

X069/12/02

NATIONAL
QUALIFICATIONS
2014

THURSDAY, 22 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.**
- 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	$3.00 \times 10^8 \text{ m s}^{-1}$	Mass of electron	m_e	$9.11 \times 10^{-31} \text{ kg}$
Magnitude of the charge on an electron	e	$1.60 \times 10^{-19} \text{ C}$	Mass of neutron	m_n	$1.675 \times 10^{-27} \text{ kg}$
Gravitational acceleration on Earth	g	9.8 m s^{-2}	Mass of proton	m_p	$1.673 \times 10^{-27} \text{ kg}$
Planck's constant	h	$6.63 \times 10^{-34} \text{ J s}$			

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	Element	Wavelength/nm	Colour
Hydrogen	656	Red	Cadmium	644	Red
	486	Blue-green		509	Green
	434	Blue-violet		480	Blue
	410	Violet	<i>Lasers</i>		
	397	Ultraviolet	Element	9550	Infrared
	389	Ultraviolet		10590	
Sodium	589	Yellow		633	Red

PROPERTIES OF SELECTED MATERIALS

Substance	Density/kg m ⁻³	Melting Point/K	Boiling Point/K
Aluminium	2.70×10^3	933	2623
Copper	8.96×10^3	1357	2853
Ice	9.20×10^2	273
Sea Water	1.02×10^3	264	377
Water	1.00×10^3	273	373
Air	1.29
Hydrogen	9.0×10^{-2}	14	20

The gas densities refer to a temperature of 273 K and a pressure of $1.01 \times 10^5 \text{ Pa}$.

SECTION A

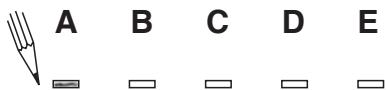
For questions 1 to 20 in this section of the paper the answer to each question is either A, B, C, D or E. Decide what your answer is, then, using your pencil, put a horizontal line in the space provided—see the example below.

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 two vector quantities and one scalar quantity?

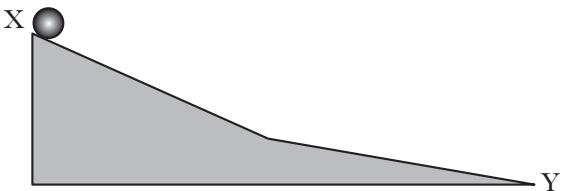
- A acceleration, mass and momentum
- B time, distance and force
- C velocity, force and momentum
- D displacement, velocity and acceleration
- E speed, distance and momentum

2. A boat is moving at a speed of 6.0 ms^{-1} . The boat now accelerates at 3.0 ms^{-2} until it reaches a speed of 12 ms^{-1} .

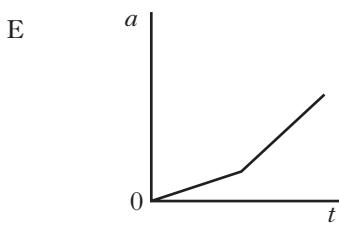
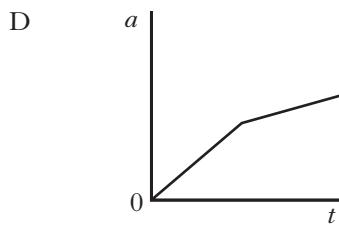
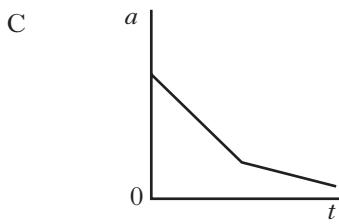
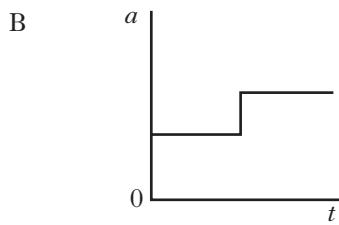
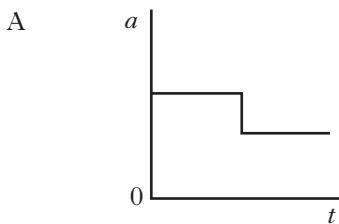
The distance travelled by the boat during this acceleration is

- A 6.0 m
- B 18 m
- C 30 m
- D 36 m
- E 54 m .

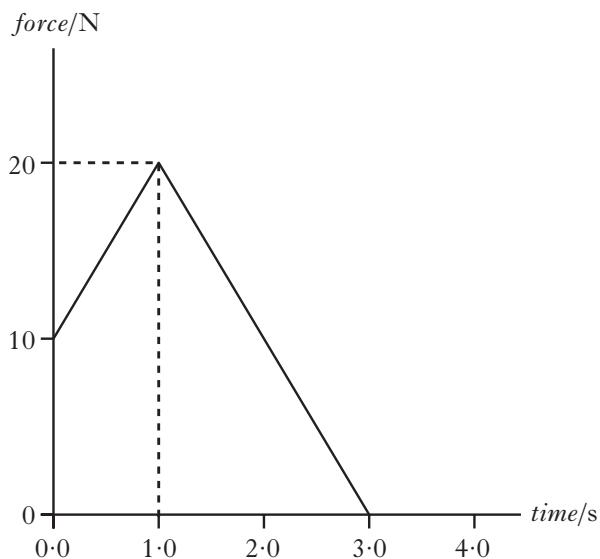
3. A ball moves down a frictionless slope from X to Y.



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



4. 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} .

5. The weight of a box is 30 N.

The dimensions of the box are

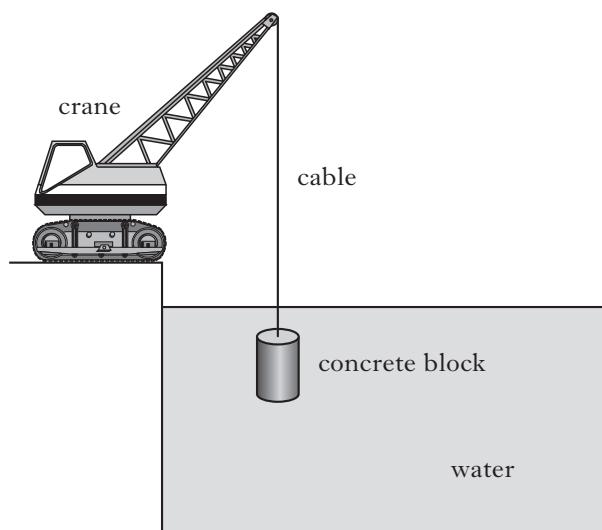
$$0.20 \text{ m} \times 0.15 \text{ m} \times 0.10 \text{ m}.$$

The box rests on one of its faces on a level surface.

The greatest pressure which the box can exert while resting on this surface is

A 204 Pa
 B 1000 Pa
 C 1500 Pa
 D 2000 Pa
 E 19600 Pa .

6. A concrete block is suspended in water by a cable from a crane as shown.



The block is now lowered at a constant speed.

Which row in the table describes the changes, if any, to:

the pressure acting on the top of the block;
 the buoyancy force on the block;
 and the tension in the cable,
 as the block is lowered in the water?

