X272/12/02

NATIONAL QUALIFICATIONS 2015

TUESDAY, 5 MAY
1.00 PM – 3.30 PM

PHYSICS
HIGHER (Revised)

Read Carefully

Reference may be made to the Physics Data Booklet and the accompanying Relationships sheet.

1 All questions should be attempted.

Section A (questions 1 to 20)

2 Check that the answer sheet is for Physics Higher (Revised) (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 32)

11 Answer the questions numbered 21 to 32 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 32.

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	$3{\cdot}00 \times 10^{8}$ m s^{-1}	Planck's constant	h	$6{\cdot}63 \times 10^{-34}$ J s
Magnitude of the charge on an electron	e	$1{\cdot}60 \times 10^{-19}$ C	Mass of electron	m_e	$9{\cdot}11 \times 10^{-31}$ kg
Universal Constant of Gravitation	G	$6{\cdot}67 \times 10^{-11}$ m^{3} kg^{-1} s^{-2}	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
Hubble's constant	H_0	$2{\cdot}3 \times 10^{-18}$ s^{-1}			

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*	*Element*	*Wavelength*/nm	*Colour*
Hydrogen	656 486 434 410 397 389	Red Blue-green Blue-violet Violet Ultraviolet Ultraviolet	Cadmium	644 509 480	Red Green Blue
			Lasers		
			Element	*Wavelength*/nm	*Colour*
Sodium	589	Yellow	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

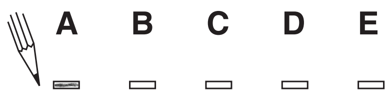
B ampere

C watt

D coulomb

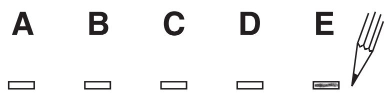
E volt.

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**.



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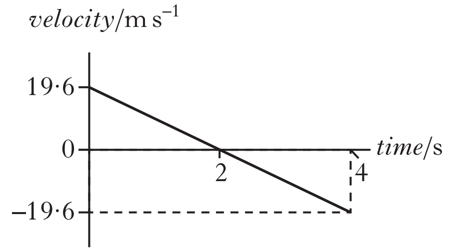
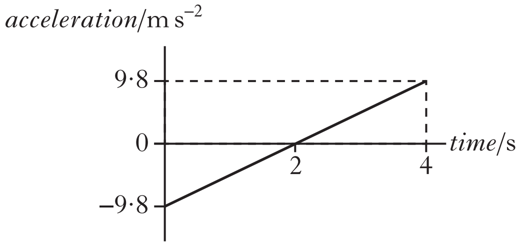
SECTION A

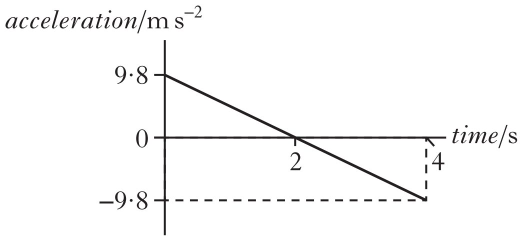
Answer questions 1–20 on the answer sheet.

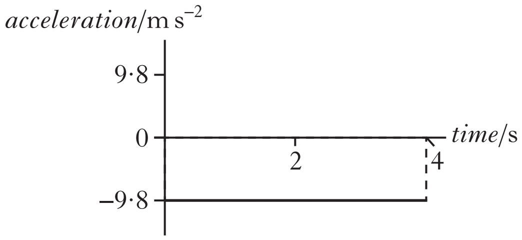
1. The following velocity-time graph represents the vertical motion of a ball.

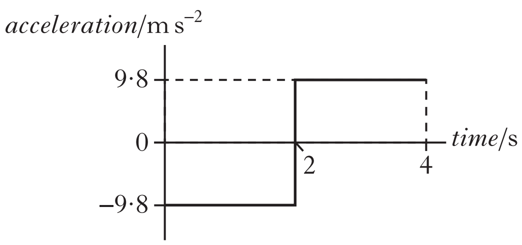


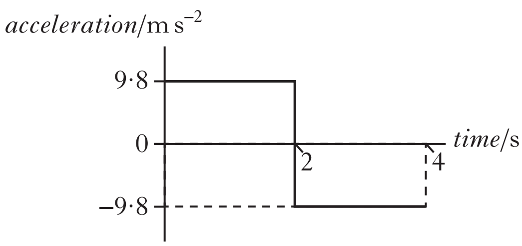
Which of the following acceleration-time graphs represents the same motion?

A 

B 

C 

D 

E 

2. The mass of a car is 900 kg. The car is being towed at a steady speed of $4{\cdot}0\,\text{m s}^{-1}$. 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.

3. 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

4. The distance between a spacecraft and a space station is 0·45 km.

The mass of the spacecraft is $1{\cdot}08 \times 10^5$ kg.

The mass of the space station is $3{\cdot}44 \times 10^5$ kg.

The gravitational force between the spacecraft and the space station is

A $1{\cdot}8 \times 10^6$ N

B 5·5 N

C $1{\cdot}2 \times 10^{-1}$ N

D $5{\cdot}5 \times 10^{-3}$ N

E $1{\cdot}2 \times 10^{-5}$ N.

5. A spacecraft is travelling at a constant speed of $0{\cdot}60c$ relative to the Moon.

An observer on the Moon measures the length of the moving spacecraft to be 190 m.

The length of the spacecraft as measured by an astronaut on the spacecraft is

A 120 m

B 152 m

C 238 m

D 297 m

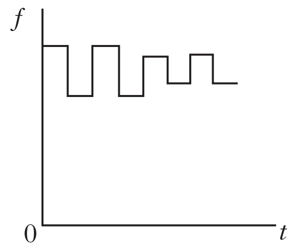
E 300 m.

