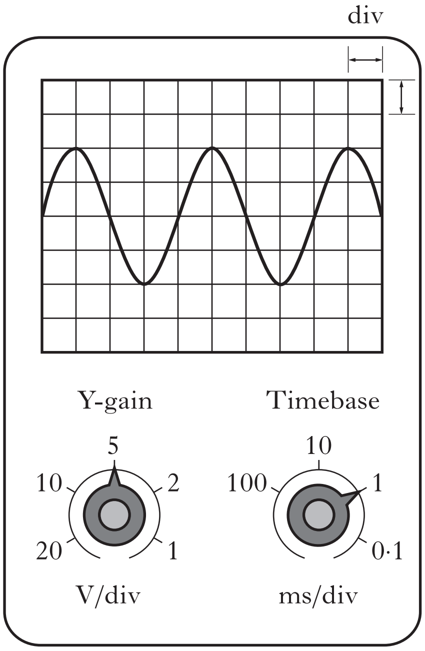
B 0·2 A

C 5·4 A

D 7·7 A

E 10·8 A.

11. The output from a signal generator is connected to the input terminals of an oscilloscope. The trace observed on the oscilloscope screen, the Y-gain setting and the timebase setting are shown.



The frequency of the signal shown is calculated using the

A Y-gain setting and the vertical height of the trace

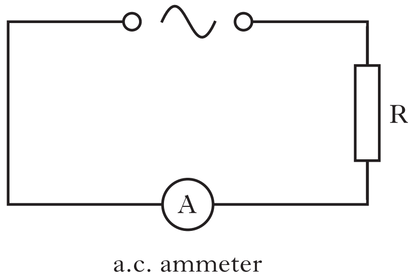
B Y-gain setting and the horizontal distance between the peaks of the trace

C Y-gain setting and the timebase setting

D timebase setting and the vertical height of the trace

E timebase setting and the horizontal distance between the peaks of the trace.

12. 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

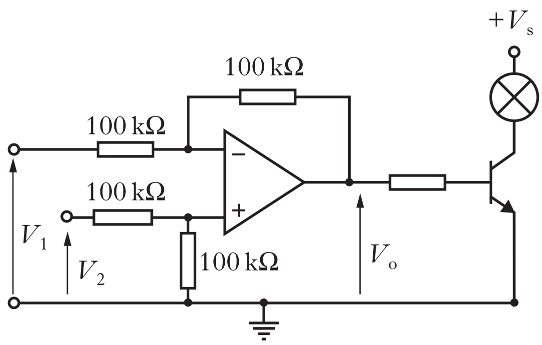
B decreases steadily

C increases steadily

D increases then decreases

E decreases then increases.

13. A circuit containing an op-amp is set up as shown.



The transistor switches on when $V_o = 0{\cdot}7$ V.

Which row in the table shows the values of V_1 and V_2 that will switch on the lamp?

	V_1/V	V_2/V
A	0·3	1·2
B	0·3	0·4
C	0·3	0·3
D	0·4	0·3
E	1·2	0·3

14. A student makes the following statements about waves.

I The energy of a wave depends on its amplitude.

II The period of a wave is the number of complete waves passing any point each second.

III The amplitude of a wave is the distance between the crest and the trough.

Which of these statements is/are correct?

A I only

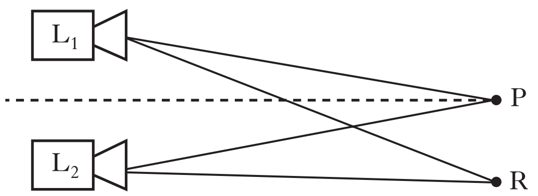
B III only

C I and II only

D I and III only

E II and III only

15. Two identical loudspeakers, L_1 and L_2, are operated at the same frequency and in phase with each other. An interference pattern is produced.



At position P, which is the same distance from both loudspeakers, there is a maximum.

The next maximum is at position R, where $L_1R = 5{\cdot}6$ m and $L_2R = 5{\cdot}3$ m.

The speed of sound is $340\,\text{m s}^{-1}$.

The frequency of the sound emitted by the loudspeakers is

A $8{\cdot}8 \times 10^{-4}$ Hz

B $3{\cdot}1 \times 10^{1}$ Hz

C $1{\cdot}0 \times 10^{2}$ Hz

D $1{\cdot}1 \times 10^{3}$ Hz

E $3{\cdot}7 \times 10^{3}$ Hz.

16. An experiment is carried out to measure the wavelength of red light from a laser.

The following values for the wavelength are obtained.

650 nm 640 nm 635 nm 648 nm 655 nm

The mean value for the wavelength and the approximate random uncertainty in the mean is

A (645 ± 1) nm

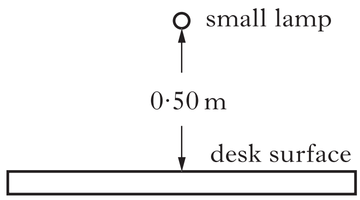
B (645 ± 4) nm

C (646 ± 1) nm

D (646 ± 4) nm

E (3228 ± 20) nm.

17. A small lamp is placed 0·50 m above the surface of a desk.



There is no other source of light.

The lamp is now moved until the irradiance at the desk surface is halved.

