X272/12/02

NATIONAL QUALIFICATIONS 2014

THURSDAY, 22 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**.

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	$3{\cdot}00 \times 10^{8}\ \text{m s}^{-1}$	Planck's constant	h	$6{\cdot}63 \times 10^{-34}\ \text{J s}$
Magnitude of the charge on an electron	e	$1{\cdot}60 \times 10^{-19}\ \text{C}$	Mass of electron	m_e	$9{\cdot}11 \times 10^{-31}\ \text{kg}$
Universal Constant of Gravitation	G	$6{\cdot}67 \times 10^{-11}\ \text{m}^3\ \text{kg}^{-1}\ \text{s}^{-2}$	Mass of neutron	m_n	$1{\cdot}675 \times 10^{-27}\ \text{kg}$
Gravitational acceleration on Earth	g	$9{\cdot}8\ \text{m s}^{-2}$	Mass of proton	m_p	$1{\cdot}673 \times 10^{-27}\ \text{kg}$
Hubble's constant	H_0	$2{\cdot}3 \times 10^{-18}\ \text{s}^{-1}$			

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*
Hydrogen	656	Red
	486	Blue-green
	434	Blue-violet
	410	Violet
	397	Ultraviolet
	389	Ultraviolet
Sodium	589	Yellow

Element	*Wavelength*/nm	*Colour*
Cadmium	644	Red
	509	Green
	480	Blue

Lasers

Element	*Wavelength*/nm	*Colour*
Carbon dioxide	9550 } 10590 }	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

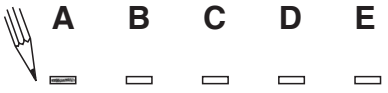
B ampere

C watt

D coulomb

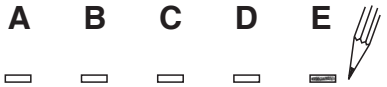
E volt.

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**.

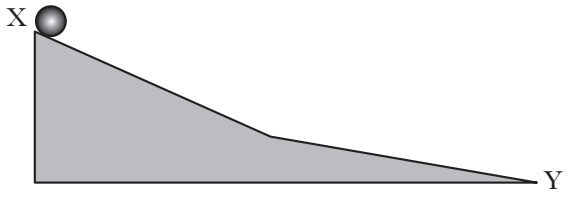


[Turn over

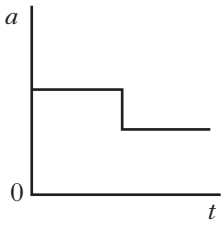
SECTION A

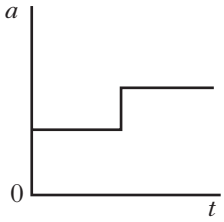
Answer questions 1–20 on the answer sheet.

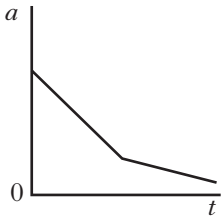
1. A ball moves down a frictionless slope from X to Y.

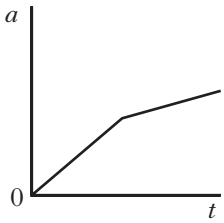


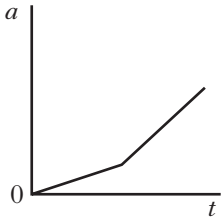
Which graph shows how the acceleration *a* of the ball varies with time *t* as it moves down the slope?

A


B


C


D


E


2. A boat is moving at a speed of 6·0 $m\,s^{-1}$. The boat now accelerates at 3·0 $m\,s^{-2}$ until it reaches a speed of 12 $m\,s^{-1}$.

The distance travelled by the boat during this acceleration is

A 6·0 m

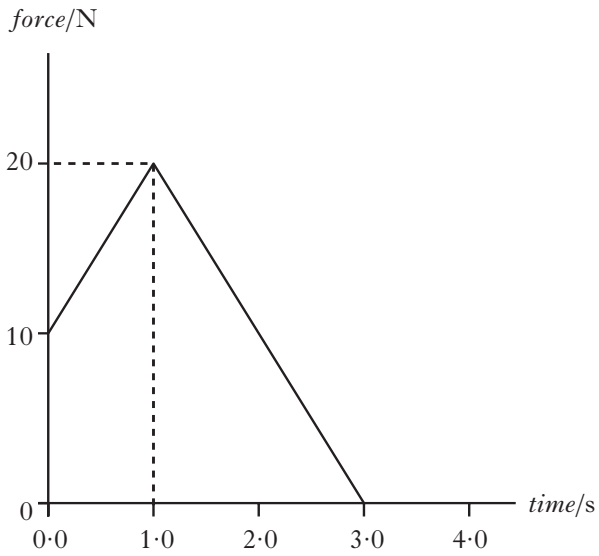
B 18 m

C 30 m

D 36 m

E 54 m.

3. The graph shows how the force acting on an object of mass 5·0 kg varies with time.



The change in momentum of the object is

A 7·0 $kg\,m\,s^{-1}$

B 30 $kg\,m\,s^{-1}$

C 35 $kg\,m\,s^{-1}$

D 60 $kg\,m\,s^{-1}$

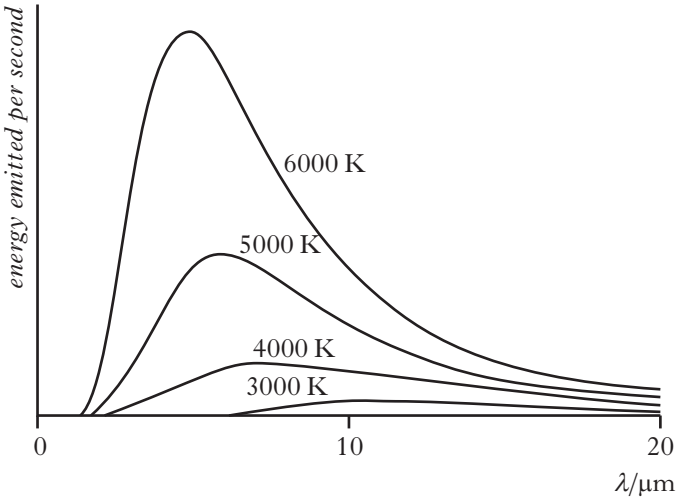
E 175 $kg\,m\,s^{-1}$.

4. A spaceship is moving with a constant speed of $0{\cdot}6c$ towards the Earth. The spaceship emits a beam of light towards the Earth. An astronaut in the spaceship and an observer on Earth both measure the speed of the emitted light.

Which row in the table shows the speed of the emitted light as measured by the astronaut and by the observer on Earth?

	Speed of emitted light as measured by astronaut	*Speed of emitted light as measured by observer on Earth*
A	$0{\cdot}4c$	$1{\cdot}6c$
B	c	c
C	c	$1{\cdot}6c$
D	$1{\cdot}6c$	$0{\cdot}4c$
E	$1{\cdot}6c$	c

5. The graph shows how the energy emitted per second from the surface of a hot object varies with the wavelength, λ, of the emitted radiation at different temperatures.



A student makes the following statements based on the information shown in the graph.

I As the temperature of the object increases, the total energy emitted per second decreases.

II As the temperature of the object increases, the peak wavelength of the emitted radiation decreases.