6. The siren on a police car emits sound which alternates between two different frequencies.

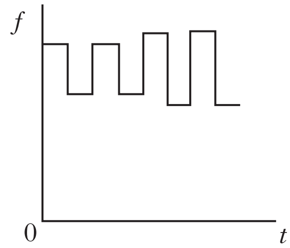
The police car moves at a steady speed as it approaches, passes and moves away from a stationary pedestrian.

Which graph shows how the frequency f of the sound heard by the pedestrian varies with time t?

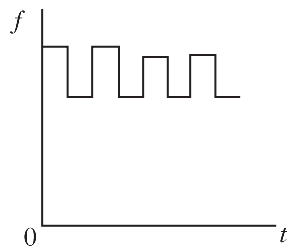
A



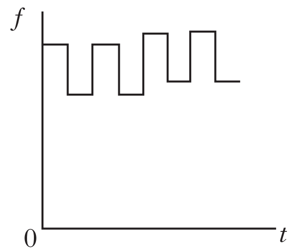
B



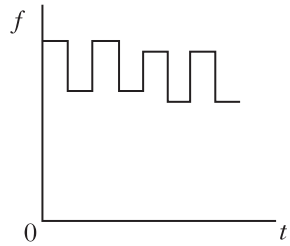
C



D

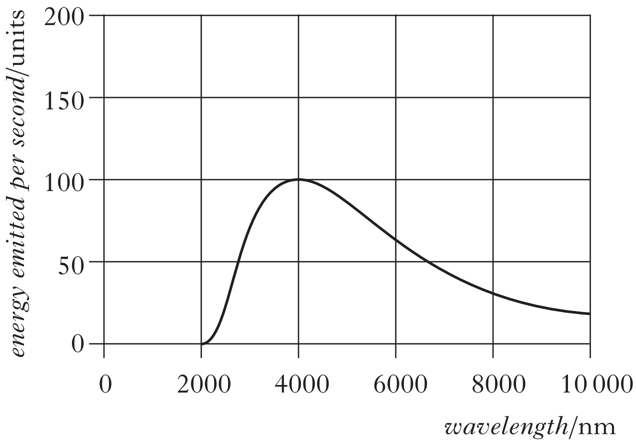


E



[Turn over

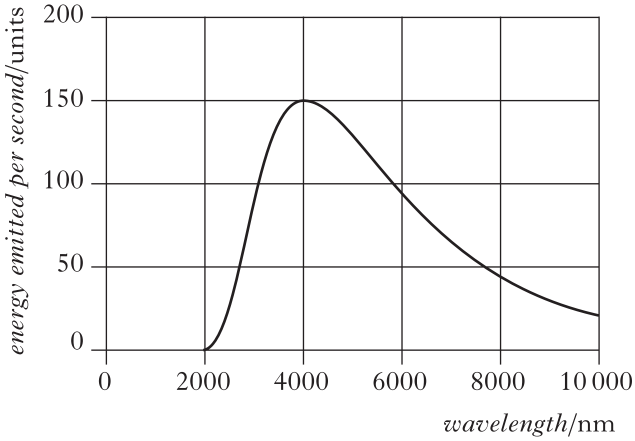
7. The graph shows how the energy emitted per second from an object varies with the wavelength of the radiation emitted by the object.



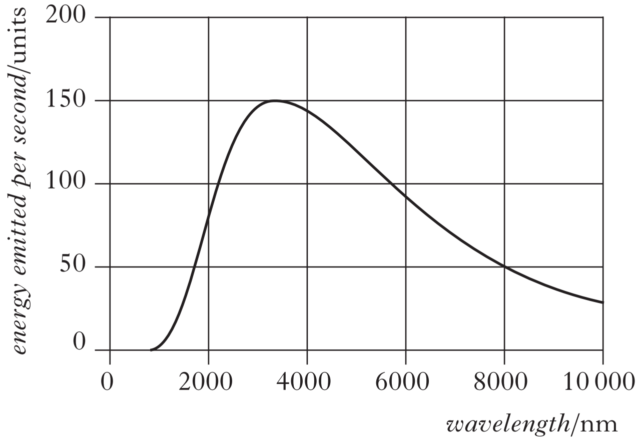
The temperature of the object is increased.

Which graph shows how the energy emitted per second now varies with the wavelength of the radiation?