	<i>Pressure acting on top of block</i>	<i>Buoyancy force</i>	<i>Tension in cable</i>
A	increases	stays the same	stays the same
B	increases	increases	decreases
C	decreases	decreases	increases
D	decreases	stays the same	stays the same
E	stays the same	increases	stays the same

[Turn over]

7. A sealed canister contains gas at a pressure of $2.07 \times 10^5 \text{ Pa}$.

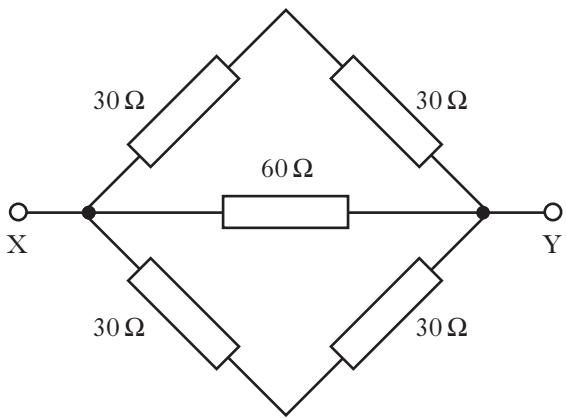
The temperature of the gas is 10°C .

The maximum safe pressure of the gas in the canister is $2.38 \times 10^5 \text{ Pa}$.

The temperature of the gas at the maximum safe pressure is

- A 11°C
- B 49°C
- C 52°C
- D 283°C
- E 325°C .

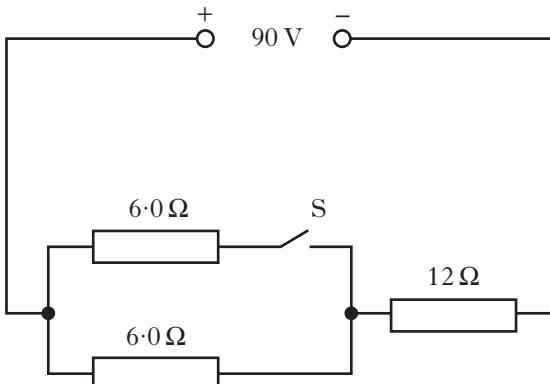
8. Five resistors are connected as shown.



The resistance between X and Y is

- A 12Ω
- B 20Ω
- C 30Ω
- D 60Ω
- E 180Ω .

9. A circuit is set up as shown.



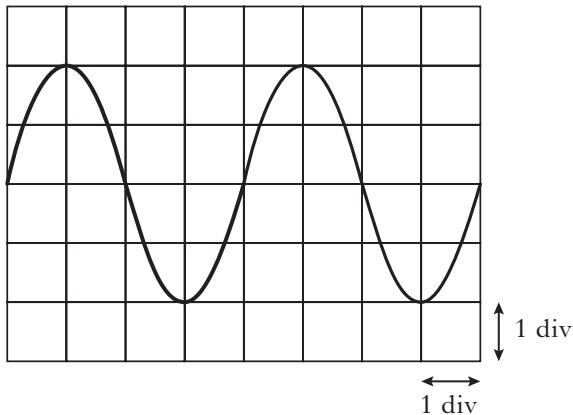
The internal resistance of the supply is negligible.

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

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

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

The trace displayed on the screen is shown.



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

The frequency of the output signal from the signal generator is

- A 4.2×10^{-3} Hz
- B 8.3×10^{-3} Hz
- C 0.28 Hz
- D 4.2 Hz
- E 8.3 Hz.

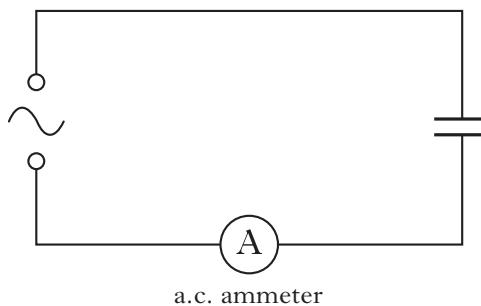
11. A capacitor has a capacitance of $20\mu\text{F}$.

The energy stored in the capacitor is 4.0 mJ.

The potential difference across the capacitor is

- A 5.0 V
- B 20 V
- C 80 V
- D 200 V
- E 400 V.

12. A capacitor is connected in a circuit as shown.



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

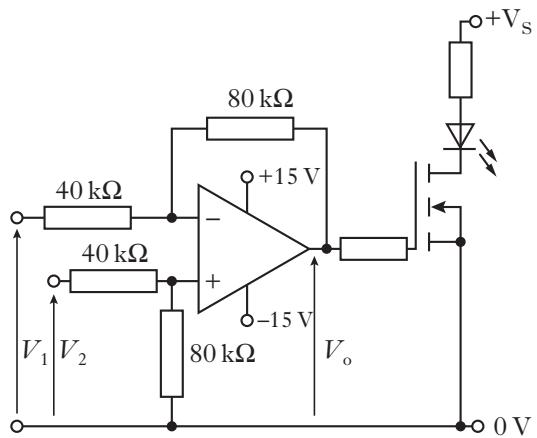
The frequency is steadily increased from 50 Hz to 5000 Hz.

The reading on the a.c. ammeter

- A remains constant
- B decreases steadily
- C increases steadily
- D increases then decreases
- E decreases then increases.

[Turn over]

13. An op-amp circuit is set up as shown.



The input voltage V_1 is 1.0 V.

The input voltage V_2 is 0.5 V.

The LED is not lit.

When V_o is greater than or equal to 2.0 V, the LED lights.

A student makes the following statements.

- I Keeping V_2 at 0.5 V and increasing V_1 to 2.5 V will cause the LED to light.
- II Keeping V_1 at 1.0 V and increasing V_2 to 2.5 V will cause the LED to light.
- III Keeping V_1 at 1.0 V, V_2 at 0.5 V and replacing both $80\text{ k}\Omega$ resistors with $400\text{ k}\Omega$ resistors will cause the LED to light.

Which of these statements is/are correct?

- A I only
- B II only
- C III only
- D I and III only
- E I, II and III

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

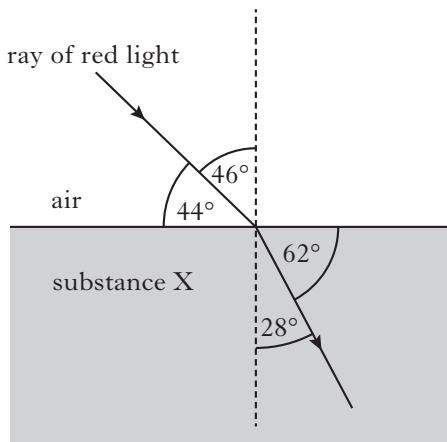
A student, asked to compare the spectra formed by the two methods, makes the following statements.

- 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

15. 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°

16. 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.

17. A student makes the following statements about the function of the mirrors in a laser.

I The mirrors reflect electrons backwards and forwards inside the laser tube.
II The mirrors reflect photons backwards and forwards inside the laser tube.
III The mirrors help to increase the irradiance of the laser beam.

Which of the statements is/are correct?

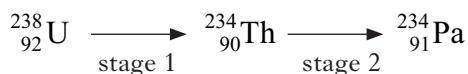
A I only
B II only
C III only
D I and III only
E II and III only

18. A sample of pure semiconductor can be doped to form an n-type semiconductor.

Which row in the table describes the majority charge carriers in the n-type semiconductor and how the resistance of the n-type semiconductor compares with that of the pure semiconductor?