III The frequency of the emitted radiation steadily increases as the emitted energy per second decreases.

Which of the statements is/are correct?

A I only

B II only

C III only

D I and II only

E II and III only

[Turn over

6. The cooling of the Universe and cosmic microwave background radiation provide evidence for

A the photoelectric effect

B the Bohr model of the atom

C the theory of special relativity

D the Big Bang theory

E Newton's Universal Law of Gravitation.

7. Astronomers use the following relationship to determine the distance, d, to a star.

$$b = \frac{L}{4\pi d^2}$$

For a particular star the following data is recorded:

apparent brightness, $b = 4{\cdot}4 \times 10^{-10}$ W m^{-2}

luminosity, $L = 6{\cdot}1 \times 10^{30}$ W

Based on this information, the distance to this star is

A $3{\cdot}3 \times 10^{19}$ m

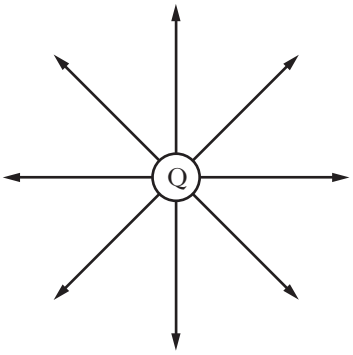
B $1{\cdot}5 \times 10^{21}$ m

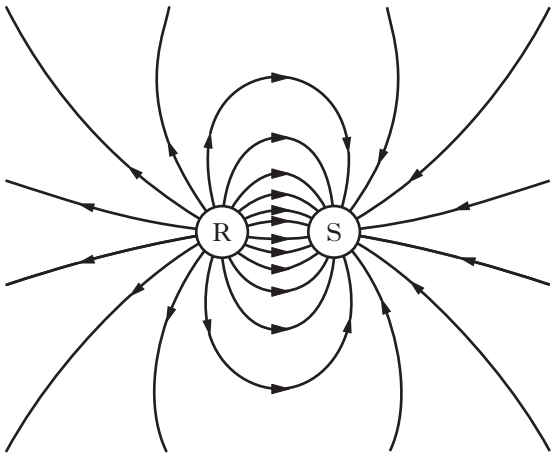
C $3{\cdot}7 \times 10^{36}$ m

D $1{\cdot}1 \times 10^{39}$ m

E $3{\cdot}9 \times 10^{39}$ m.

8. The electric field patterns around charged particles Q, R and S are shown.

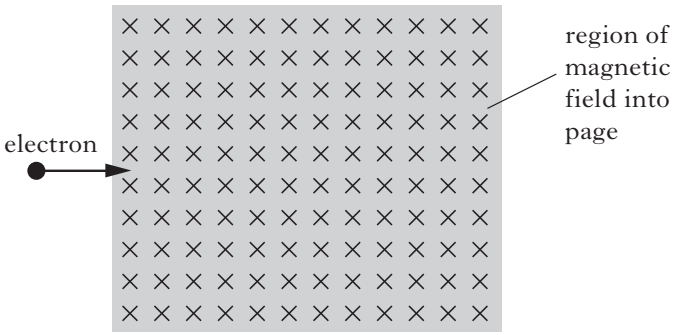




Which row in the table shows the charges on particles Q, R and S?

	Charge on Q	*Charge on R*	*Charge on S*
A	positive	positive	negative
B	negative	negative	positive
C	negative	positive	negative
D	negative	negative	negative
E	positive	positive	positive

9. An electron enters a region of magnetic field as shown.



The direction of the force exerted by the magnetic field on the electron as it enters the field is

A to the left

B into the page

C out of the page

D towards the top of the page

E towards the bottom of the page.

10. An isotope of uranium decays into an isotope of protactinium in two stages as shown.

$$^{238}_{92}\mathrm{U} \xrightarrow[\text{stage 1}]{} {}^{234}_{90}\mathrm{Th} \xrightarrow[\text{stage 2}]{} {}^{234}_{91}\mathrm{Pa}$$

Which row in the table identifies the radiations which must be emitted at each stage?

	stage 1	*stage 2*
A	alpha	gamma
B	beta	gamma
C	gamma	beta
D	beta	alpha
E	alpha	beta

11. The following statement represents a fission reaction.

$$^{235}_{92}\mathrm{U} + {}^{1}_{0}\mathrm{n} \rightarrow {}^{139}_{57}\mathrm{La} + {}^{95}_{42}\mathrm{Mo} + 2\,{}^{1}_{0}\mathrm{n} + 7\,{}^{0}_{-1}e$$

The total mass of the particles before the reaction is $391{\cdot}848 \times 10^{-27}$ kg.

The total mass of the particles after the reaction is $391{\cdot}478 \times 10^{-27}$ kg.

The energy released in this reaction is

A $3{\cdot}53 \times 10^{-8}$ J

B $3{\cdot}52 \times 10^{-8}$ J

C $3{\cdot}33 \times 10^{-11}$ J

D $1{\cdot}67 \times 10^{-11}$ J

E $1{\cdot}11 \times 10^{-19}$ J.

12. The spectrum of white light from a filament lamp may be viewed using a prism or a grating.

A student, asked to compare the spectra formed by the two methods, makes the following statements.

I The prism produces a spectrum by refraction and the grating produces a spectrum by interference.

II The spectrum formed by the prism consists of all the wavelengths present in the white light and the spectrum formed by the grating consists of only a few specific wavelengths.

III The prism produces a single spectrum and the grating produces more than one spectrum.

Which of the statements is/are correct?

A I only

B II only

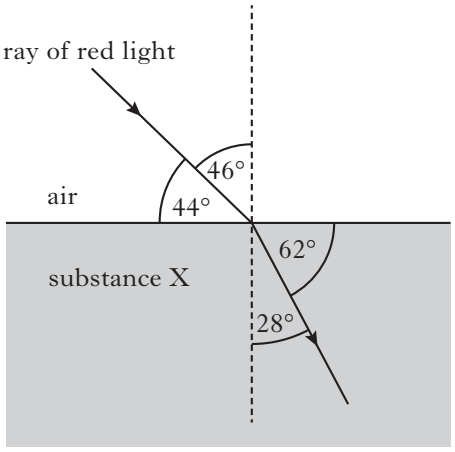
C I and II only

D I and III only

E I, II and III

[Turn over

13. The diagram shows the path of a ray of red light as it passes from air into substance X.



The critical angle for the light in substance X is

A 32°

B 41°

C 45°

D 52°

E 90°.

14. The irradiance of light from a point source is 160 units at a distance of 0·50 m from the source.

At a distance 2·0 m from this source, the irradiance is

A 160 units

B 80 units

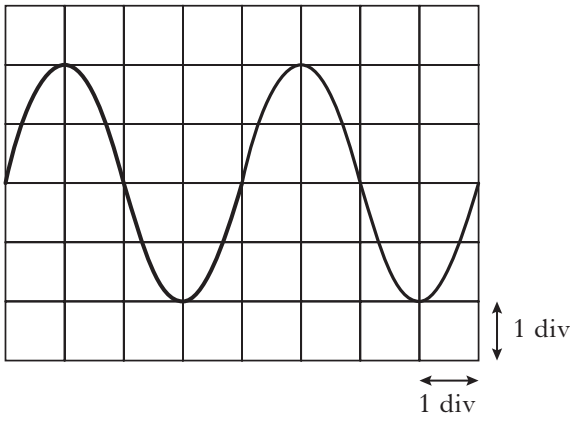
C 40 units

D 10 units

E 5 units.