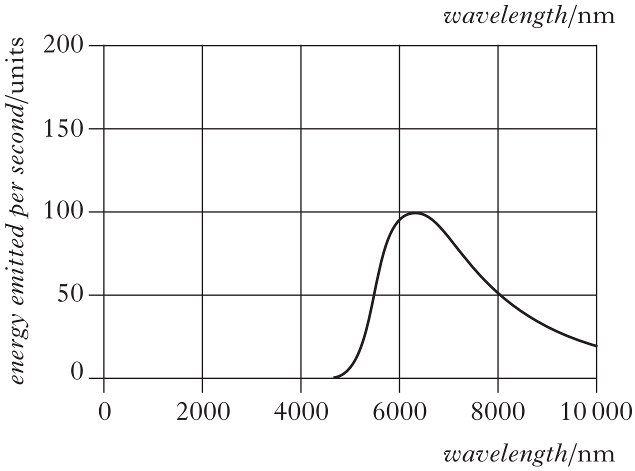
A



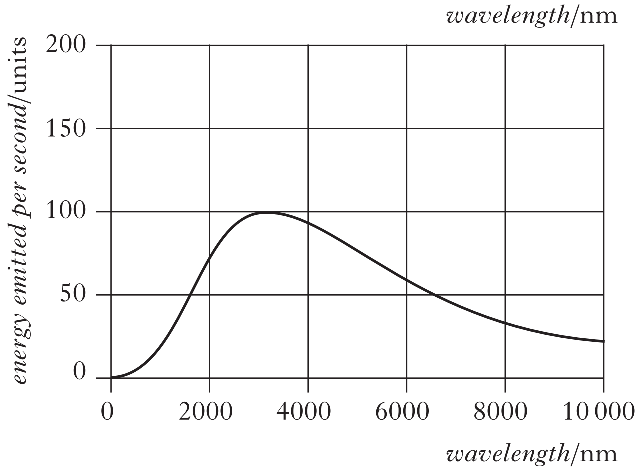
B



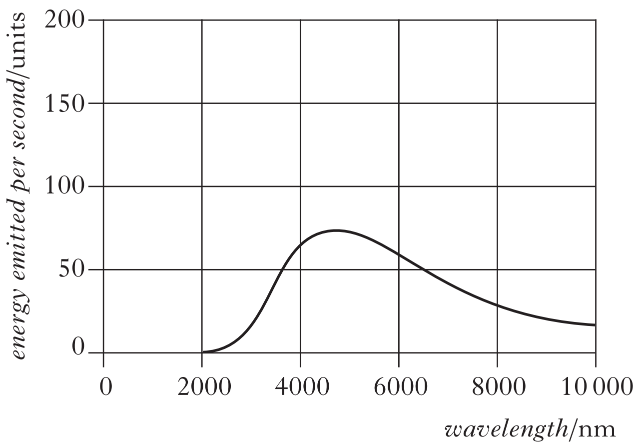
C



D



E



8. A student makes the following statements about a proton.

I A proton is a fermion.

II A proton is a baryon.

III A proton is a meson.

Which of these statements is/are correct?

A I only

B II only

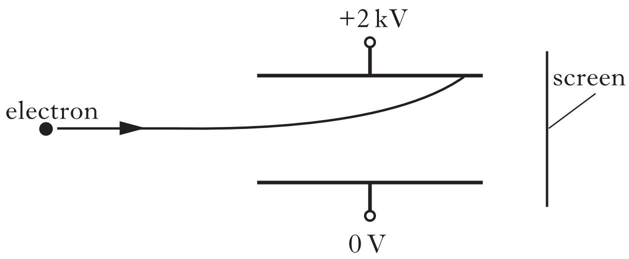
C III only

D I and II only

E I and III only

9. A potential difference of 2 kV is applied across two metal plates.

An electron passes between the metal plates and follows the path shown.



A student makes the following statements about changes that could be made to allow the electron to pass between the plates and reach the screen.

I Increasing the initial speed of the electron could allow the electron to reach the screen.

II Increasing the potential difference across the plates could allow the electron to reach the screen.

III Reversing the polarity of the plates could allow the electron to reach the screen.

Which of these statements is/are correct?

A I only

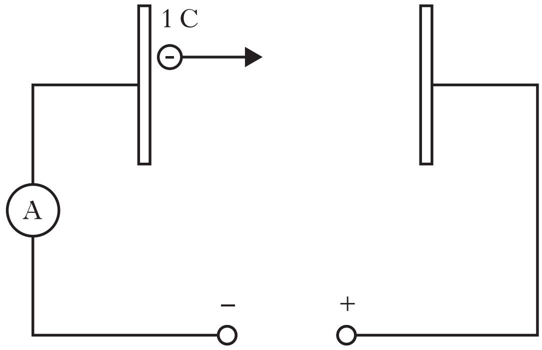
B II only

C III only

D I and II only

E I and III only

10. 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.

11. Radiation of frequency $9{\cdot}40 \times 10^{14}$ Hz is incident on a clean metal surface.

The work function of the metal is $3{\cdot}78 \times 10^{-19}$ J.

The maximum kinetic energy of an emitted photoelectron is

A $2{\cdot}45 \times 10^{-19}$ J

B $3{\cdot}78 \times 10^{-19}$ J

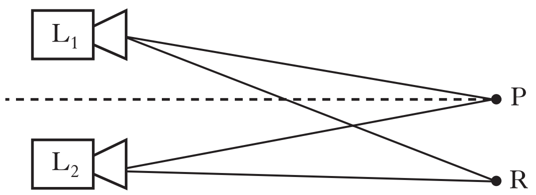
C $6{\cdot}23 \times 10^{-19}$ J

D $1{\cdot}00 \times 10^{-18}$ J

E $2{\cdot}49 \times 10^{33}$ J.

[Turn over

12. 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 $340\,\text{m}\,\text{s}^{-1}$.

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.

13. 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

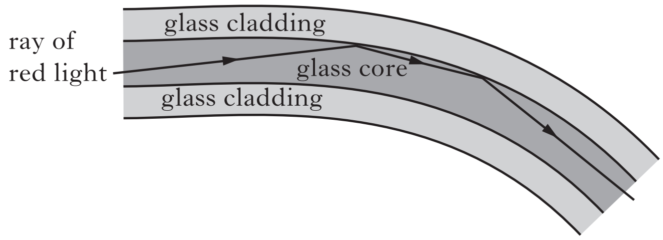
B (645 ± 4) nm

C (646 ± 1) nm

D (646 ± 4) nm

E (3228 ± 20) nm.

14. An optical fibre consists of a glass core surrounded by cladding made of different glass. A ray of red light travels through the optical fibre as shown.



The red light travels as shown because

A the speed of light in the core is greater than the speed of light in the cladding

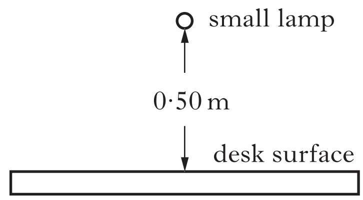
B the refractive index of the core is greater than the refractive index of the cladding

C the refractive index of the core is less than the refractive index of the cladding

D the frequency of light in the core is greater than the frequency of light in the cladding

E the frequency of light in the core is less than the frequency of light in the cladding.