	<i>Majority charge carriers</i>	<i>Resistance of n-type semiconductor compared to resistance of pure semiconductor</i>
A	negative	greater
B	positive	greater
C	negative	less
D	positive	less
E	negative	unchanged

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



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

	<i>stage 1</i>	<i>stage 2</i>
A	alpha	gamma
B	beta	gamma
C	gamma	beta
D	beta	alpha
E	alpha	beta

20. A sample of tissue receives an absorbed dose of 0.70 mGy from a source of alpha radiation.

The mass of the tissue is 120 g.

The radiation weighting factor for alpha radiation is 20.

The equivalent dose received by the tissue is

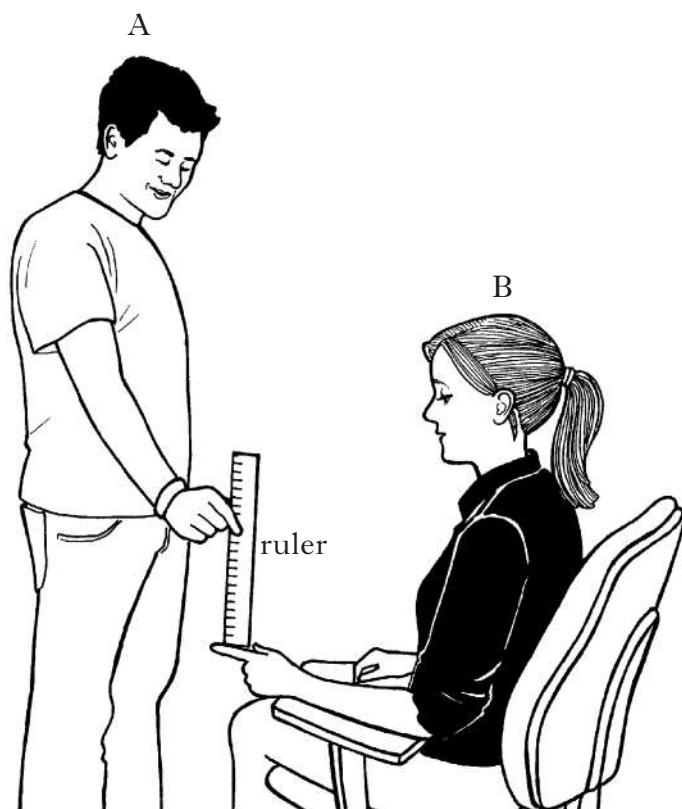
A 2400 mSv
B 1680 mSv
C 14 mSv
D 4.2 mSv
E 0.12 mSv.

[Turn over

SECTION B*Marks*

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

21. Two students are investigating reaction time. Student A holds a ruler vertically between the fingers of student B as shown.



Student A then releases the ruler from rest and student B catches it as quickly as she can. The distance that the ruler falls before being caught is measured. The experiment is repeated a number of times and the following distances recorded.

0.164 m 0.190 m 0.188 m 0.155 m 0.163 m

(a) Calculate:

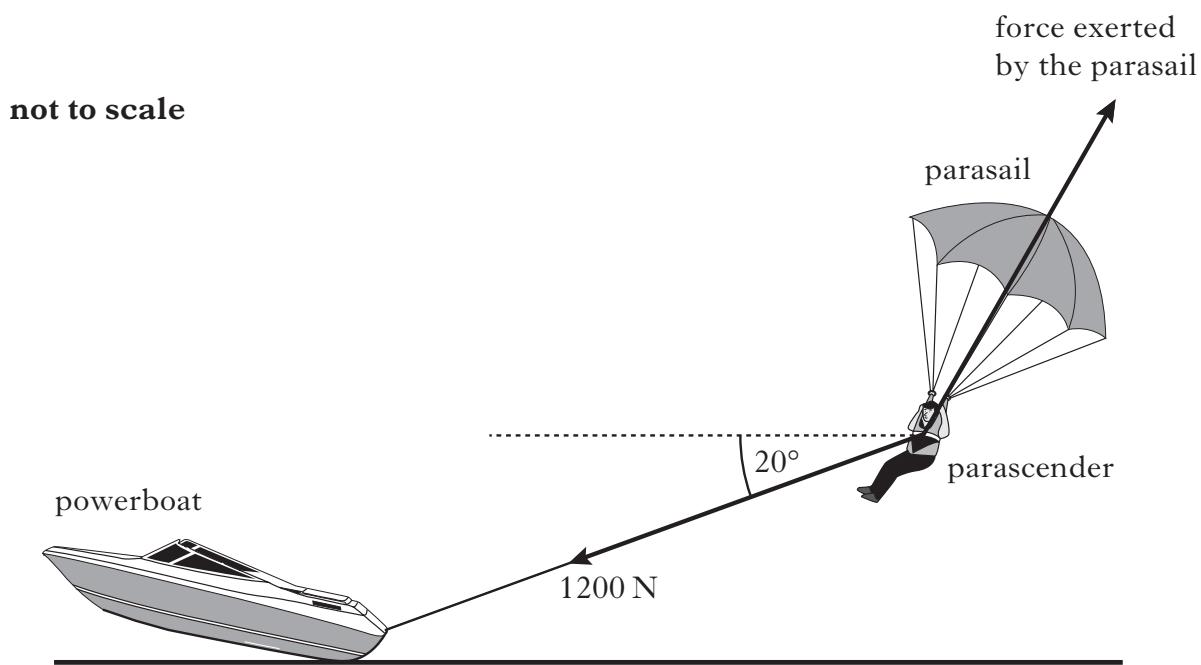
(i) the mean value of the distance fallen; 1

(ii) the approximate random uncertainty in this value. 1

(b) Use the mean value of the distance fallen to calculate the reaction time of student B. The uncertainty in the reaction time is not required. 2

(4)

22. 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.

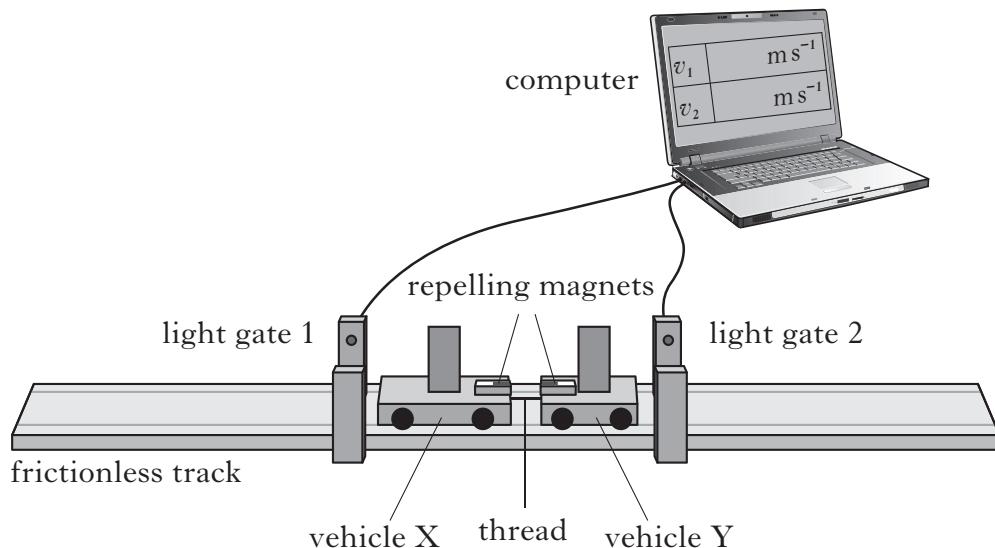
Explain, in terms of the forces acting, why the parascender rises. 2