The new distance of the lamp above the desk surface is approximately

A 0·7 m

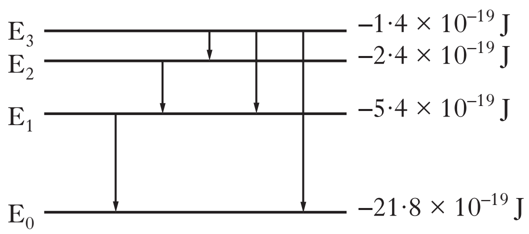
B 1·0 m

C 1·4 m

D 1·5 m

E 2·0 m.

18. The diagram represents some electron transitions between energy levels in an atom.



The radiation emitted with the shortest wavelength is produced by an electron making transition

A E_1 to E_0

B E_2 to E_1

C E_3 to E_2

D E_3 to E_1

E E_3 to E_0.

19. A student writes the following statement to represent a series of nuclear decays.

$$^{234}_{91}\text{Pa} \xrightarrow{x} {}^{234}_{92}\text{U} \xrightarrow{y} {}^{230}_{90}\text{Th} \xrightarrow{z} {}^{226}_{88}\text{Ra}$$

Which row in the table identifies the radiations represented by x, y and z?

	x	y	z
A	alpha	beta	beta
B	beta	alpha	gamma
C	gamma	beta	beta
D	beta	alpha	alpha
E	gamma	alpha	beta

20. A detector is placed in front of a radioactive source.

The corrected count rate recorded by the detector is 20 000 counts per minute.

An absorber is placed between the source and the detector.

The thickness of the absorber is 18 mm. The corrected count rate now recorded by the detector is 1250 counts per minute.

The half-value thickness of the absorber for this source is

A 3·6 mm

B 4·5 mm

C 18 mm

D 72 mm

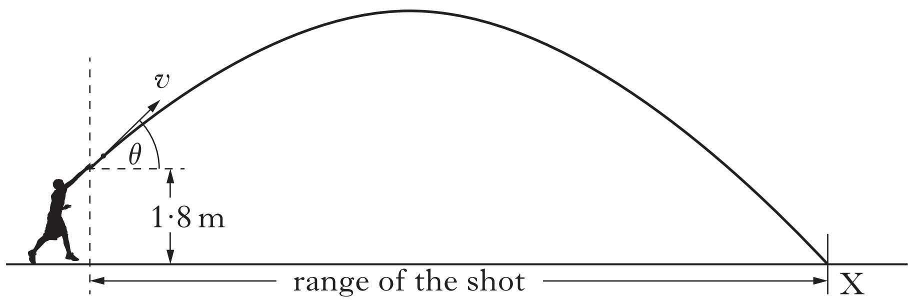
E 90 mm.

[Turn over

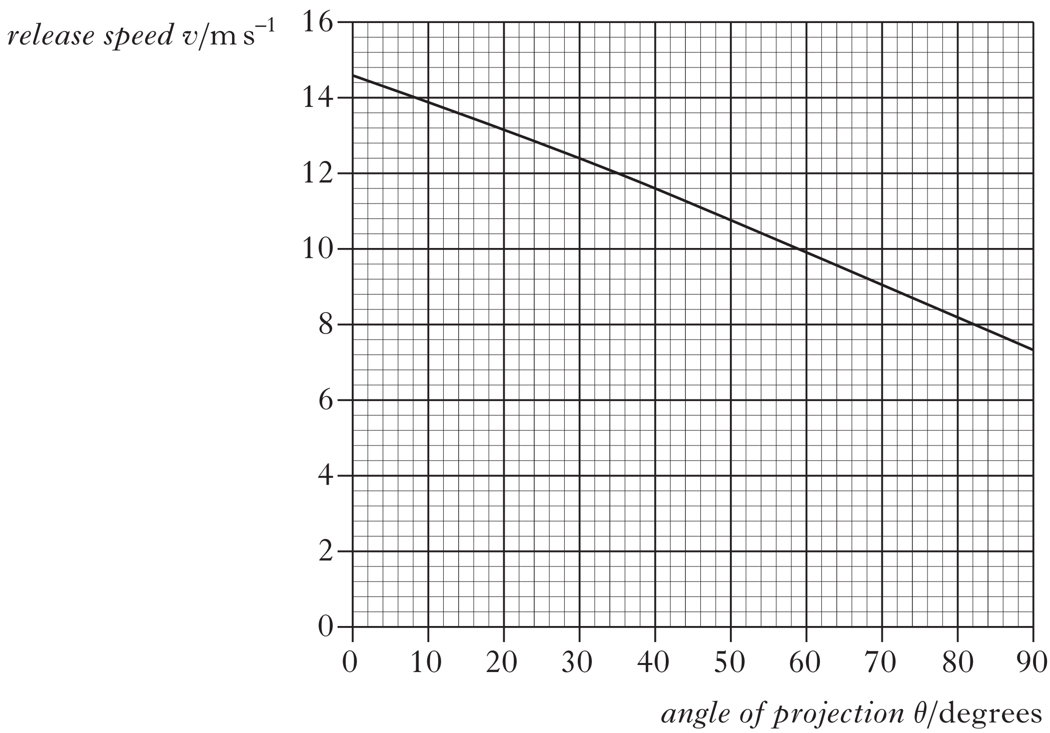
Write your answers to questions 21 to 31 in the answer book.

21. The shot put is an athletics event in which competitors "throw" a shot as far as possible. The shot is a metal ball of mass 4·0 kg. One of the competitors releases the shot at a height of 1·8 m above the ground and at an angle θ to the horizontal. The shot travels through the air and hits the ground at X.

not to scale



The graph shows how the release speed of the shot v varies with the angle of projection θ.