15. 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

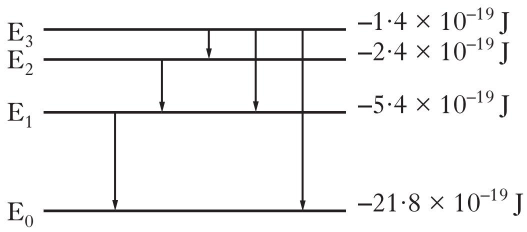
B 1·0 m

C 1·4 m

D 1·5 m

E 2·0 m.

16. 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

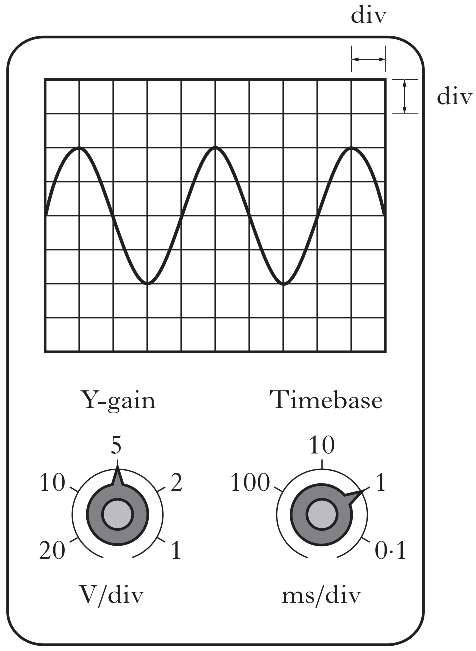
B E_2 to E_1

C E_3 to E_2

D E_3 to E_1

E E_3 to E_0.

17. 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 timebase setting and the vertical height of the trace

B timebase setting and the horizontal distance between the peaks of the trace

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

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

E Y-gain setting and the timebase setting.

[Turn over

18. 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.

19. A student makes the following statements about energy bands in different materials.

I In metals, which are good conductors, the highest occupied energy band is not completely full.

II In an insulator the highest occupied energy band is full.

III The gap between the valence band and conduction band is smaller in semiconductors than in insulators.

Which of these statements is/are correct?

A I only

B II only

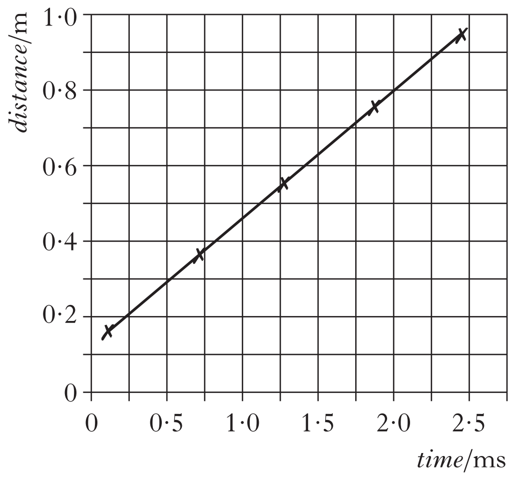
C I and II only

D I and III only

E I, II and III

20. A student makes measurements of the time taken for sound to travel various distances in air.

The measurements are used to produce the following graph.



The student makes the following statements.

I The graph proves that the distance travelled is directly proportional to the time taken.

II The graph indicates that there is a systematic uncertainty in the measurements.

III The speed of sound can be calculated from the gradient of the graph.

Which of these statements is/are correct?

A I only

B I and II only

C I and III only

D II and III only

E I, II and III

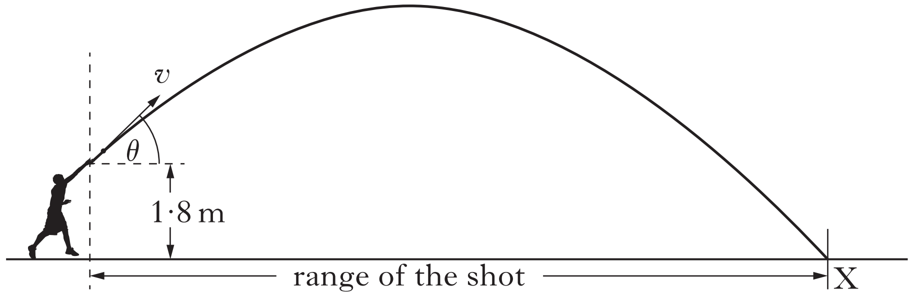
[Turn over for Section B on *Page twelve*