15. An oscilloscope is connected to the output terminals of a signal generator.

The trace displayed on the screen is shown below.



The timebase of the oscilloscope is set at 30 ms/div.

The frequency of the output signal from the signal generator is

A $4{\cdot}2 \times 10^{-3}$ Hz

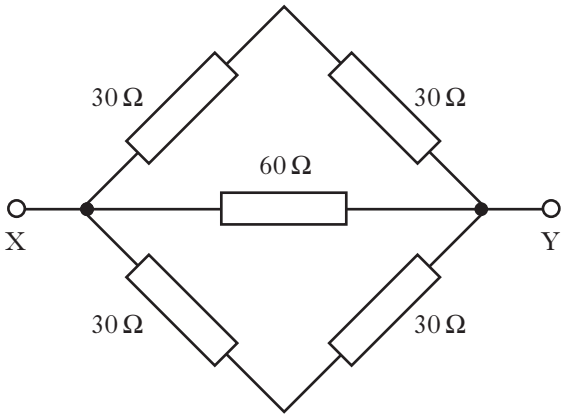
B $8{\cdot}3 \times 10^{-3}$ Hz

C 0·28 Hz

D 4·2 Hz

E 8·3 Hz.

16. Five resistors are connected as shown.



The resistance between X and Y is

A 12 Ω

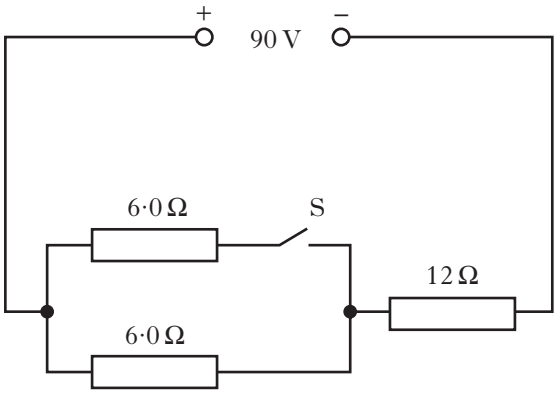
B 20 Ω

C 30 Ω

D 60 Ω

E 180 Ω.

17. A circuit is set up as shown.



The internal resistance of the supply is negligible.

Which row in the table shows the potential difference (p.d.) across the 12 Ω resistor when switch S is open and when S is closed?

	p.d. across 12 Ω resistor when S is open/V	*p.d. across 12 Ω resistor when S is closed*/V
A	30	18
B	45	45
C	60	45
D	60	72
E	72	60

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

Solids can be divided into 3 broad categories: conductors, insulators and semiconductors.

In ..... the conduction band is not completely full and this allows electrons to move easily.

In ..... the valence band is full.

In ..... electrons can move from the valence to the conduction band at room temperature.

Which row in the table shows the missing words?

	X	**Y**	**Z**
A	conductors	insulators	semiconductors
B	semiconductors	insulators	conductors
C	insulators	semiconductors	conductors
D	conductors	semiconductors	insulators
E	insulators	conductors	semiconductors

19. A student makes the following statements about p-n junction devices.

I In solar cells, a potential difference is produced when photons are incident on the junction.

II The photovoltaic effect occurs in solar cells.

III In LEDs, photons are emitted from the junction when a current is passed through it.

Which of these statements is/are correct?

A I only

B III only

C I and II only

D I and III only

E I, II and III

20. A ball is dropped several times from the same height.

A student records the following times for the ball to reach the ground.

1·15 s 1·13 s 1·09 s 1·13 s 1·05 s

Which row in the table shows the mean time for the ball to reach the ground and the approximate random uncertainty in this mean?

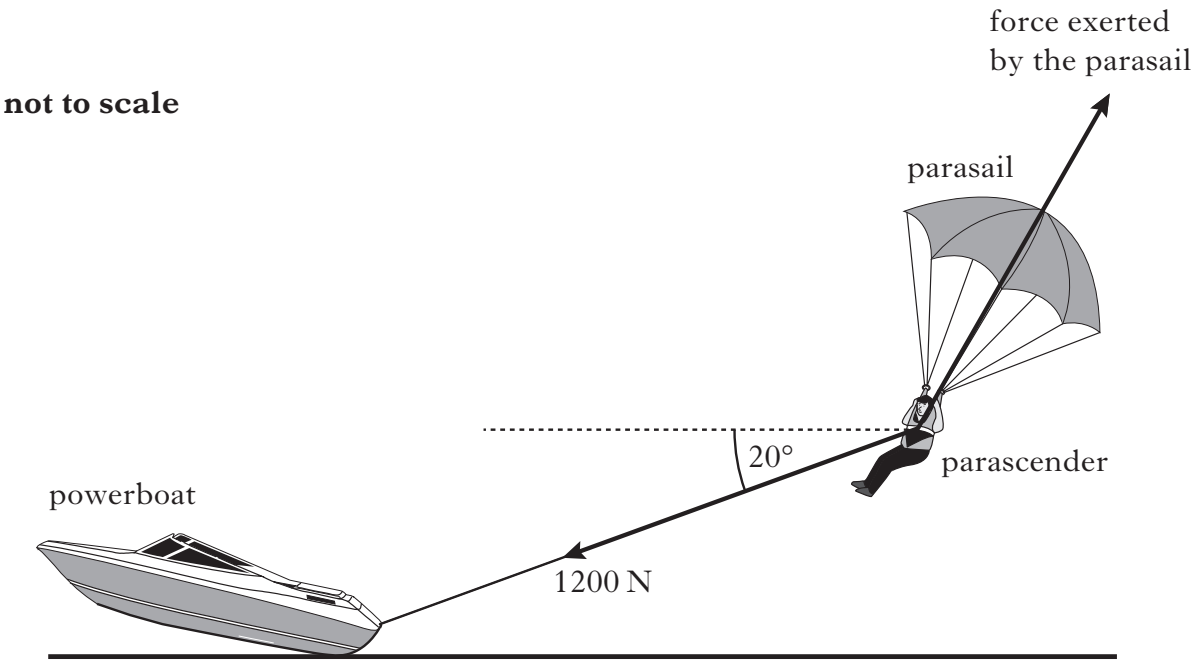
	Mean time/s	*Approximate random uncertainty*/s
A	1·11	0·02
B	1·11	0·10
C	1·13	0·02
D	1·13	0·10
E	4·71	0·94

SECTION B

Marks

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

21. A powerboat is used to pull a parascender at a constant speed and height.



The weight of the parascender is 900 N.

A rope exerts a force of 1200 N on the parascender at an angle of 20° to the horizontal.

Another force is exerted on the parascender by the parasail.

(*a*) The resultant force acting on the parascender is 0 N.

(i) State what is meant by the *resultant of a number of forces*. **1**

(ii) By scale drawing or otherwise, determine the magnitude and direction of the force exerted on the parascender by the parasail. **3**

(*b*) The parascender releases the rope and initially rises higher.