(6)

[Turn over

23. 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:

$$\text{Mass of vehicle X} = 0.70 \text{ kg}$$

$$\text{Mass of vehicle Y} = 0.30 \text{ kg}$$

$$\text{Speed of vehicle X through light gate 1} = 0.51 \text{ m s}^{-1}$$

$$\text{Speed of vehicle Y through light gate 2} = 1.19 \text{ m s}^{-1}$$

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

2

23. (continued)

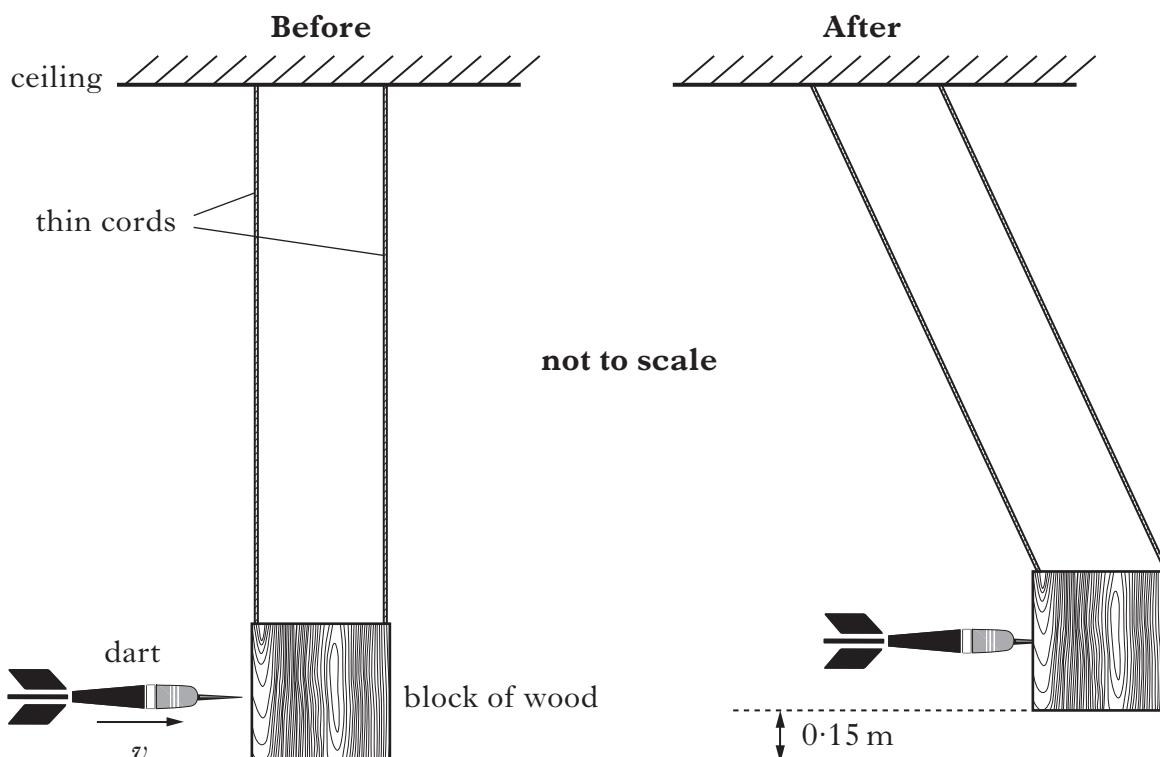
(b) In a second experiment, a block of wood of mass 0.20 kg is suspended from the ceiling by thin cords of negligible mass.

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

(iii) The experiment is repeated.

Just before it hits the block, the dart is travelling with the same velocity as in (b)(ii).

This time the dart bounces backwards off the block.

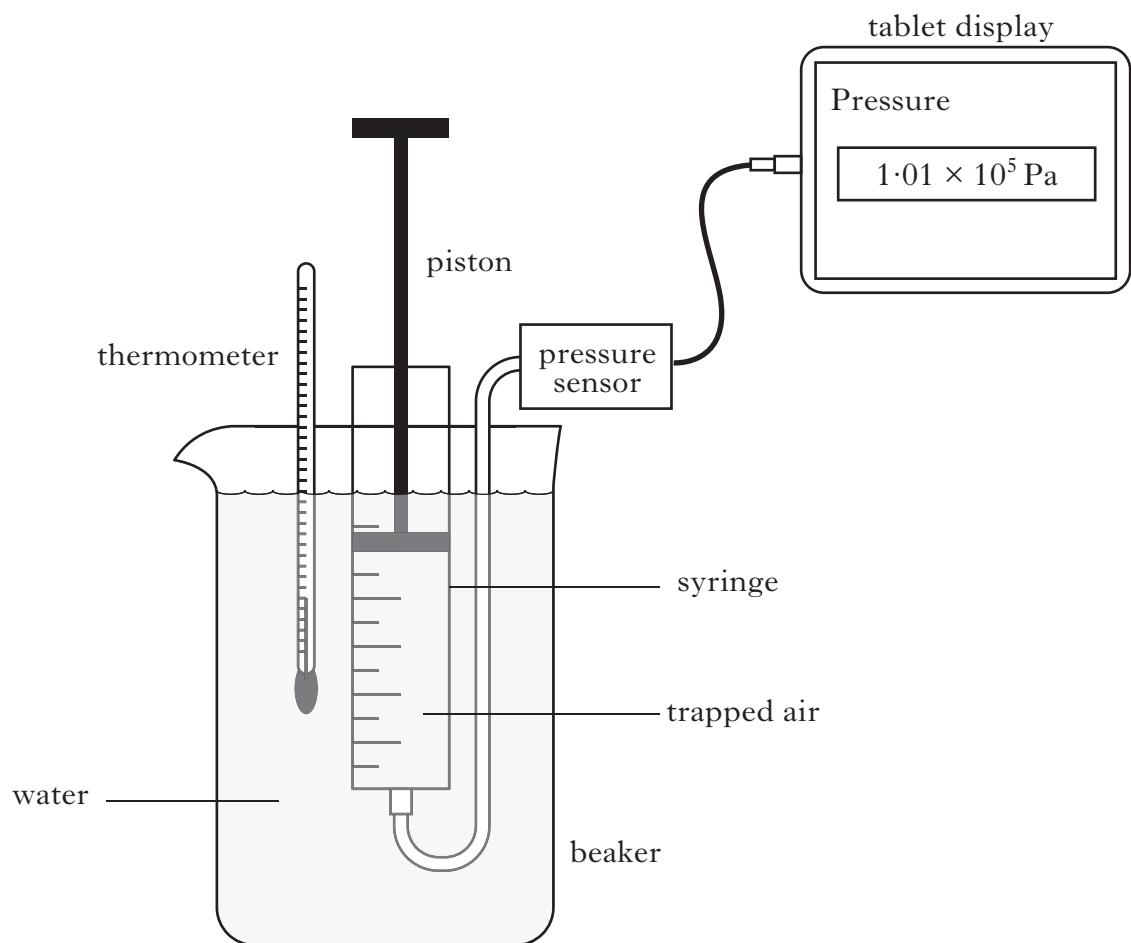
Explain why the block now swings to a greater vertical height. 2

(7)

[Turn over

24. Air is trapped in a syringe. The mass of the trapped air is $1.45 \times 10^{-3} \text{ kg}$.

The syringe of trapped air is set up with other apparatus as shown.