DO NOT WRITE ON THIS PAGE

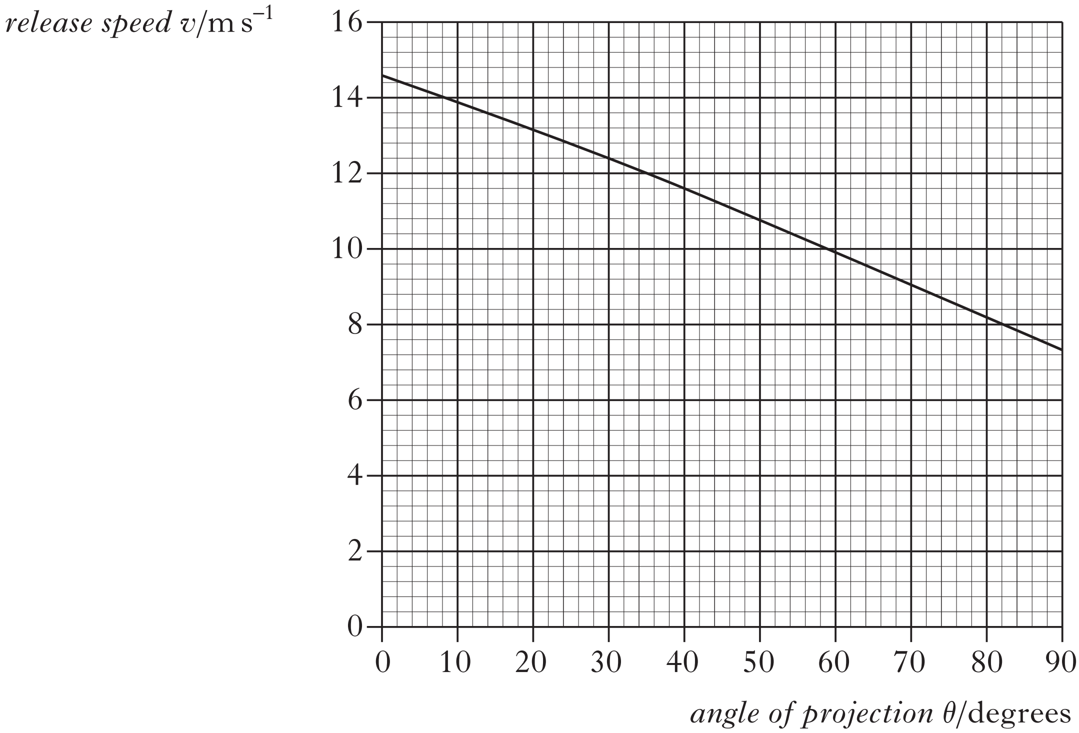
Write your answers to questions 21 to 32 in the answer book.

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**

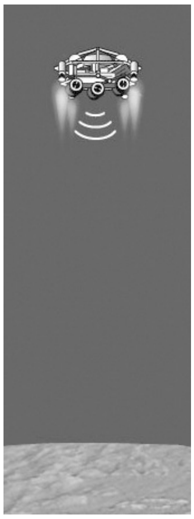
(B) Calculate the range of the shot for this throw. **2**

(*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*



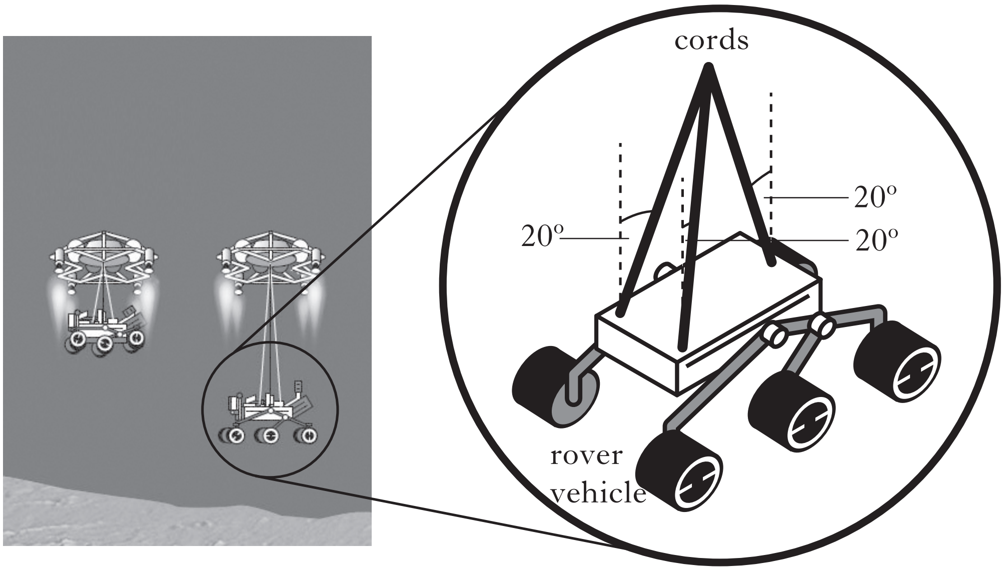
During the descent the average gravitational field strength for this moon is $1{\cdot}25\ \mathrm{N\,kg^{-1}}$.

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

This causes the speed of the spacecraft to be $0\ \mathrm{m\,s^{-1}}$ 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 $39\ \mathrm{m\,s^{-1}}$.

(*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 $39\ \mathrm{m\,s^{-1}}$.

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)

24. A physics student notices that the digital clock in the family car loses one minute every six months.

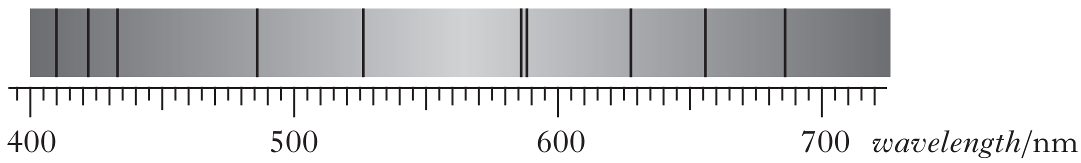
The student states "This must be due to time dilation as the car is driven at motorway speeds for much of the time."

