X069/12/02

NATIONAL QUALIFICATIONS 2013

MONDAY, 27 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.

SA X069/12/02 6/13510

DATA SHEET

COMMON PHYSICAL QUANTITIES

Quantity	*Symbol*	*Value*	*Quantity*	*Symbol*	*Value*
Speed of light in vacuum	c	$3{\cdot}00 \times 10^8$ m s^{-1}	Mass of electron	m_e	$9{\cdot}11 \times 10^{-31}$ kg
Magnitude of the charge on an electron	e	$1{\cdot}60 \times 10^{-19}$ C	Mass of neutron	m_n	$1{\cdot}675 \times 10^{-27}$ kg
Gravitational acceleration on Earth	g	$9{\cdot}8$ m s^{-2}	Mass of proton	m_p	$1{\cdot}673 \times 10^{-27}$ kg
Planck's constant	h	$6{\cdot}63 \times 10^{-34}$ J s			

REFRACTIVE INDICES

The refractive indices refer to sodium light of wavelength 589 nm and to substances at a temperature of 273 K.

Substance	*Refractive index*	*Substance*	*Refractive index*
Diamond	2·42	Water	1·33
Crown glass	1·50	Air	1·00

SPECTRAL LINES

Element	*Wavelength*/nm	*Colour*
Hydrogen	656	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

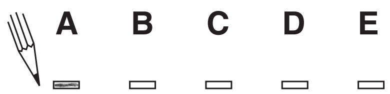
B ampere

C watt

D coulomb

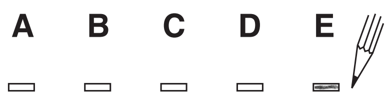
E volt.

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**.



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SECTION A

Answer questions 1–20 on the answer sheet.

1. Which of the following is a vector quantity?

A distance

B time

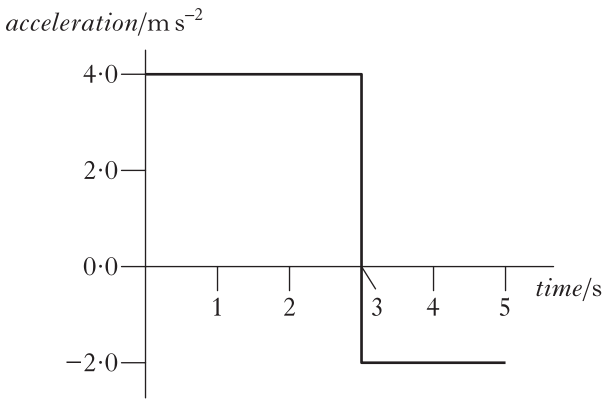
C speed

D energy

E weight

2. An object starts from rest and accelerates in a straight line.

The graph shows how the acceleration of the object varies with time.



The speed of the object at 5 seconds is

A $2\,m\,s^{-1}$

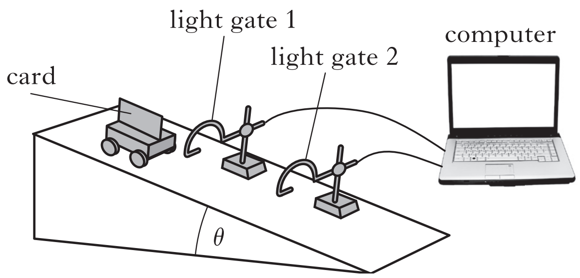
B $8\,m\,s^{-1}$

C $12\,m\,s^{-1}$

D $16\,m\,s^{-1}$

E $20\,m\,s^{-1}$.

3. A vehicle runs down a slope as shown.



The following results are obtained.

angle of slope,
$\theta = 15{\cdot}0 \pm 0{\cdot}5°$

length of card on top of vehicle,
$d = 0{\cdot}020 \pm 0{\cdot}001$ m

time for card to pass light gate 1,
$t_1 = 0{\cdot}40 \pm 0{\cdot}01$ s

time for card to pass light gate 2,
$t_2 = 0{\cdot}25 \pm 0{\cdot}01$ s

time for vehicle to travel between the light gates,
$t_3 = 0{\cdot}50 \pm 0{\cdot}01$ s

Which quantity has the largest percentage uncertainty?

A θ

B d

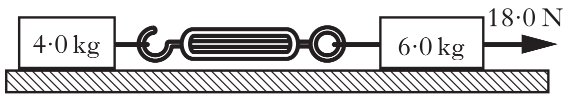
C t_1

D t_2

E t_3

4. Two blocks are linked by a newton balance of negligible mass.

The blocks are placed on a level, frictionless surface. A force of 18·0 N is applied to the blocks as shown.



The reading on the newton balance is

A 7·2 N

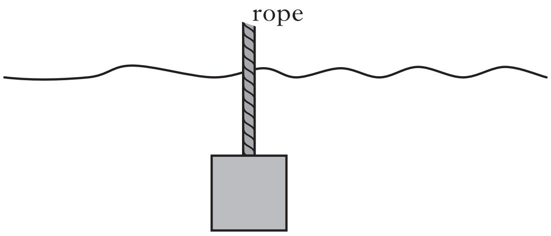
B 9·0 N

C 10·8 N

D 18·0 N

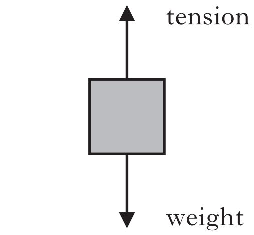
E 40·0 N.

5. A box is suspended by a rope under the surface of the sea.

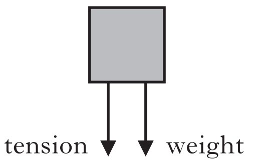


Which diagram shows the vertical forces acting on the box?