(*a*) The angle of projection for a particular throw is 40°.

(i) (A) State the release speed of the shot at this angle. **1**

(B) Calculate the horizontal component of the initial velocity of the shot. **1**

(C) Calculate the vertical component of the initial velocity of the shot. **1**

Marks

21. (*a*) (continued)

(ii) The maximum height reached by the shot is 4·7 m above the ground. The time between release and reaching this height is 0·76 s.

(A) Calculate the total time between the shot being released and hitting the ground. **2**

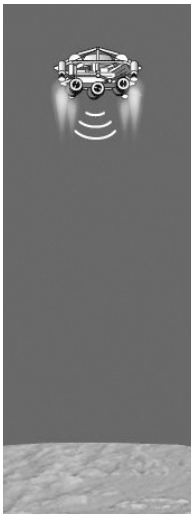
(B) Calculate the range of the shot for this throw. **2**

(*b*) Using information from the graph, explain the effect of increasing the angle of projection on the kinetic energy of the shot at release. **1**

(8)

[Turn over

22. A spacecraft has a mass of 3520 kg and is descending vertically towards the surface of a moon. *Marks*



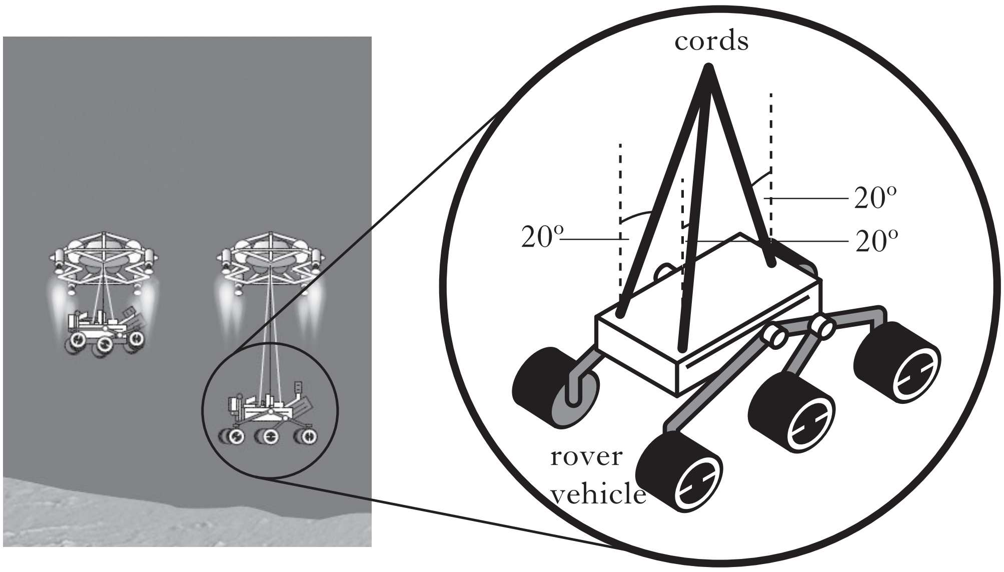
During the descent the average gravitational field strength for this moon is $1{\cdot}25\ \text{N kg}^{-1}$.

(*a*) When the spacecraft is at a height of $2{\cdot}00 \times 10^3$ m it has a vertical velocity of $90{\cdot}0\ \text{m s}^{-1}$. Rocket engines exert a constant force on the spacecraft to reduce its speed.

This causes the speed of the spacecraft to be $0\ \text{m s}^{-1}$ at a height of 20·0 m.

Calculate the average vertical force exerted by the rocket engines during this descent. **3**

(*b*) At this height of 20·0 m the spacecraft is kept stationary by the rockets while a rover vehicle is lowered at a constant speed towards the surface of the moon.



The rover vehicle has a weight of 1380 N.

There are **three** cords supporting the rover as it descends.

At one instant, the angle between each cord and the vertical is 20°.

Show that the tension in each cord is 490 N at this instant. **2**

(5)

Marks

23. During a hockey match a penalty is awarded.

This gives a player a free hit at a stationary ball with only the goalkeeper between the player and the goal.

The mass of the ball is 0·16 kg.

The hockey stick is in contact with the ball for 0·020 s.

The speed of the ball immediately after impact is $39\,m\,s^{-1}$.

(*a*) (i) Calculate the average force exerted by the stick on the ball. **2**

(ii) Sketch a graph showing how the force exerted by the stick on the ball varies with time during the impact.

You may wish to use the square ruled paper provided. **1**

(*b*) The ball is replaced by a second ball with the same mass and dimensions as the first ball. However, the material of the second ball is softer.

The speed of this second ball immediately after being struck by the hockey stick is also $39\,m\,s^{-1}$.