Use your knowledge of physics to comment on the student's statement. **(3)**

Marks

25. Light from the Sun is used to produce a visible spectrum.

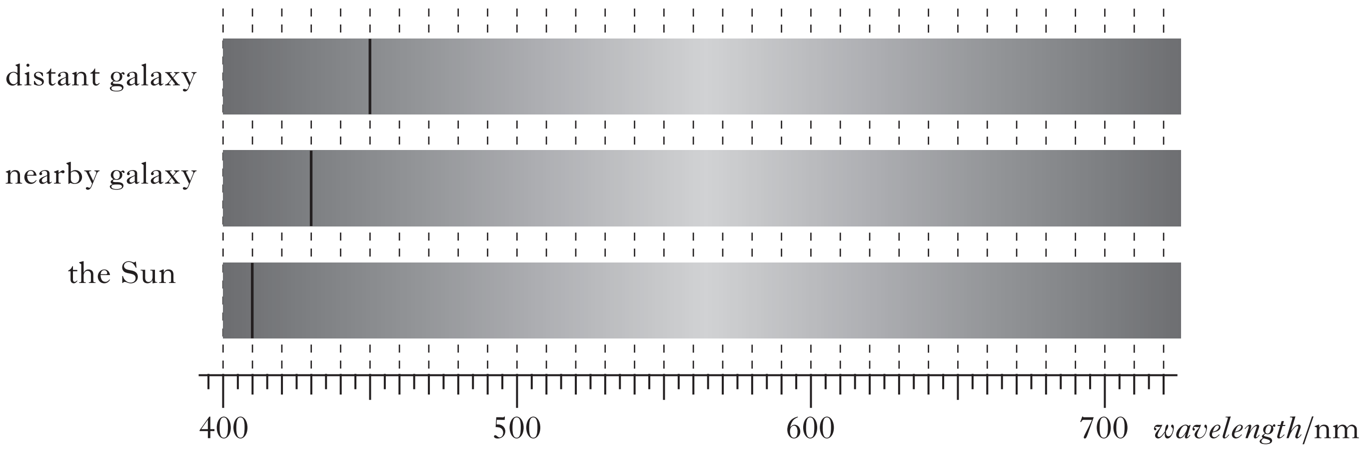
A student views this spectrum and observes a number of dark lines as shown.



(*a*) Explain how these dark lines in the spectrum of sunlight are produced. **1**

(*b*) One of the lines is due to hydrogen.

The position of this hydrogen line in the visible spectrum is shown for a distant galaxy, a nearby galaxy and the Sun.



(i) Explain why the position of the line is different in each of the spectra. **1**

(ii) Show that the redshift of the light from the distant galaxy is 0·098. **1**

(iii) Calculate the approximate distance to the distant galaxy. **3**

(*c*) Explain why the spectra in the diagram in part (*b*) support the theory of the expanding Universe. **1**

(7)

Marks

26. (*a*) The Standard Model classifies *force mediating particles* as bosons.

Name the boson associated with the electromagnetic force. **1**

(*b*) In July 2012 scientists at CERN announced that they had found a particle that behaved in the way that they expected the Higgs boson to behave. Within a year this particle was confirmed to be a Higgs boson.

This Higgs boson had a mass-energy equivalence of 126 GeV.
($1\ \text{eV} = 1{\cdot}6 \times 10^{-19}\ \text{J}$)

(i) Show that the mass of the Higgs boson is $2{\cdot}2 \times 10^{-25}$ kg. **2**

(ii) Compare the mass of the Higgs boson with the mass of a proton in terms of orders of magnitude. **1**

(4)

27. (*a*) The following statement represents a nuclear decay in which an alpha particle is emitted.

$$^{238}_{92}\text{U} \rightarrow {}^{234}_{90}\text{Th} + {}^{4}_{2}\alpha$$

The energy released in this decay is $6{\cdot}9 \times 10^{-13}$ J.

(i) Explain why energy is released in this decay. **1**

(ii) Explain why the kinetic energy of the alpha particle is less than $6{\cdot}9 \times 10^{-13}$ J. **1**

(*b*) Calcium-47 decays by releasing a beta particle, ${}^{0}_{-1}e$.

The following statement represents this decay.

$$^{47}_{20}\text{Ca} \rightarrow \text{X} + {}^{0}_{-1}e$$

(i) Identify the element represented by X. **1**

(ii) The total energy released in each calcium-47 decay is constant. However, this total energy is not accounted for by the products shown in the statement.

From this evidence, what conclusion have particle physicists drawn about what happens in beta decay?

Justify your answer. **2**

(5)

[Turn over

Marks

28. The use of analogies from everyday life can help better understanding of physics concepts. Throwing different balls at a coconut shy to dislodge a coconut is an analogy which can help understanding of the photoelectric effect.

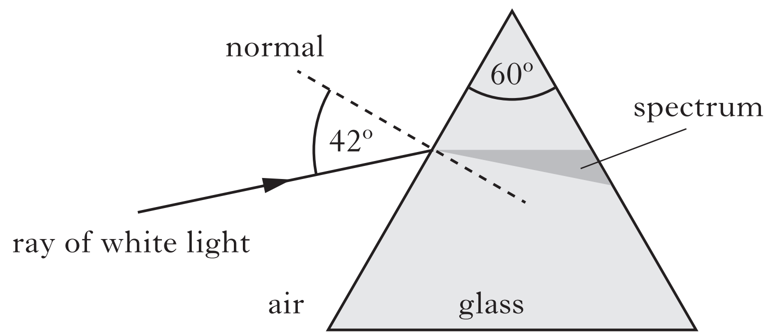
Use your knowledge of physics to comment on this analogy **(3)**

Marks

29. 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



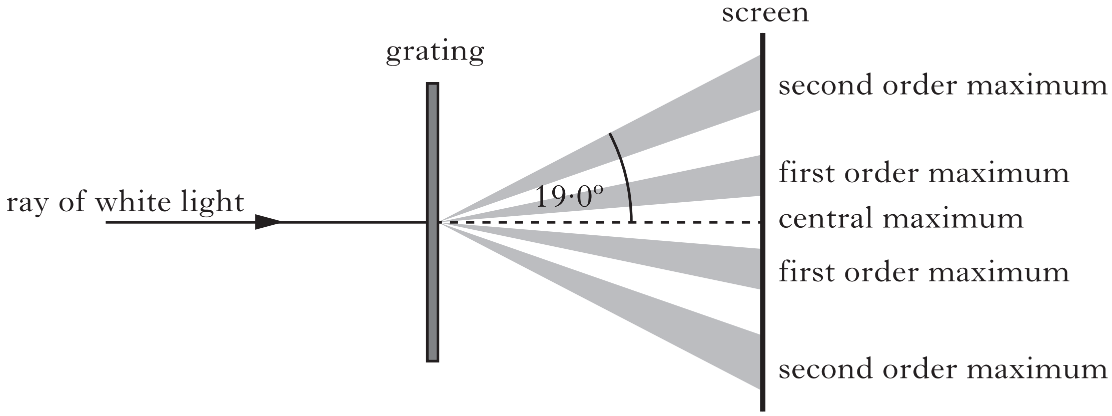
(i) Explain why a spectrum is produced in the glass prism. **1**