(a) The trapped air is at a temperature of 20°C , a pressure of $1.01 \times 10^5 \text{ Pa}$ and its volume is $5.00 \times 10^{-4} \text{ m}^3$.

The piston on the syringe is now pushed in until the volume of the trapped air is reduced to $1.25 \times 10^{-4} \text{ m}^3$.

The temperature of the trapped air remains constant.

- (i) Calculate the pressure of the trapped air when its volume is $1.25 \times 10^{-4} \text{ m}^3$. 2
- (ii) Calculate the density of the trapped air when its volume is $1.25 \times 10^{-4} \text{ m}^3$. 2
- (iii) Use the kinetic model to explain what happens to the pressure of the trapped air as its volume is decreased. 2

(b) The temperature of the trapped air is now increased to 40°C .

The volume is kept constant at $1.25 \times 10^{-4} \text{ m}^3$.

Explain what happens to the density of the trapped air when its temperature is increased.

1

(7)

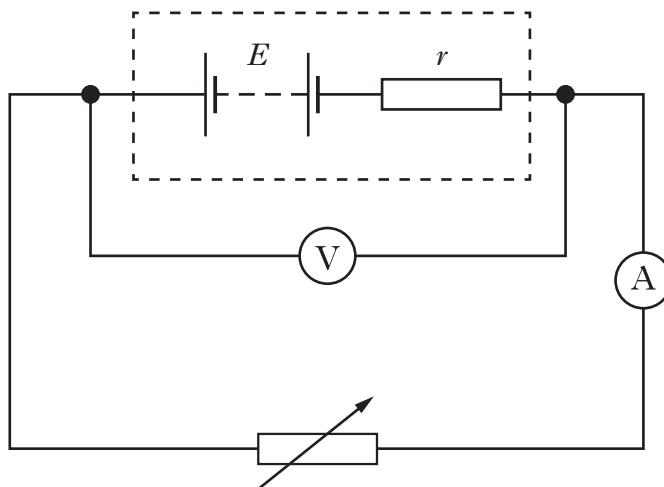
[Turn over for Question 25 on *Page sixteen*

25. A technician is testing a new design of car battery.

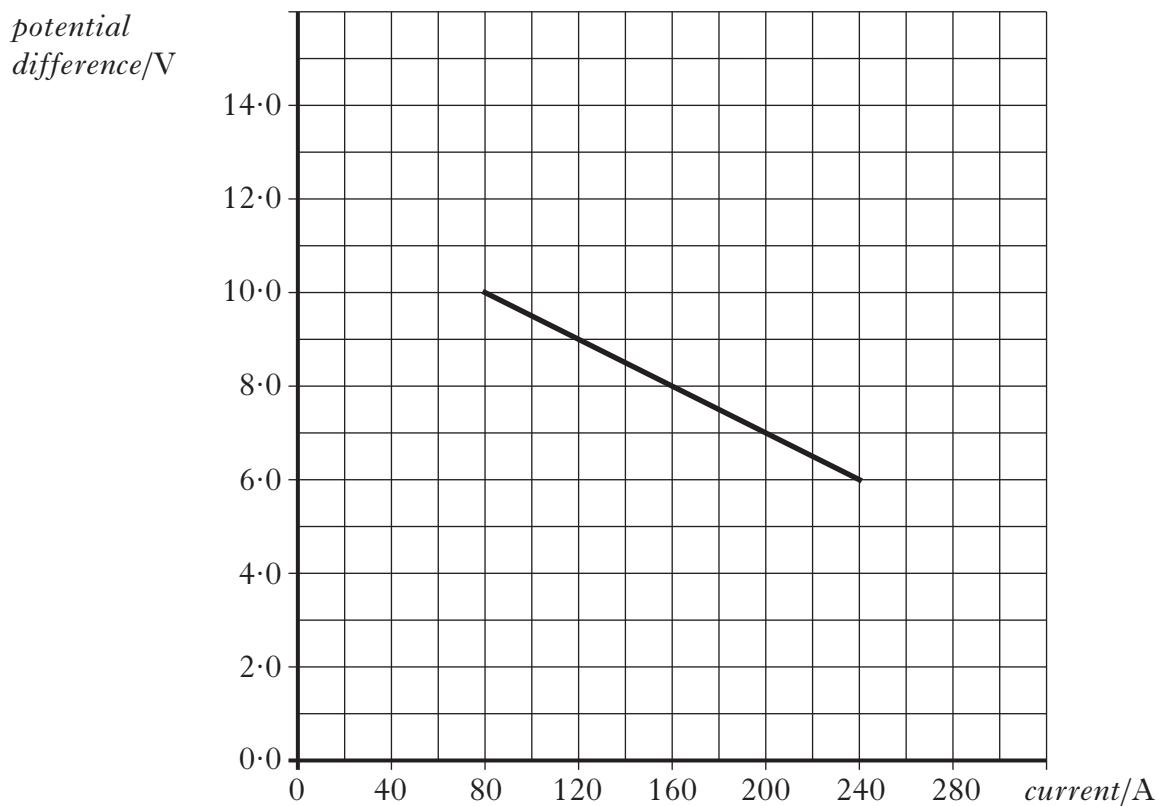
Marks

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

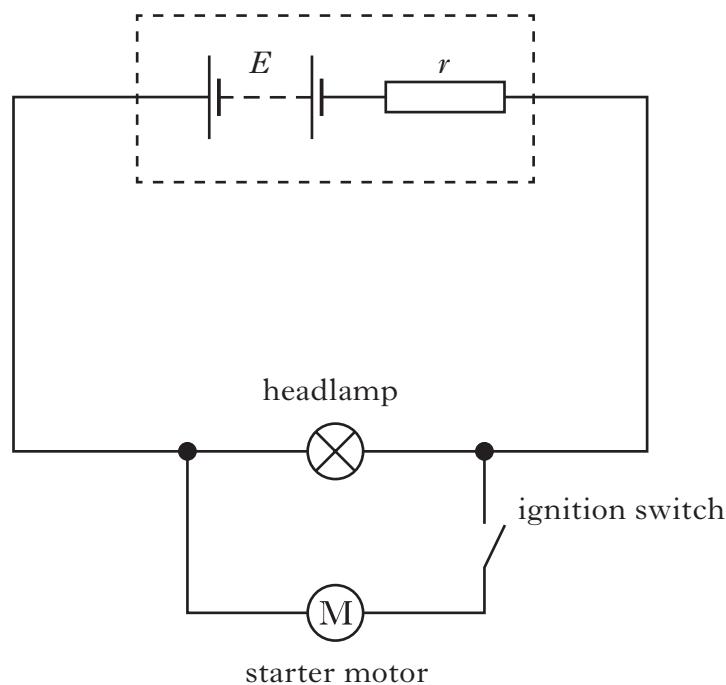
(ii) Calculate the internal resistance of the car battery. 2

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

Calculate the short circuit current. 2

25. (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.