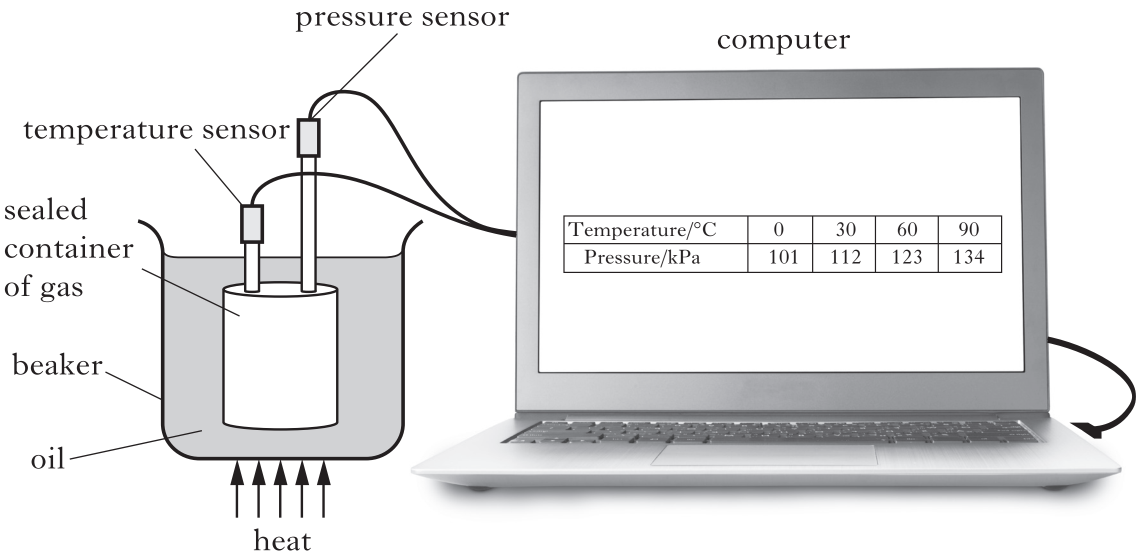
On the graph sketched for (*a*)(ii), draw another graph to show how the force exerted on this second ball varies with time.

You must label each graph clearly. **2**

(5)

[Turn over

24. A student investigates the relationship between the pressure and the temperature of a fixed mass of gas using the apparatus shown.



A sealed container of gas is submerged in a beaker of oil.

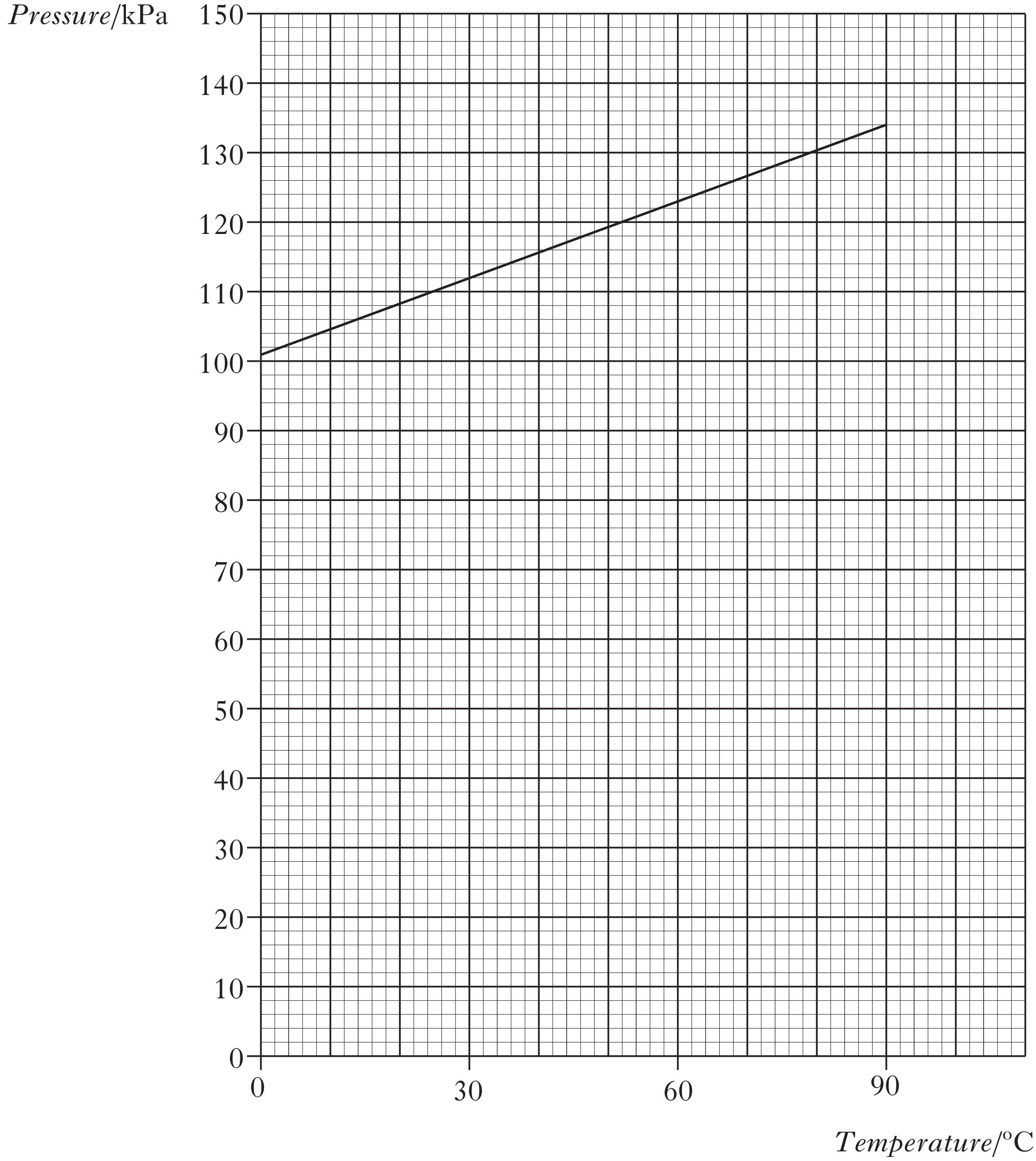
The volume of the container remains constant during the experiment.