(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**

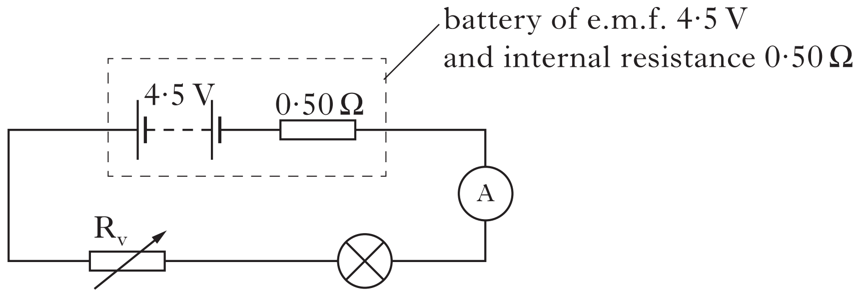
(ii) Explain why the angle to the second order maximum for blue light is different to that for red light. **2**

(8)

[Turn over

30. 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.

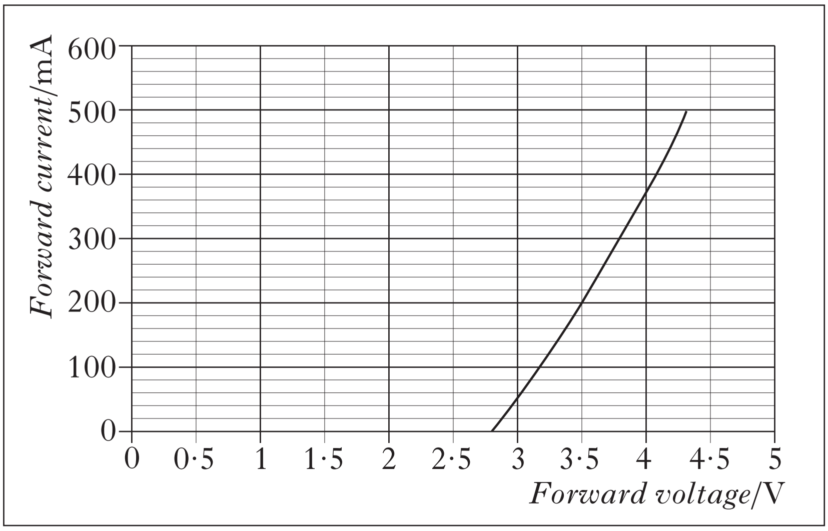
(i) Show that the resistance of the lamp is 12 Ω at this current. **2**

(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.

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.

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

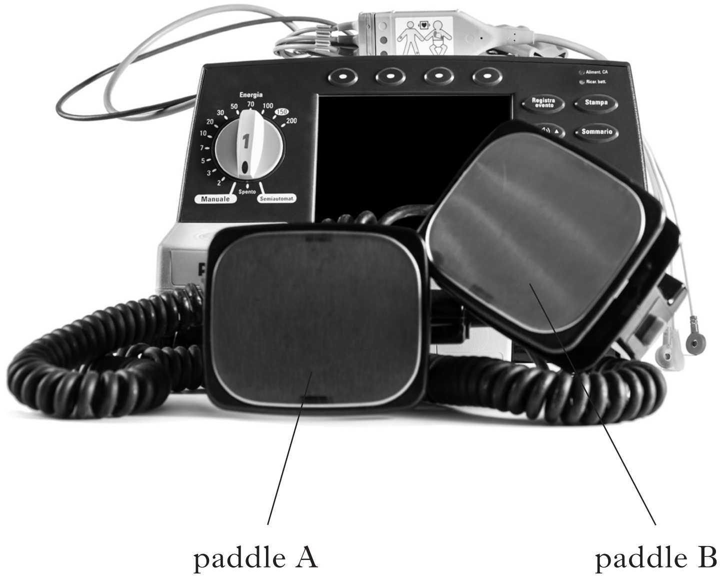
(ii) Calculate the potential difference across the variable resistor. **2**

(*c*) Describe how an LED operates. **2**

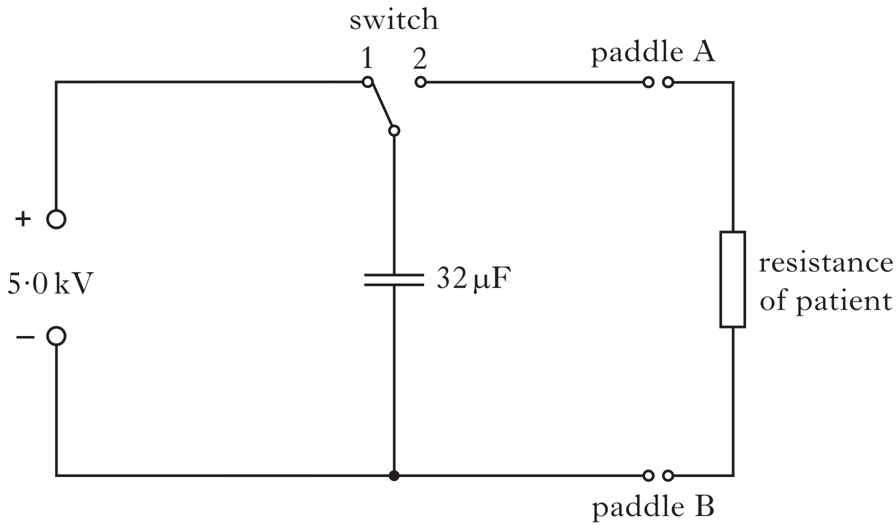
(9)