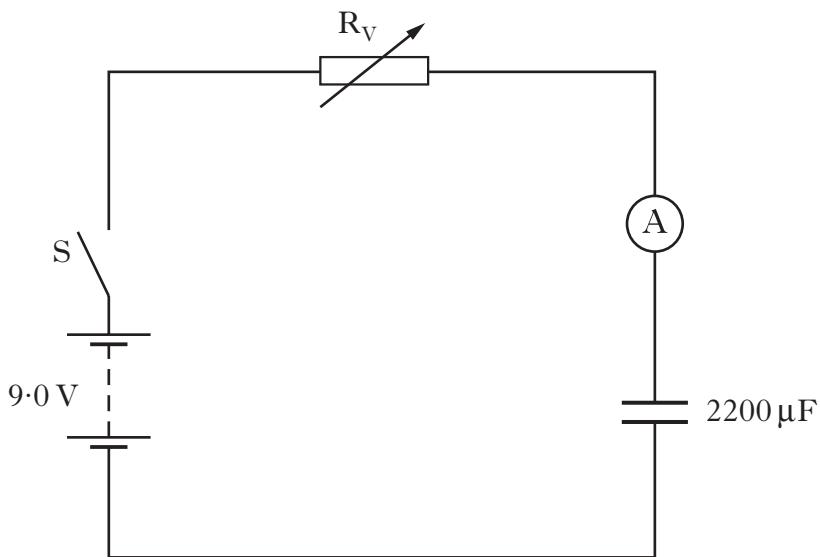
Explain why this happens.

2

(7)

[Turn over

26. A student sets up the circuit shown to investigate the charging of a capacitor.



The battery has an e.m.f. of 9.0 V and negligible internal resistance.

Initially the capacitor is uncharged and the variable resistor R_V is set to 12 k Ω .

(a) Switch S is now closed and the capacitor charges.

Sketch a graph of the current in the circuit against time from the moment the switch is closed until the capacitor is fully charged.

Numerical values are only required on the current axis.

2

(b) Capacitors have an insulator between their plates.

Explain why there is a current in the circuit during the charging process.

1

(c) At one instant during the charging process, the current in the 12 k Ω resistor is 5.0×10^{-4} A.

Calculate the charge stored on the capacitor at this time.

3

(d) Switch S is now opened and the capacitor is fully discharged. The variable resistor is adjusted to a greater resistance.

Switch S is closed and the capacitor charges again.

Explain what effect, if any, this increase in resistance has on:

(i) the maximum potential difference across the capacitor;

1

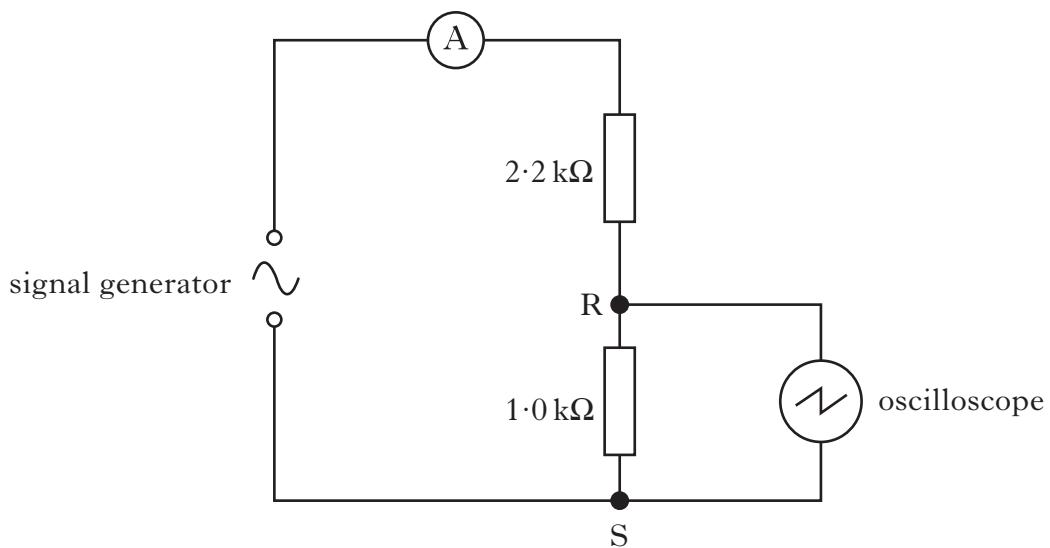
(ii) the maximum current in the circuit.

1

(8)

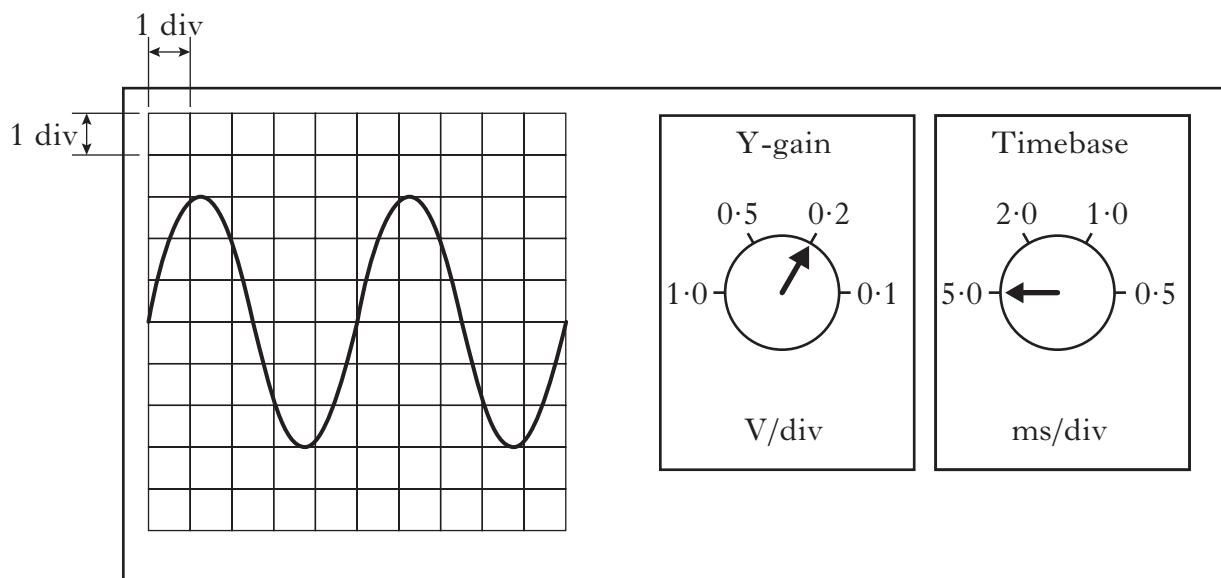
[Turn over for Question 27 on *Page twenty*]

27. A student sets up the following circuit to investigate alternating current.



(a) An oscilloscope is connected across the $1.0\text{ k}\Omega$ resistor.