Explain, in terms of the forces acting, why the parascender rises. **2**

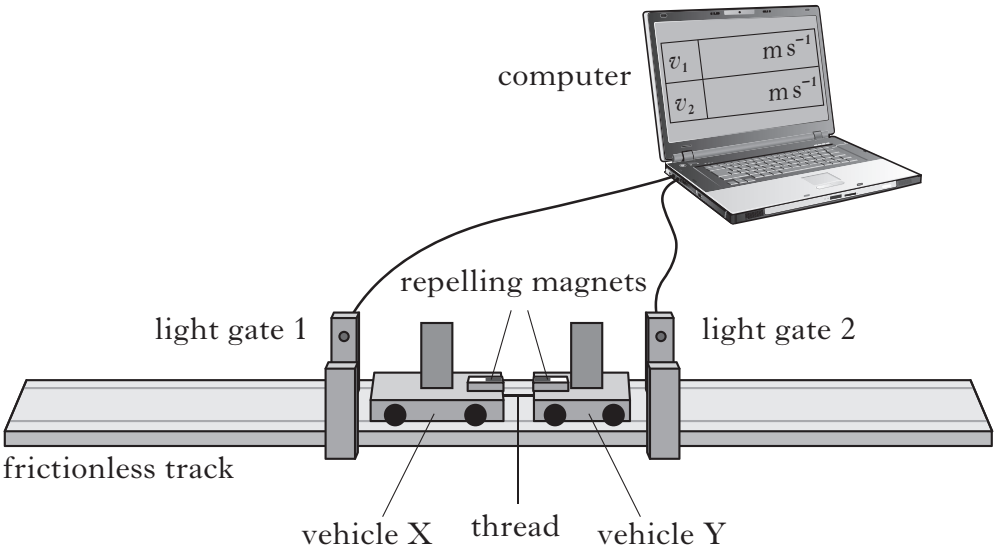
(6)

[Turn over for Question 22 on *Page twelve*

Marks

22. Interactions between objects can be analysed using the law of conservation of momentum.

(*a*) An experiment is set up to verify that momentum is conserved when two vehicles explode apart.



Initially both vehicles are stationary on the horizontal track and are held together by a thread.

The thread is cut and the force between the magnets pushes the vehicles apart.

The computer then displays the speed of each vehicle as it passes through a light gate.

The following data is recorded:

Mass of vehicle X = 0·70 kg
Mass of vehicle Y = 0·30 kg
Speed of vehicle X through light gate 1 = 0·51 m s^{-1}
Speed of vehicle Y through light gate 2 = 1·19 m s^{-1}

Use this data to show that momentum is conserved in this interaction. **2**

22. (continued)

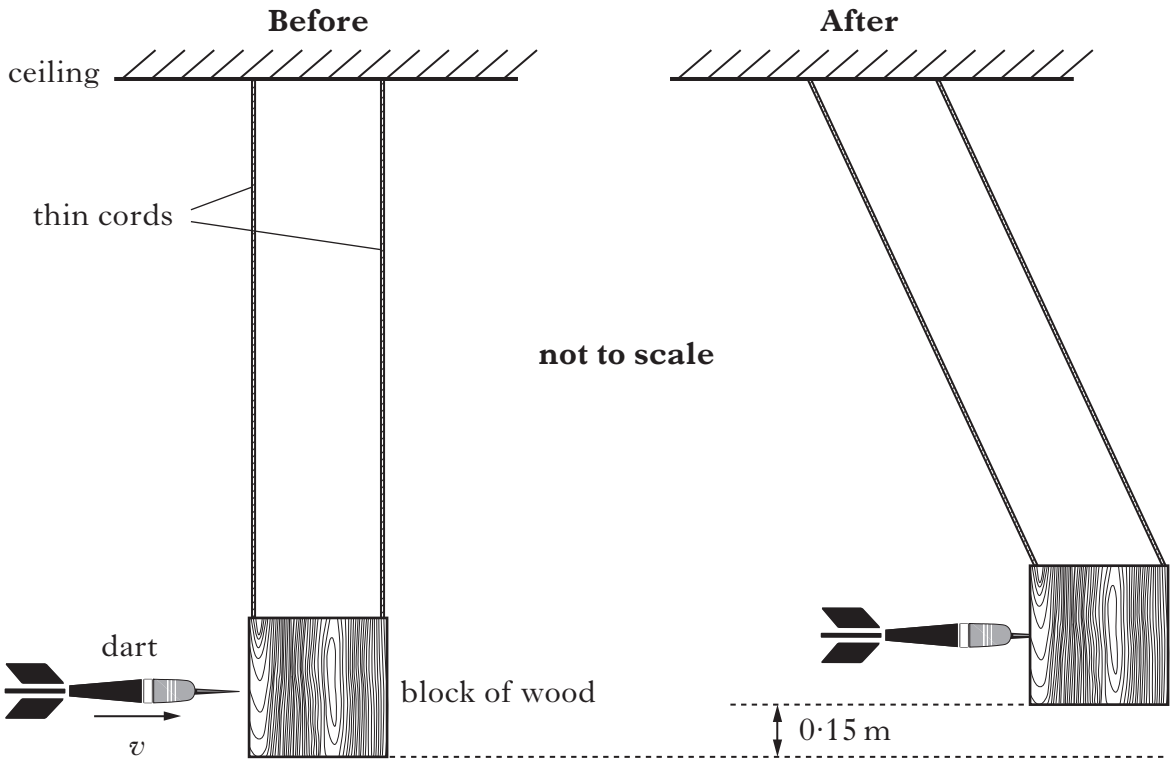
(*b*) In a second experiment, a block of wood of mass 0·20 kg is suspended from the ceiling by thin cords of negligible mass.

A dart of mass 0·050 kg is thrown at the stationary block of wood.

Just before the dart hits the block it is travelling horizontally at a velocity v.

The dart sticks into the block.

The dart and block then swing to a maximum height of 0·15 m as shown.



(i) Use conservation of energy to show that the velocity of the dart and block just after the collision is 1·7 m s^{-1}. **1**

(ii) Calculate the velocity v of the dart just before it hits the block. **2**

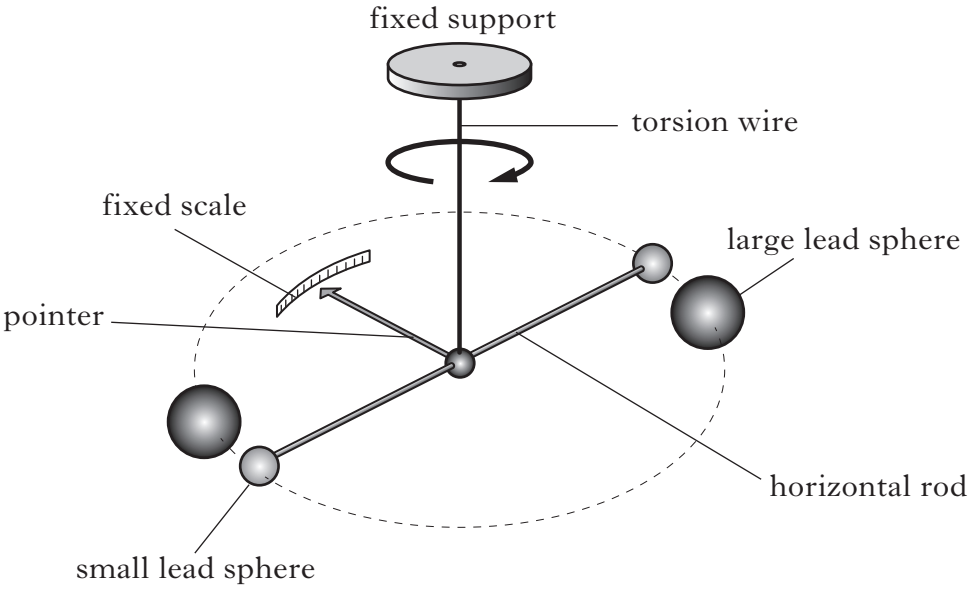
(5)