The oil is heated slowly and readings of the temperature and pressure of the gas are recorded. The results are shown in the table.

Temperature/°C	0	30	60	90
Pressure/kPa	101	112	123	134

24. (continued)

The student uses these results to produce the following graph.



(*a*) The student deduces that the pressure is **not** directly proportional to the temperature of the gas in degrees celsius.

Explain, with reference to the graph, why the student is correct. **1**

(*b*) The temperature of the gas is increased to 170 °C.

Calculate the pressure of the gas at this temperature. **2**

(*c*) The gas is now allowed to cool.

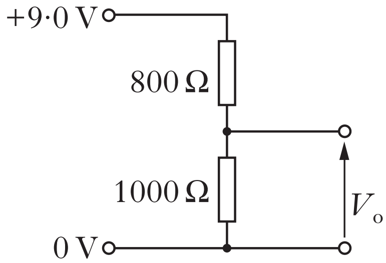
Use the kinetic model to explain what happens to the pressure of the gas as its temperature decreases. **2**

(5)

Marks

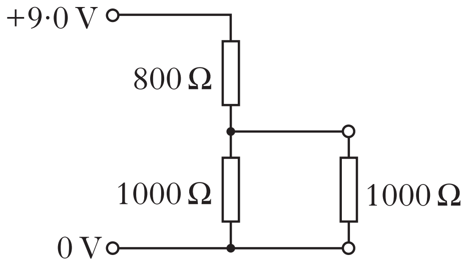
25. Two students are each given the task of designing an arrangement of resistors to provide an output voltage of 5·0 V from a 9·0 V supply.

(*a*) (i) Student **A** designs the circuit shown.



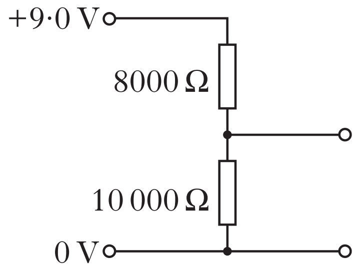
Show that the output voltage V_o is 5·0 V. **1**

(ii) Student **A** now connects a load resistor of resistance 1000 Ω across the output terminals as shown.

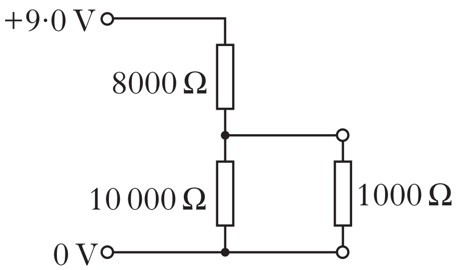


Calculate the potential difference across the load resistor. **2**

(*b*) Student **B** designs the circuit shown below.



Student **B** now connects the same load resistor as shown.



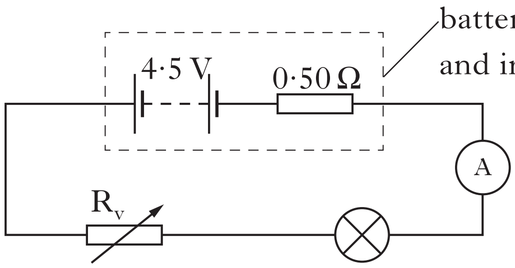
State which student's design achieves a potential difference closer to 5·0 V across the 1000 Ω load resistor.

You must justify your answer. **2**

(5)

26. A technician investigates the use of different light sources for torches. *Marks*

The following circuit is set up.



(*a*) The resistance of variable resistor R_v is set to 2·5 Ω. The reading on the ammeter is 0·30 A.

(i) Show that the resistance of the lamp is 12 Ω at this current. **2**

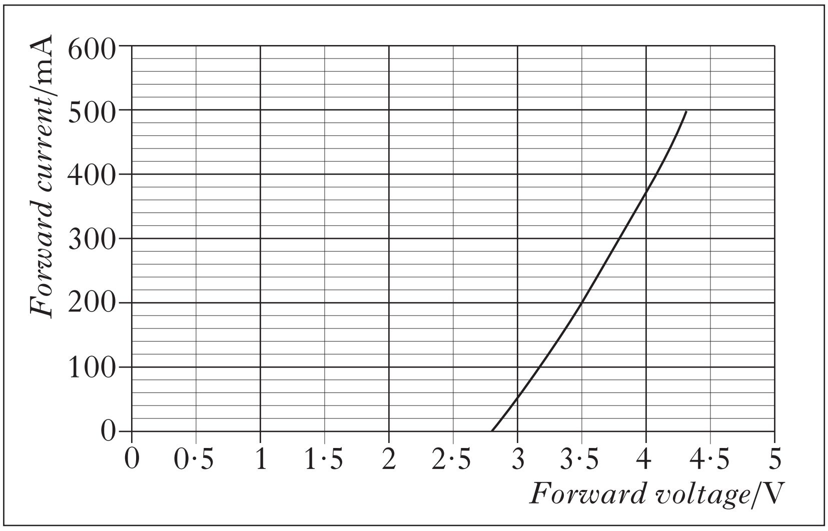
(ii) Calculate the power output of the lamp at this current. **2**

(*b*) To increase the life of the battery the lamp is replaced by an LED. The LED emits bright light.