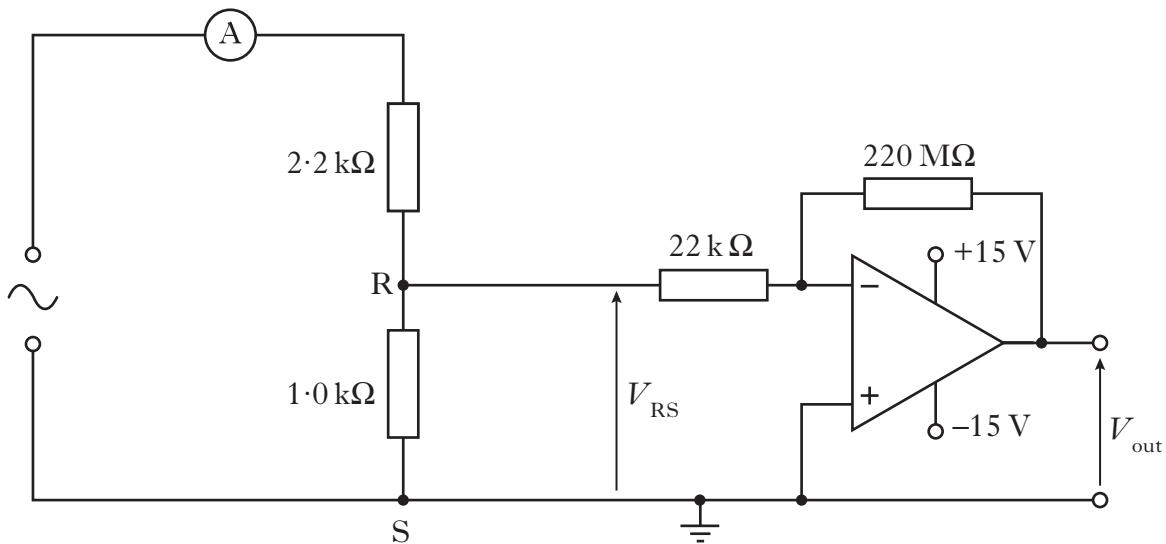
The oscilloscope control settings and the trace displayed on its screen are shown.



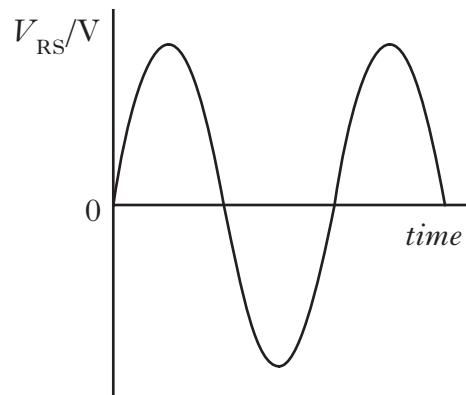
(i) Determine the peak voltage across the $1.0\text{ k}\Omega$ resistor.	1
(ii) Calculate the r.m.s. current in the $1.0\text{ k}\Omega$ resistor.	3
(iii) Calculate the r.m.s. output voltage of the signal generator.	2

27. (continued)

(b) The oscilloscope is now disconnected and points R and S are connected to an op-amp circuit as shown.



The input signal to the op-amp, V_{RS} , is shown below.



The peak voltage of V_{RS} is the same as in (a)(i).

Sketch the corresponding output signal from the op-amp, V_{out} , for the input signal shown.

Numerical values are only required on the vertical axis.

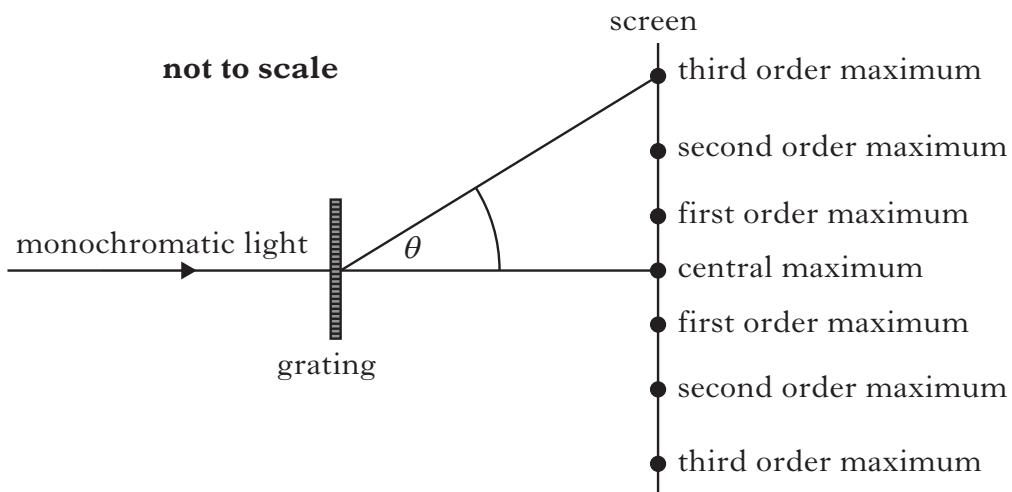
2

(8)

[Turn over

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

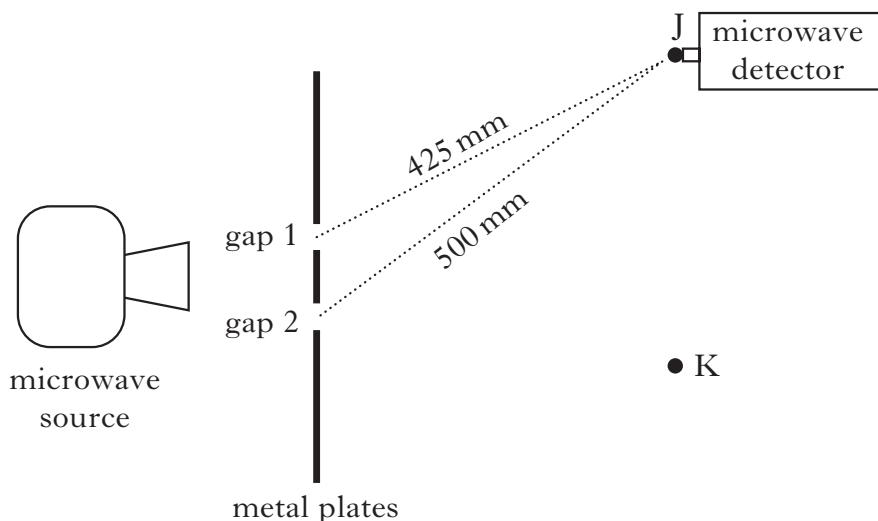
(a) In the first experiment, monochromatic light of wavelength 589 nm passes through a grating. The distance between the slits on the grating is 5.0×10^{-6} m.



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.