[Turn over

Marks

23. A student carries out an experiment to measure the Universal Constant of Gravitation.

The apparatus consists of a horizontal rod with small lead spheres at each end. The rod is suspended from its centre by a thin torsion wire. The student places a large lead sphere near each of the small spheres. The gravitational attraction between each pair of large and small spheres causes the torsion wire to twist. The angle of twist is indicated on a fixed scale by the position of a pointer attached to the rod.



The torsion wire twists by one degree when each small lead sphere experiences a force of $1{\cdot}56 \times 10^{-9}$ N.

(*a*) (i) The student measures the angle of twist to be 0·45°.

Show that the gravitational force between one pair of large and small spheres is $7{\cdot}0 \times 10^{-10}$ N. **1**

(ii) The small lead spheres each have a mass of 0·0148 kg.

The large lead spheres each have a mass of 1·52 kg.

The student measures the distance from the centre of mass of each of the large spheres to the centre of mass of its adjacent small sphere to be 46·5mm.

What value does the student determine for the Universal Constant of Gravitation from these results? **2**

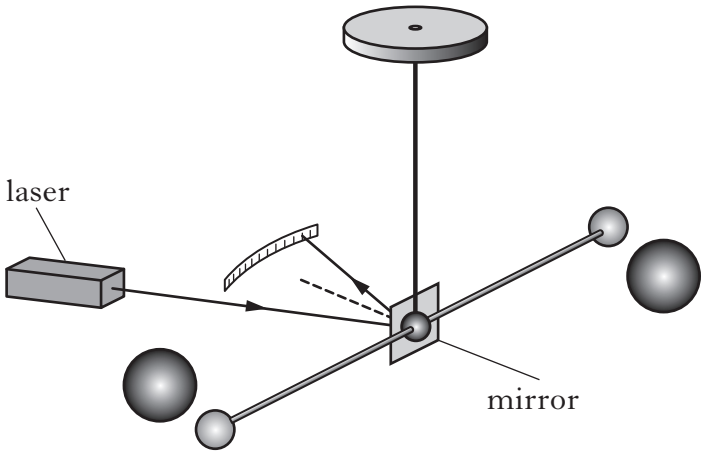
23. (continued)

(*b*) The manufacturer of the apparatus claims that this experiment can achieve an accuracy to within ±2·5% of the accepted value for the Universal Constant of Gravitation.

Does the student's value for the Universal Constant of Gravitation agree with this claim?

You must justify your answer by calculation. **2**

(*c*) The student now decides to replace the pointer on the horizontal rod with a small mirror. A laser beam is then directed at the mirror in such a way that the beam is reflected onto the scale as shown.



Explain how this modification improves the accuracy of the experiment. **2**

(7)

24. According to the lyrics of a popular comedy song:

The universe itself keeps on expanding and expanding in all of the directions it can whizz.

As fast as it can go, at the speed of light, you know, twelve million miles a minute, and that's the fastest speed there is.

Use your knowledge of physics to comment on these lyrics. **(3)**

[Turn over

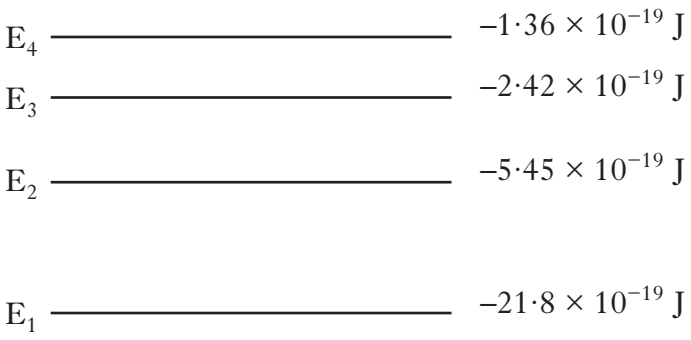
Marks

25. A binary star is a star system consisting of two stars orbiting around each other.

One of the techniques astronomers use to detect binary stars is to examine the spectrum of light emitted by the stars. In particular they look for the changes in wavelength of a specific spectral line, called the hydrogen alpha line, over a period of time.

Accurate measurements of the wavelength of the hydrogen alpha line on Earth have determined it to be 656·28 nm.

(*a*) The following diagram shows some of the energy levels for the hydrogen atom.



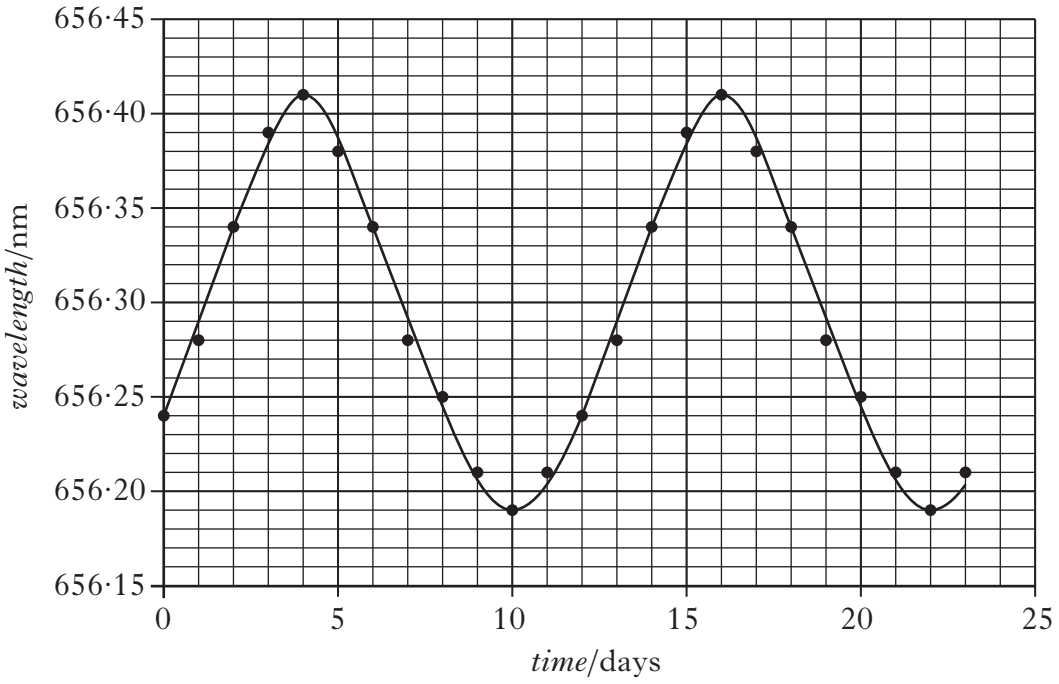
Radiation is emitted when electrons make transitions from higher to lower energy levels.