Marks

31. 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**

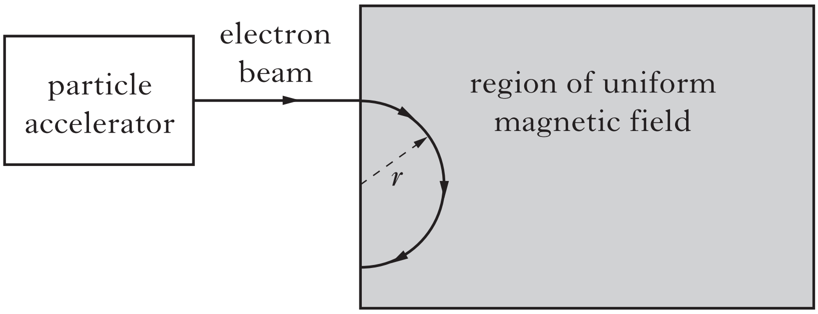
(5)

Marks

32. A particle accelerator is used to produce a beam of electrons. This accelerator can be adjusted to select the speed of the emitted electrons.

The beam of electrons then enters a region of uniform magnetic field.

The electrons follow a semicircular path in the magnetic field as shown.



(*a*) Determine the direction of the magnetic field. **1**

(*b*) The radius, r, of the semicircular path depends on the magnetic field strength B.

The unit of magnetic field strength is the tesla (T).

The speed of the electrons is set at a particular value.

A student then measures the radius of the semicircular path for several values of magnetic field strength. The student's results are shown in the table.

B/T	r/m	$\frac{1}{B}$ / T^{-1}
$2{\cdot}0 \times 10^{-3}$	$9{\cdot}9 \times 10^{-3}$	500
$4{\cdot}0 \times 10^{-3}$	$5{\cdot}0 \times 10^{-3}$	250
$5{\cdot}0 \times 10^{-3}$	$4{\cdot}1 \times 10^{-3}$	200
$8{\cdot}0 \times 10^{-3}$	$2{\cdot}5 \times 10^{-3}$	125
$10{\cdot}0 \times 10^{-3}$	$1{\cdot}9 \times 10^{-3}$	100

(i) Using square ruled paper, plot a graph of r against $\frac{1}{B}$. **2**

(ii) Calculate the gradient of your graph. **1**

(iii) The radius r of the semicircular path is given by the relationship

$$r = \frac{mv}{Q} \times \frac{1}{B}$$

where r is the radius of the semicircular path in metres
m is the mass of an electron in kilograms
v is the speed of the electron in metres per second
B is the magnetic field strength in tesla
Q is the charge on an electron in coulombs.

Use this relationship and the gradient of your graph to calculate the speed of the electrons in the magnetic field. **2**

Marks

32. (continued)

(*c*) Describe how the student could use this apparatus to investigate the relationship between the speed v of an electron and the radius r of its path in a magnetic field. **2**

(8)

[*END OF QUESTION PAPER*]

ACKNOWLEDGEMENTS

Question 22 – Image is taken from **www.en.ria.ru/images/17501/70/175017024.jpg**.

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Question 23 – **Rob Byron/shutterstock.com**

Question 28 – **daseaford/shutterstock.com**

Question 31 – **Dario Lo Presti/shutterstock.com**

$d = \bar{v}t$

$s = \bar{v}t$

$v = u + at$

$s = ut + \frac{1}{2}at^2$

$v^2 = u^2 + 2as$

$s = \frac{1}{2}(u + v)t$

$W = mg$

$F = ma$

$E_w = Fd$

$E_p = mgh$

$E_k = \frac{1}{2}mv^2$

$P = \frac{E}{t}$

$p = mv$

$Ft = mv - mu$

$F = G\frac{m_1 m_2}{r^2}$

$t' = \frac{t}{\sqrt{1 - \left(\frac{v}{c}\right)^2}}$

$l' = l\sqrt{1 - \left(\frac{v}{c}\right)^2}$

$f_o = f_s\left(\frac{v}{v \pm v_s}\right)$

$z = \frac{\lambda_{observed} - \lambda_{rest}}{\lambda_{rest}}$

$z = \frac{v}{c}$

$v = H_0 d$

$E_w = QV$

$E = mc^2$

$E = hf$

$E_k = hf - hf_0$

$E_2 - E_1 = hf$

$T = \frac{1}{f}$

$v = f\lambda$

$d\sin\theta = m\lambda$

$n = \frac{\sin\theta_1}{\sin\theta_2}$

$\frac{\sin\theta_1}{\sin\theta_2} = \frac{\lambda_1}{\lambda_2} = \frac{v_1}{v_2}$

$\sin\theta_c = \frac{1}{n}$

$I = \frac{k}{d^2}$

$I = \frac{P}{A}$

$V_{peak} = \sqrt{2}V_{rms}$

$I_{peak} = \sqrt{2}I_{rms}$

$Q = It$

$V = IR$

$P = IV = I^2R = \frac{V^2}{R}$

$R_T = R_1 + R_2 + \ldots$

$\frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{R_2} + \ldots$

$E = V + Ir$

$V_1 = \left(\frac{R_1}{R_1 + R_2}\right)V_s$

$\frac{V_1}{V_2} = \frac{R_1}{R_2}$

$C = \frac{Q}{V}$

$E = \frac{1}{2}QV = \frac{1}{2}CV^2 = \frac{1}{2}\frac{Q^2}{C}$

path difference $= m\lambda$ or $\left(m + \frac{1}{2}\right)\lambda$ where $m = 0, 1, 2 \ldots$

random uncertainty $= \dfrac{\text{max. value} - \text{min. value}}{\text{number of values}}$

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