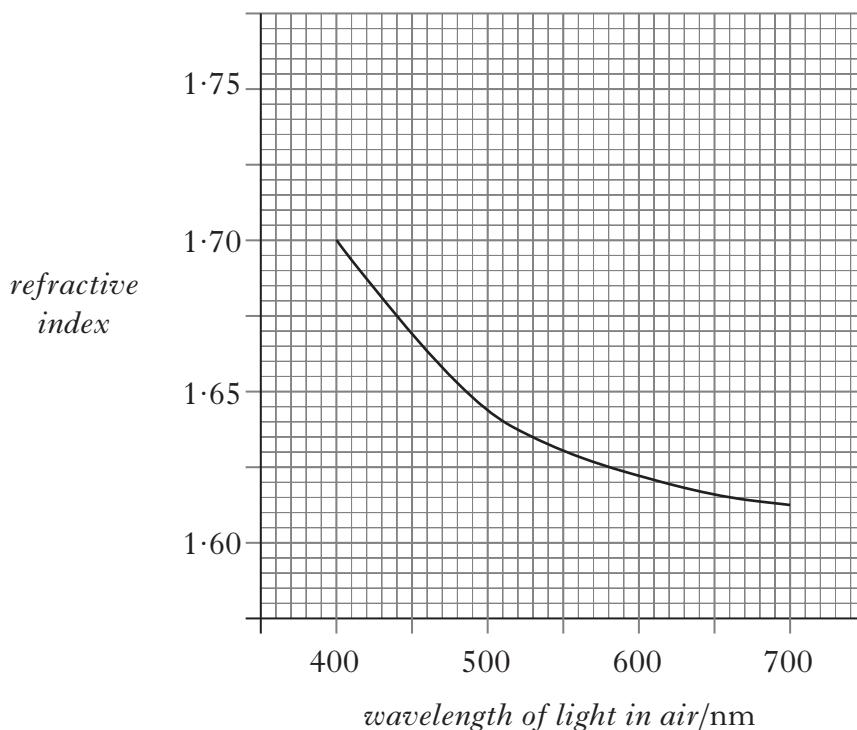
Does the strength of the signal detected at K increase, decrease or stay the same? You must justify your answer.

2

(6)

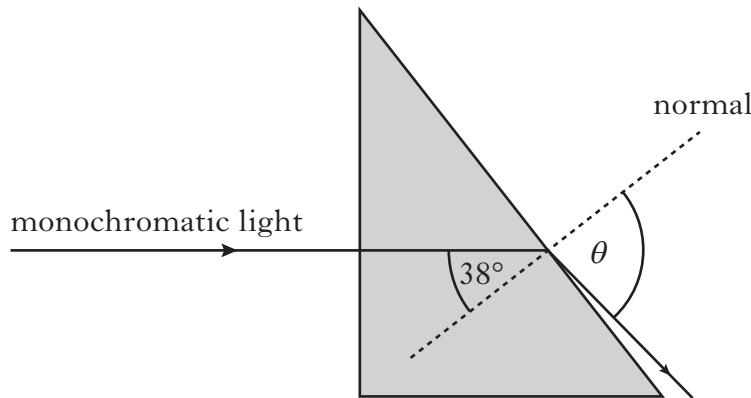
29. Monochromatic light is shone into a triangular prism of flint glass.

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.

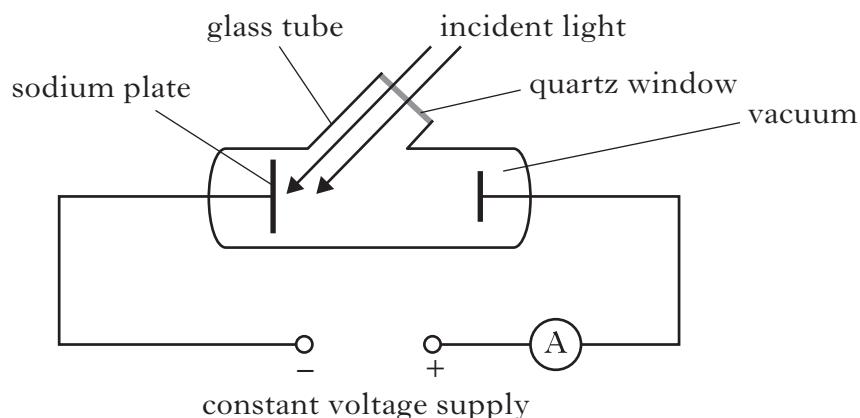
Is the speed of this new ray in the prism less than, the same as or greater than the speed of the 660 nm ray in the prism?

Justify your answer.

2

(4)

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



The work function of sodium is 3.78×10^{-19} J.

Light of frequency 6.74×10^{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

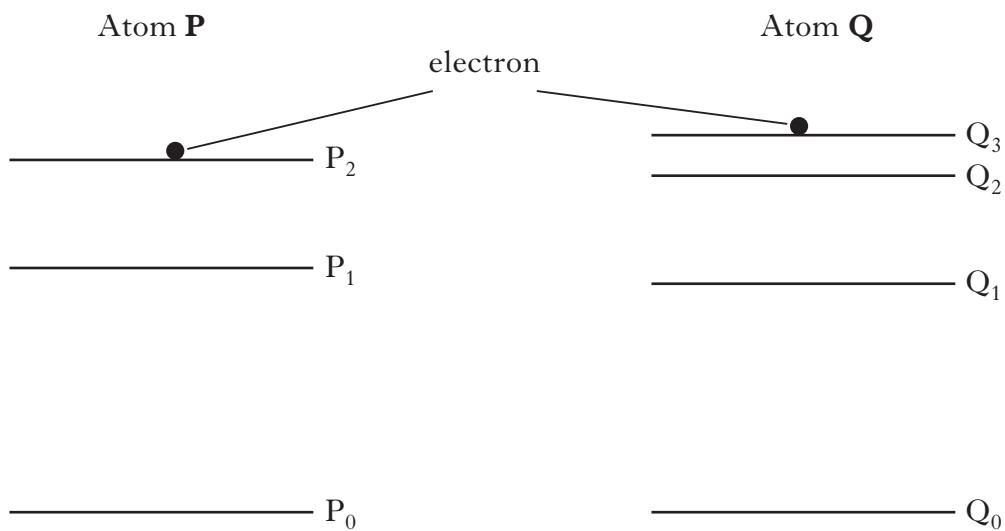
(b) The irradiance of this incident light is now decreased.

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

2

(6)

31. The following diagrams represent some of the energy levels for two different atoms **P** and **Q**. The diagrams are drawn to the same scale.



Electrons are continuously excited to levels P_2 and Q_3 .

When electrons make transitions to lower energy levels, photons of light are emitted.

This light is observed as various lines in the emission spectrum of each atom.

(a) For atom **Q**, determine the number of lines in the emission spectrum for the energy levels shown. 1

(b) Considering both atoms, identify the transition that produces radiation of the lowest frequency. 1

(c) The table shows information about the energy levels in atom **P**.

Energy Level	Energy/J
P_2	-2.4×10^{-19}
P_1	-5.4×10^{-19}
P_0	-21.8×10^{-19}

Calculate the shortest wavelength of radiation emitted from atom **P**. 3

(d) (i) The emission line due to the transition from P_2 to P_1 is the **same colour** as the emission line due to the transition from Q_2 to Q_1 .

Explain this observation. 1

(ii) The emission line due to the transition from P_2 to P_1 is **brighter** than the emission line due to the transition from Q_2 to Q_1 .

Explain this observation. 1

[END OF QUESTION PAPER] (7)

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ACKNOWLEDGEMENT

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