Which transition, between these energy levels, produces the hydrogen alpha line?

Justify your answer by calculation. **3**

25. (continued)

(*b*) The graph shows how the wavelength of the hydrogen alpha line for one of the stars in a binary pair varies with time, as observed on Earth.



Using information from the graph:

(i) determine the period of orbit of this star; **1**

(ii) calculate the maximum recessional velocity of the star; **3**

(iii) explain how the maximum approach velocity of the star compares to its maximum recessional velocity. **2**

(9)

[Turn over

Marks

26. Physicists study subatomic particles using particle accelerators.

(*a*) Pions are subatomic particles made up of two quarks.

There are three types of pion:

π^+ particles which have a charge of +1;
π^- particles which have a charge of –1;
and π^0 particles which have a zero charge.

The π^+ particle is made up of an up quark and an anti-down quark.

(i) Is a pion classed as a baryon or a meson?

Justify your answer. **1**

(ii) The charge on an up quark is $+\frac{2}{3}$.

Determine the charge on an anti-down quark. **1**

(iii) The π^- particle is the antiparticle of the π^+ particle.

State the names of the quarks that make up a π^- particle. **1**

(iv) π^+ particles have a mean lifetime of $2{\cdot}6 \times 10^{-8}$ s in their own frame of reference.

In an experiment in a particle accelerator, π^+ particles are accelerated to a velocity of $0{\cdot}9c$.

Calculate the mean lifetime of these π^+ particles relative to a stationary observer. **2**

(*b*) Explain how particle accelerators, such as the Large Hadron Collider at CERN, are able to:

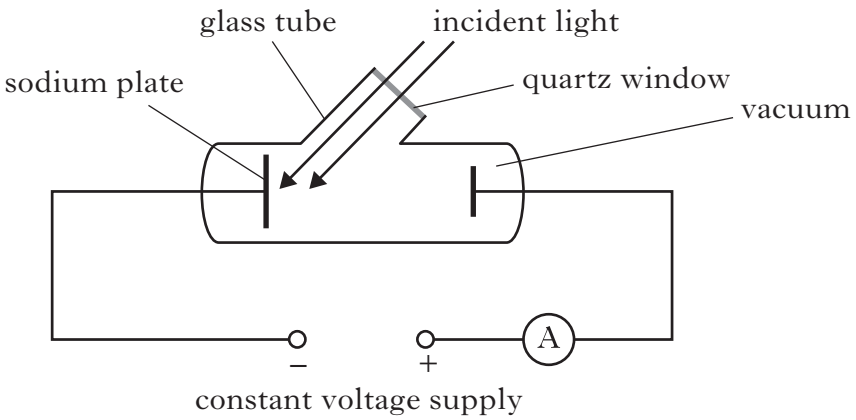
(i) accelerate charged particles; **1**

(ii) deflect charged particles. **1**

(7)

Marks

27. The following apparatus is set up in a physics laboratory to investigate the photoelectric effect.



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

Light of frequency $6{\cdot}74 \times 10^{14}$ Hz is incident on the sodium plate and photoelectrons are emitted.

(*a*) (i) Calculate the maximum kinetic energy of a photoelectron just as it is emitted from the sodium plate. **2**

(ii) Calculate the maximum velocity of a photoelectron just as it is emitted from the sodium plate. **2**

(*b*) The irradiance of this incident light is now decreased.

Explain how this affects the maximum velocity of a photoelectron just as it is emitted from the sodium plate. **2**

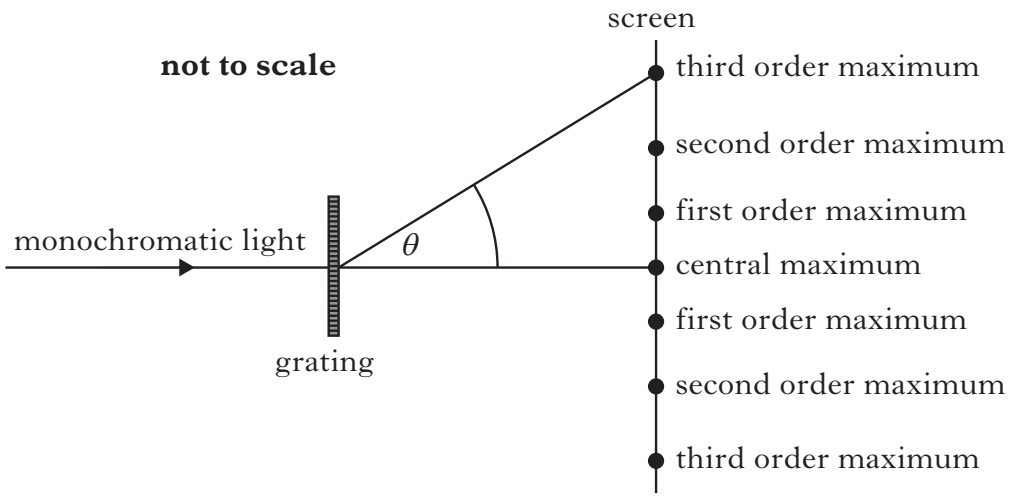
(6)

[Turn over

Marks

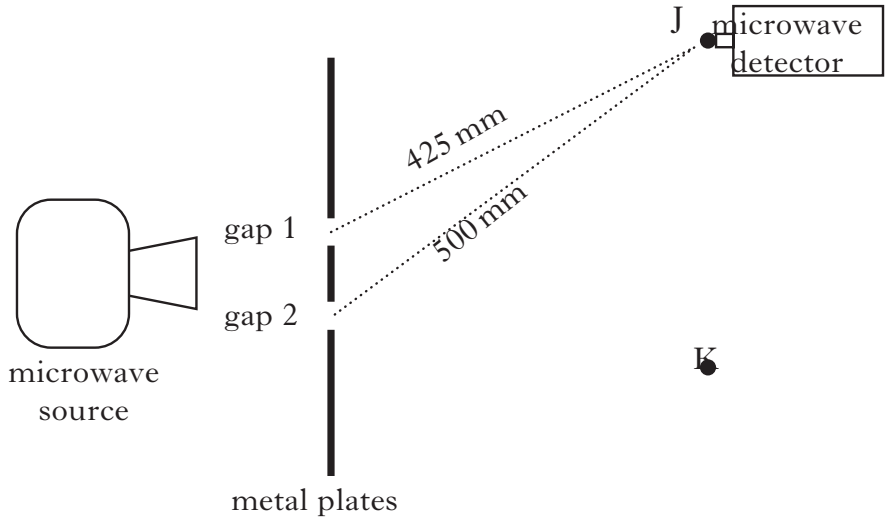
28. Two experiments are carried out to study the interference of waves.

(*a*) In the first experiment, monochromatic light of wavelength 589 nm passes through a grating. The distance between the slits on the grating is $5{\cdot}0 \times 10^{-6}$ m.



Calculate the angle θ between the central maximum and the third order maximum. **2**

(*b*) In the second experiment, microwaves of wavelength 30 mm pass through two gaps between metal plates as shown.



(i) The distances from each of the gaps to point J are shown in the diagram.