(i) Redraw the circuit diagram to show the LED connected in place of the lamp. **1**

(ii) An extract from the manufacturer's data sheet for the LED is shown.

Forward current/mA	*Relative luminosity*
0	0
100	0·6
200	1·0
300	1·5
400	1·8
500	2·1



The variable resistor is adjusted until the relative luminosity of the LED is 1·0.

(A) Determine the forward voltage across the LED. **1**

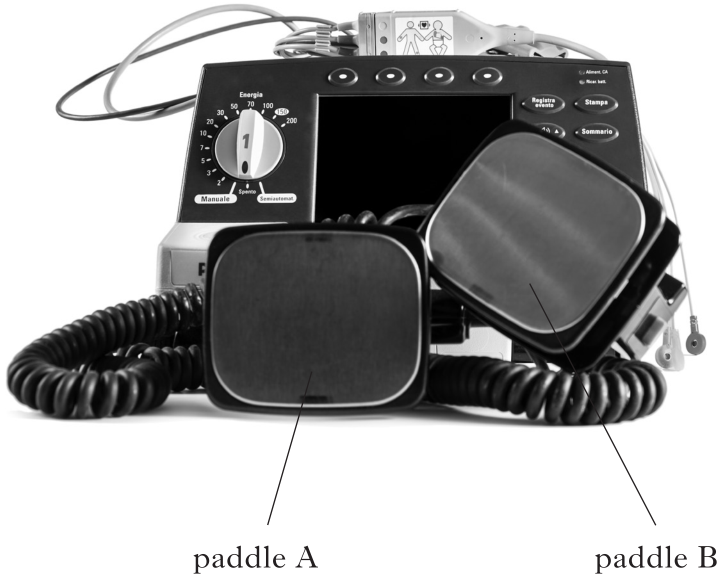
(B) Calculate the potential difference across the variable resistor. **2**

(iii) Using the terms *electrons*, *holes* and *photons*, explain how light is produced at the p-n junction of the LED. **1**

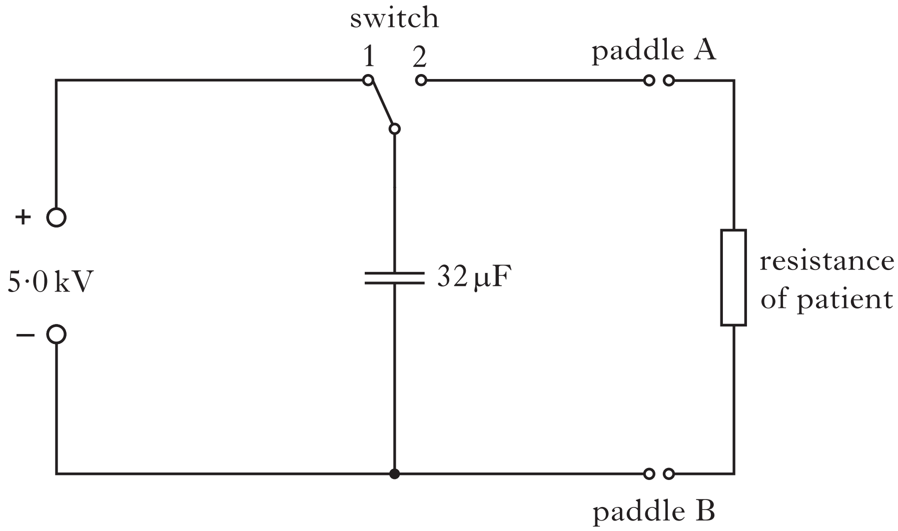
(9)

Marks

27. A defibrillator is a device that provides a high energy electrical impulse to correct abnormal heart beats.



The diagram shows a simplified version of a defibrillator circuit.



The switch is set to position 1 and the capacitor charges.

(*a*) Show that the charge on the capacitor when it is fully charged is 0·16 C. **1**

(*b*) Calculate the energy stored in the capacitor when it is fully charged. **2**

(*c*) The defibrillator is now used on a patient. Paddles A and B are placed on the patient's chest to complete the circuit. The switch is set to position 2 and the capacitor discharges through the patient.

The resistance of a patient can vary from 40 Ω to 150 Ω.

Calculate the maximum current in the circuit when the capacitor is discharged through a patient. **2**

(5)

Marks

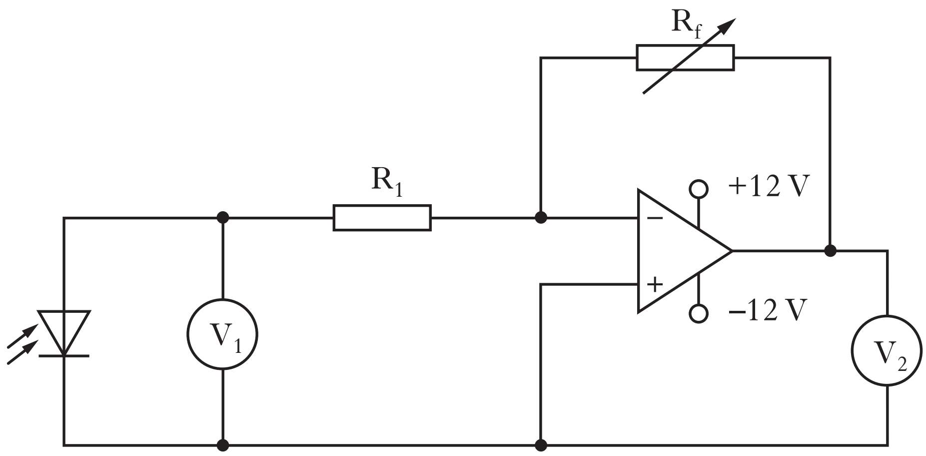
28. A sample of pure semiconductor has a high resistance at room temperature. Doping this sample decreases its resistance and can create n-type or p-type semiconductors. Semiconductors are used to make many solid state devices such as the photodiode.