Use this information to determine whether J is a point of constructive or destructive interference.

You must justify your answer by calculation. **2**

(ii) The microwave detector is now moved to K, which is a point of destructive interference.

Gap 1 is then covered with a sheet of metal.

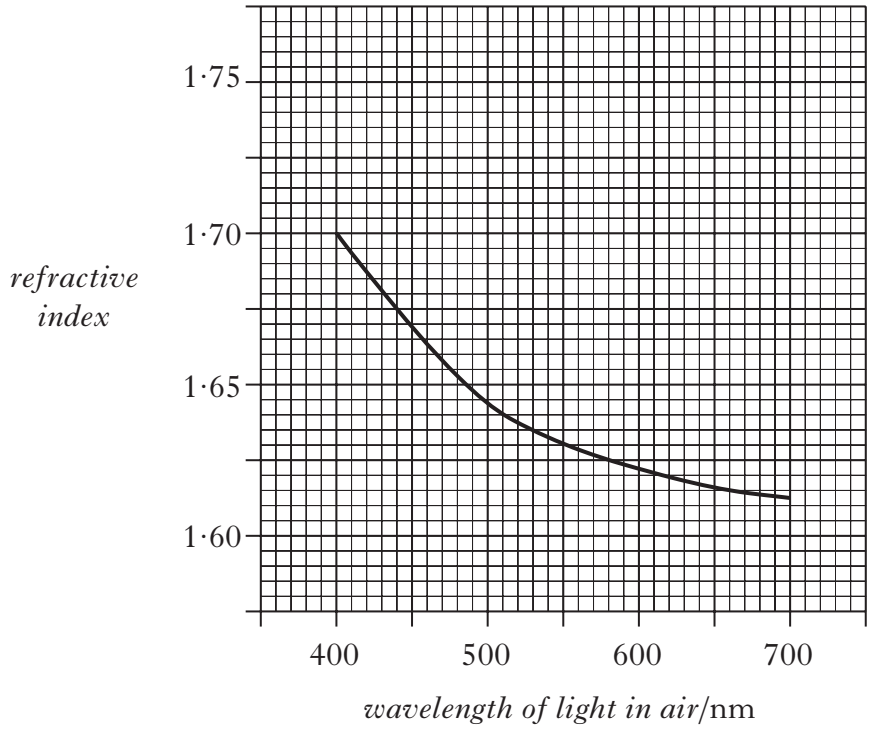
Does the strength of the signal detected at K increase, decrease or stay the same? You must justify your answer. **2**

(6)

Marks

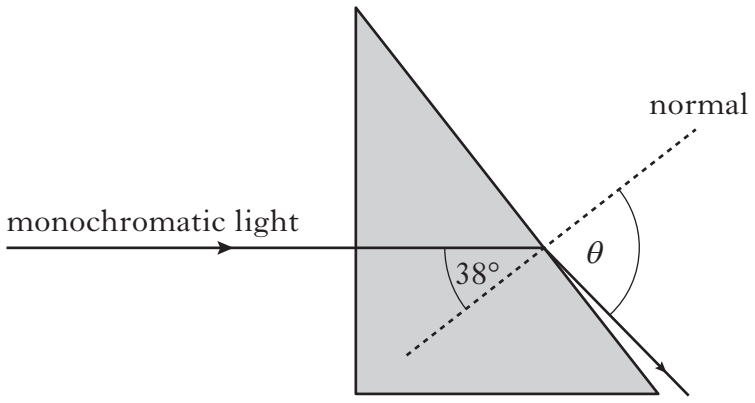
29. Monochromatic light is shone into a triangular prism of flint glass.

The graph shows how the refractive index of flint glass varies with the wavelength of light in air.



(*a*) A ray of monochromatic light of wavelength 660 nm in air passes through the prism as shown.

not to scale



Calculate the angle of refraction θ. **2**

(*b*) The ray of light is now replaced with one of shorter wavelength.

Is the speed of this new ray in the prism less than, the same as or greater than the speed of the 660 nm ray in the prism?

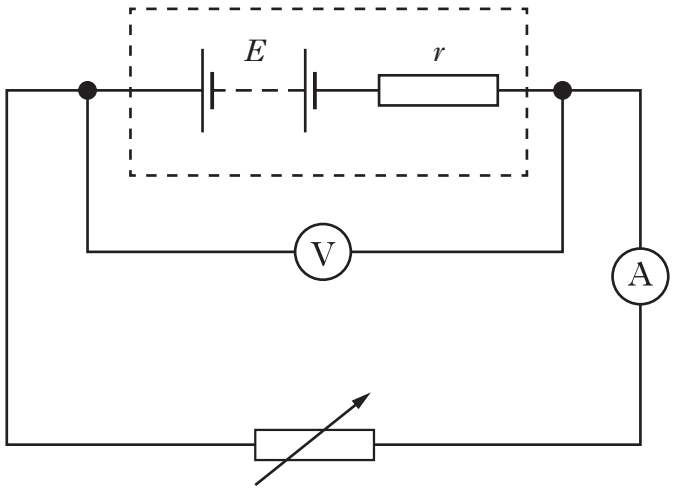
Justify your answer. **2**

(4)

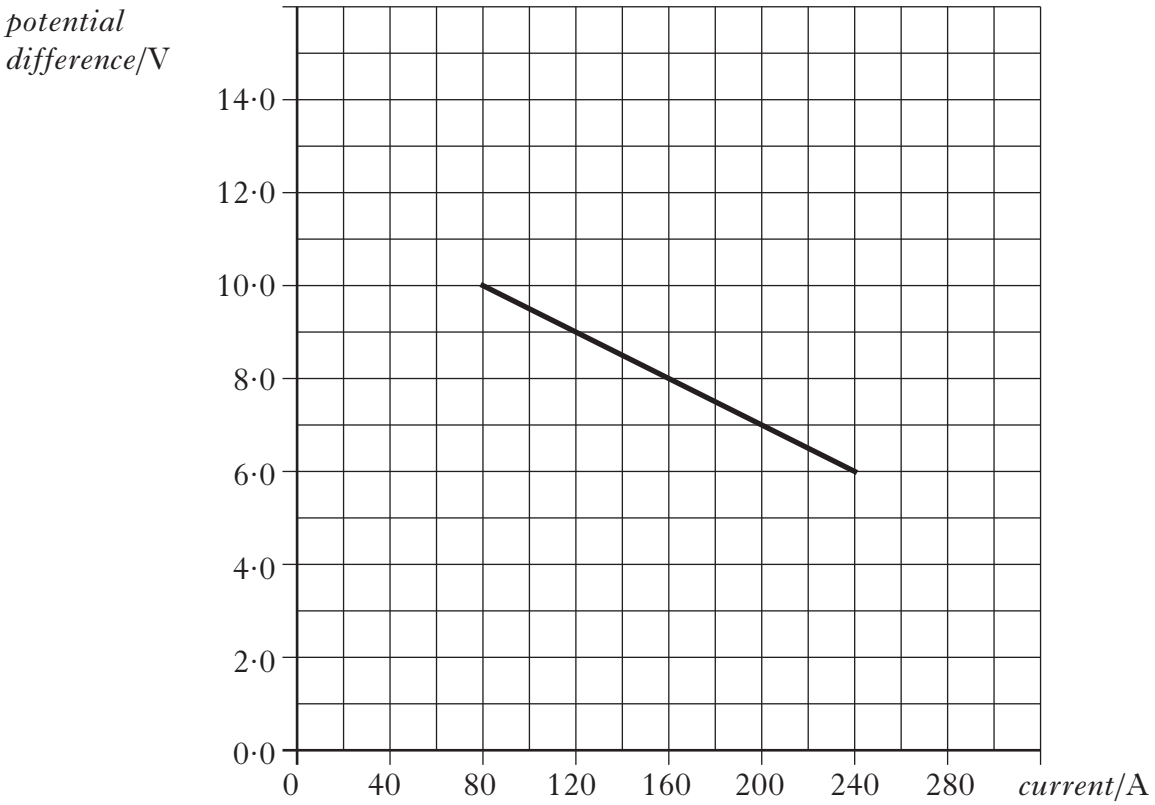
30. A technician is testing a new design of car battery. *Marks*

The battery has an e.m.f. E and internal resistance r.

(*a*) In one test, the technician uses this battery in the following circuit.



Readings from the voltmeter and ammeter are used to plot the following graph.



(i) Use information from the graph to determine the e.m.f. of the car battery. **1**

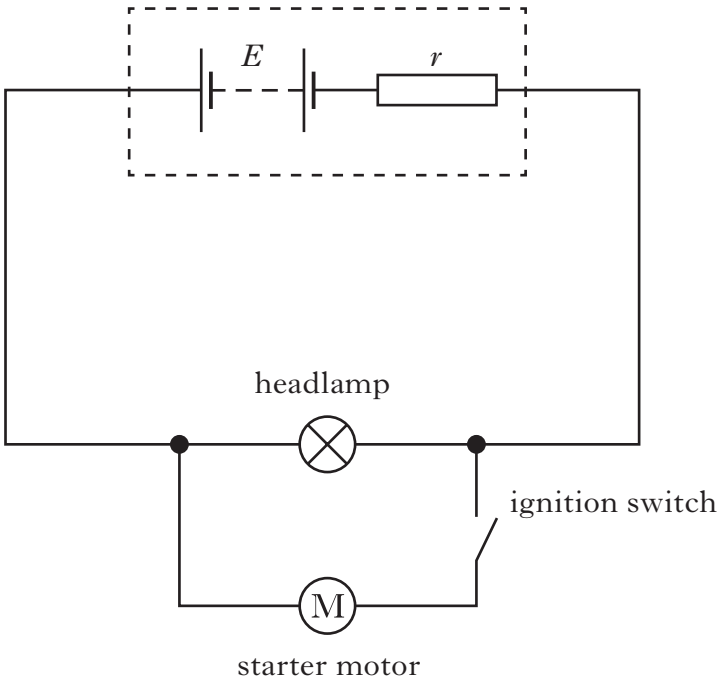
(ii) Calculate the internal resistance of the car battery. **2**

(iii) The technician accidently drops a metal spanner across the terminals of the battery. This causes a short circuit.

Calculate the short circuit current. **2**

30. (continued)

(*b*) In a second test, the technician connects the battery to a headlamp in parallel with a starter motor as shown.



The technician notices that the headlamp becomes dimmer when the ignition switch is closed and the starter motor operates.

Explain why this happens. **2**

(7)

31. Recent innovations in capacitor technology have led to the development of "ultracapacitors". Ultracapacitors of a similar size to standard AA rechargeable cells are now available with ratings of around 100 F with a maximum working voltage of 2·7 V.

By comparison, AA rechargeable cells operate at 1·5 V and can store up to 3400 mA h of charge.
(*charge* in mA h = *current* in mA × *time* in hours)

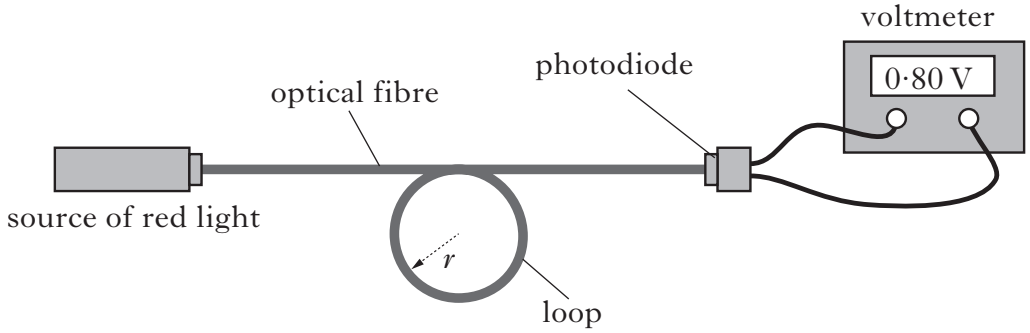
Use your knowledge of physics to compare the advantages and/or disadvantages of using ultracapacitors and rechargeable cells. **(3)**

[Turn over

Marks

32. A group of students carries out an experiment to investigate the transmission of light through an optical fibre.

Red light is transmitted through a loop of optical fibre and detected by a photodiode connected to a voltmeter as shown.



The photodiode produces a voltage proportional to the irradiance of light incident on it.

The students vary the radius, r, of the loop of optical fibre and measure the voltage produced by the photodiode.

The results are shown in the table.

Radius of loop/mm	*Voltage*/V
5	0·48
10	0·68
15	0·76
20	0·79
30	0·80
40	0·80

(*a*) Using the square ruled paper provided, draw a graph of these results. **2**

(*b*) For use in communication systems, the amount of light transmitted through a loop of optical fibre must be at least 75% of the value for the fibre with no loop.

With no loop in this fibre the reading on the voltmeter is 0·80 V.

Use your graph to estimate the minimum radius of loop when using this fibre in communication systems. **1**

(*c*) Using the same apparatus, the students now wish to determine more precisely the minimum radius of loop when using this fibre in communication systems.

Suggest **two** improvements to the experimental procedure that would achieve this. **2**

(*d*) Describe further experimental work that could be carried out to investigate another factor that may affect the transmission of light through an optical fibre. **2**

(7)

[*END OF QUESTION PAPER*]

[BLANK PAGE]

[BLANK PAGE]

[BLANK PAGE]

ACKNOWLEDGEMENTS

Question 24 – Two lines of lyrics from ‘Galaxy Song’ by Idle/Du Prez.

SQA has made every effort to trace the owners of copyright materials reproduced in this question paper, and seek permissions. We will be happy to incorporate any missing acknowledgements. Please contact Janine.Anderson@sqa.org.uk.

$d = \bar{v}t$

$s = \bar{v}t$

$v = u + at$

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

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

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

$W = mg$

$F = ma$

$E_w = Fd$

$E_p = mgh$

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

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

$p = mv$

$Ft = mv - mu$

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

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

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

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

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

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

$v = H_0 d$

$E_w = QV$

$E = mc^2$

$E = hf$

$E_k = hf - hf_0$

$E_2 - E_1 = hf$

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

$v = f\lambda$

$d\sin\theta = m\lambda$

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

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

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

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

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

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

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

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

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

$Q = It$

$V = IR$

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

$R_T = R_1 + R_2 + \ldots.$

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

$E = V + Ir$

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

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

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

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

[BLANK PAGE]