(*a*) State what is meant by the terms:

(i) *doping*; **1**

(ii) *n-type semiconductor*. **1**

(*b*) The diagram shows a photodiode connected in an op-amp circuit.



(i) In which mode is the photodiode being used? **1**

(ii) The resistance of R_1 is 5·0 kΩ and the variable resistor R_f is set to 45 kΩ. At a certain light level the reading on voltmeter V_1 is 0·60 V.

Calculate the reading on voltmeter V_2. **2**

(iii) The light level remains constant.

The value of R_f is now adjusted to 200 kΩ.

Determine the new reading on voltmeter V_2. **1**

(6)

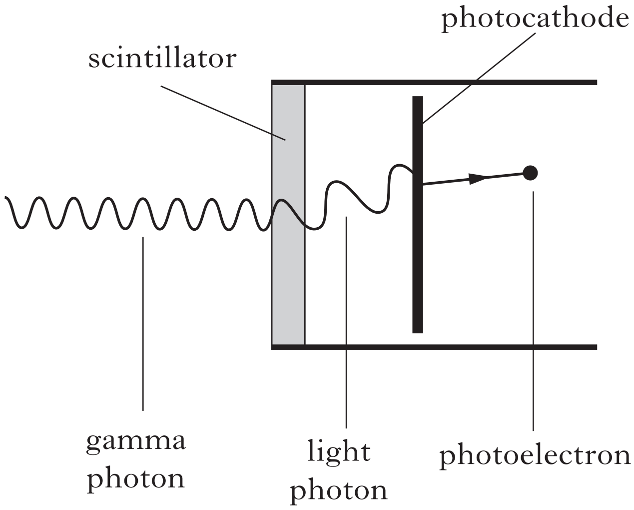
[Turn over

Marks

29. In the exploration for oil and gas the detection and measurement of gamma radiation from rocks can give important information about rock structures.

One type of gamma detector has two parts.

(*a*) The first part consists of a scintillator in which the gamma radiation produces photons of light. These photons then produce photoelectrons at a photocathode as shown.



The work function of the photocathode is $3{\cdot}20 \times 10^{-19}$ J.

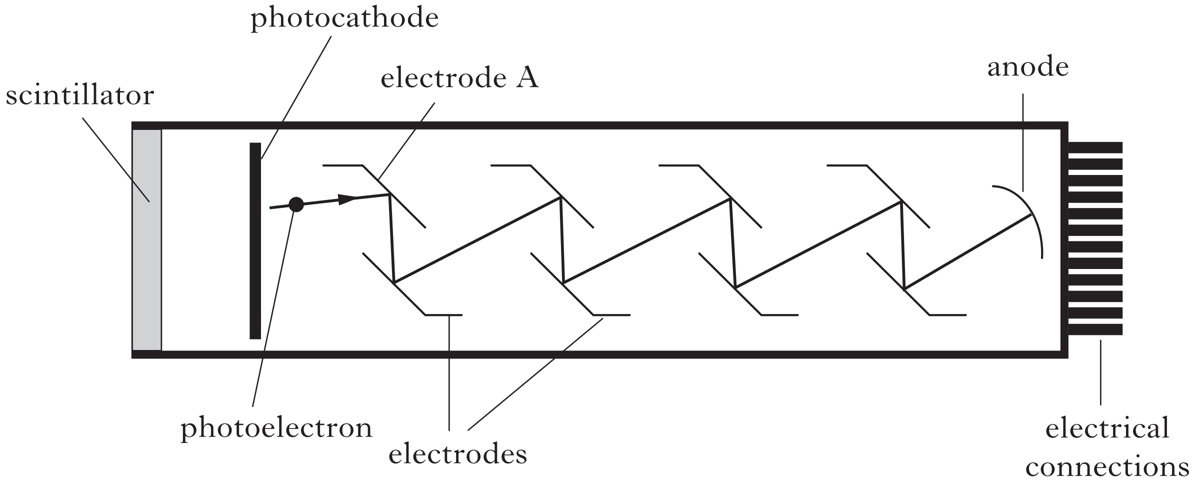
(i) State what is meant by the term *work function*. **1**

(ii) The wavelength of the photons emitted from the scintillator is 425 nm.

Calculate the maximum kinetic energy of a photoelectron released from the photocathode. **2**

29. (continued)

(*b*) The second part of the gamma detector consists of a series of electrodes which accelerate photoelectrons towards the anode.



A particular photoelectron is released from the photocathode with a kinetic energy of $1 \cdot 36 \times 10^{-19}$ J. It is then accelerated by a potential difference of 120 V between the photocathode and electrode A.

(i) Calculate the maximum speed of this photoelectron as it reaches electrode A. **3**

(ii) The potential difference between the photocathode and electrode A is now doubled to 240 V.

A student states that the maximum speed of the photoelectrons at electrode A is also doubled.

Is this statement correct?

You must justify your answer. **2**

(8)

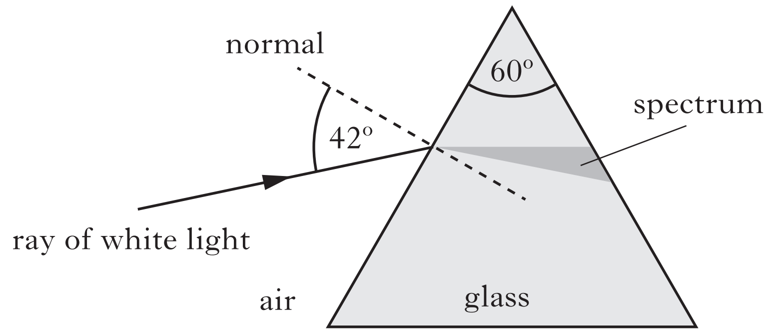
[Turn over

Marks

30. A student carries out two experiments to investigate the spectra produced from a ray of white light.

(*a*) In the first experiment, a ray of white light is incident on a glass prism as shown.

not to scale



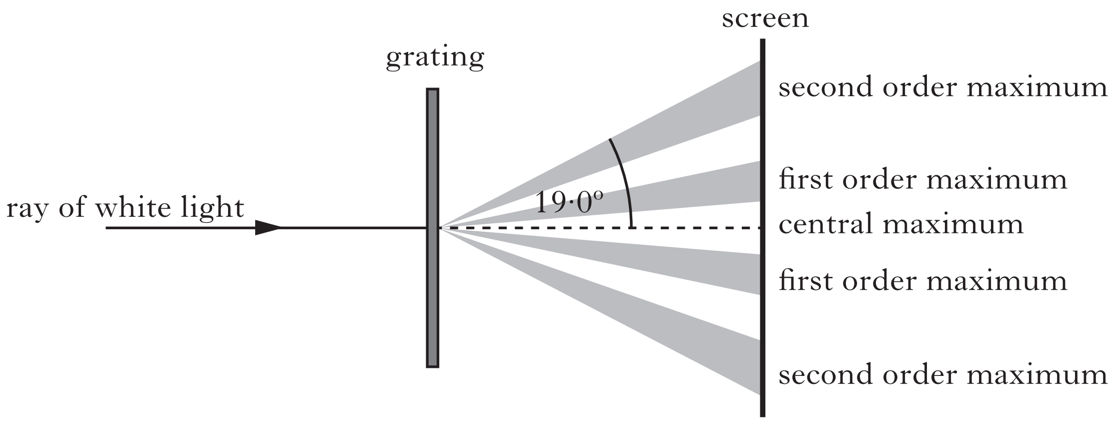
(i) Explain why a spectrum is produced in the glass prism. **1**

(ii) The refractive index of the glass for red light is 1·54.

Calculate the speed of the red light in the glass prism. **2**

(*b*) In the second experiment, a ray of white light is incident on a grating.

not to scale



The angle between the central maximum and the second order maximum for red light is 19·0°.

The frequency of this red light is $4{\cdot}57 \times 10^{14}$ Hz.

(i) Calculate the distance between the slits on this grating. **3**

(ii) Explain why the angle to the second order maximum for blue light is different to that for red light. **2**

(8)

Marks

31. (*a*) In a certain star, one of the fusion reactions taking place is represented by the following statement.

$$^{1}_{1}\mathrm{H} + ^{15}_{7}\mathrm{N} \rightarrow ^{12}_{6}\mathrm{C} + ^{4}_{2}\mathrm{He}$$

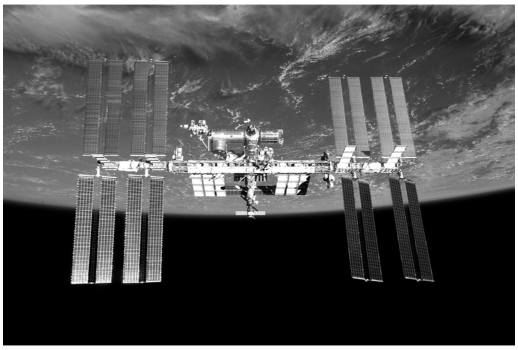
The energy released by this reaction is $7{\cdot}96662 \times 10^{-13}$ J.

The table shows the masses of three of the particles.

Particle	*Mass*/kg
$^{1}_{1}\mathrm{H}$	$1{\cdot}68706 \times 10^{-27}$
$^{12}_{6}\mathrm{C}$	$20{\cdot}1031 \times 10^{-27}$
$^{4}_{2}\mathrm{He}$	$6{\cdot}69944 \times 10^{-27}$

Calculate the mass of the nitrogen nucleus. **3**

(*b*) The International Space Station (ISS) orbits the earth.



Astronauts in the ISS are exposed to cosmic radiation.

During a mission lasting 180 days an astronaut receives an equivalent dose of 95 mSv due to a specific type of radiation.

(i) Show that the equivalent dose rate during the mission is $22\,\mu\mathrm{Sv\,h^{-1}}$. **1**

(ii) The absorbed dose rate inside the ISS for this radiation is $11\,\mu\mathrm{Gy\,h^{-1}}$.

Calculate the radiation weighting factor of this radiation. **2**

(6)

[*END OF QUESTION PAPER*]

ACKNOWLEDGEMENTS

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