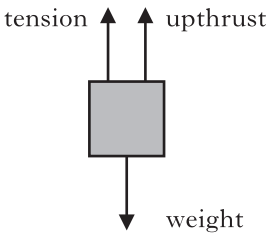
A



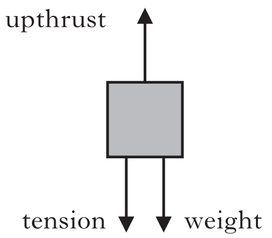
B



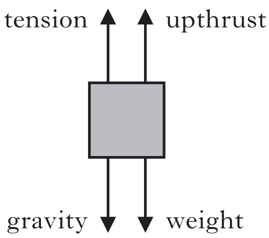
C



D



E



6. A cannon of mass $2{\cdot}0 \times 10^3$ kg fires a cannonball of mass 5·00 kg.

The cannonball leaves the cannon with a speed of $50{\cdot}0\,\mathrm{m\,s^{-1}}$.

The speed of the cannon immediately after firing is

A $0{\cdot}125\,\mathrm{m\,s^{-1}}$

B $8{\cdot}00\,\mathrm{m\,s^{-1}}$

C $39{\cdot}9\,\mathrm{m\,s^{-1}}$

D $40{\cdot}1\,\mathrm{m\,s^{-1}}$

E $200\,\mathrm{m\,s^{-1}}$.

7. The pressure of a gas in a sealed syringe is $1{\cdot}5 \times 10^5$ Pa.

The temperature of the gas is 27 °C.

The temperature of the gas is now raised by 10 °C and the volume of the gas halved.

The new pressure of the gas in the syringe is

A $1{\cdot}1 \times 10^5$ Pa

B $2{\cdot}8 \times 10^5$ Pa

C $3{\cdot}1 \times 10^5$ Pa

D $4{\cdot}1 \times 10^5$ Pa

E 11×10^5 Pa.

8. A student writes the following statements about electric fields.

I There is a force on a charge in an electric field.

II When an electric field is applied to a conductor, the free electric charges in the conductor move.

III Work is done when a charge is moved in an electric field.

Which of the statements is/are correct?

A I only

B II only

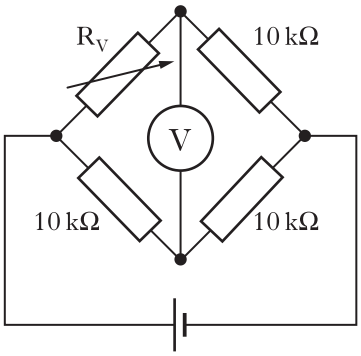
C I and II only

D I and III only

E I, II and III

[Turn over

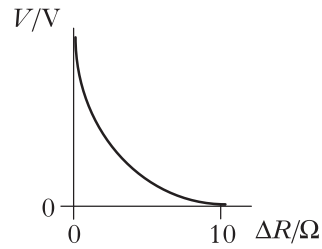
9. The diagram shows a Wheatstone bridge.

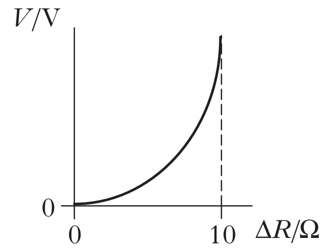


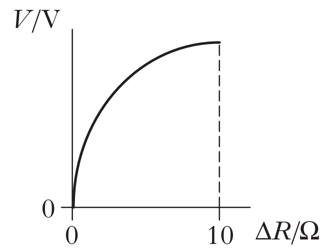
The reading on the voltmeter is zero.

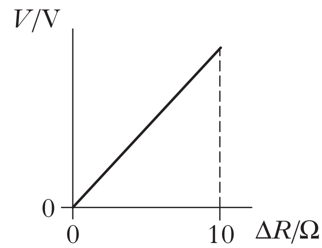
The variable resistor R_V is now altered in steps of 1 Ω and each corresponding reading on the voltmeter is noted.

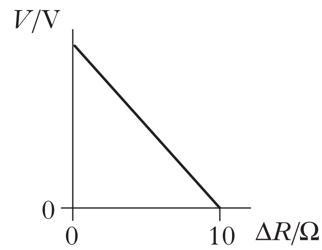
Which of the following graphs shows how the reading on the voltmeter, V, varies with the change in resistance ΔR?

A


B


C


D


E


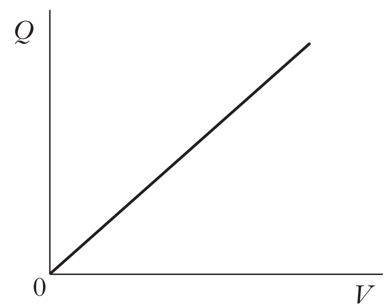
10. The capacitance of a capacitor is 1000 μF. The potential difference (p.d.) across the capacitor is 100 V. The charge stored by the capacitor is 0·10 C.

The charge on the capacitor is now reduced to half its original value.

Which row in the table shows the capacitance of the capacitor and the p.d. across the capacitor, for this new value of charge?

	Capacitance/μF	*p.d.*/V
A	1000	200
B	500	100
C	1000	100
D	500	50
E	1000	50

11. The graph shows how the charge, Q, stored on a capacitor varies with the potential difference, V, across the capacitor.



Which of the following statements is/are correct?

I The gradient of the graph represents the capacitance of the capacitor.

II The area under the graph represents the work done in charging the capacitor.

III The energy, E, stored in the capacitor is given by the equation $E = QV$.

A I only

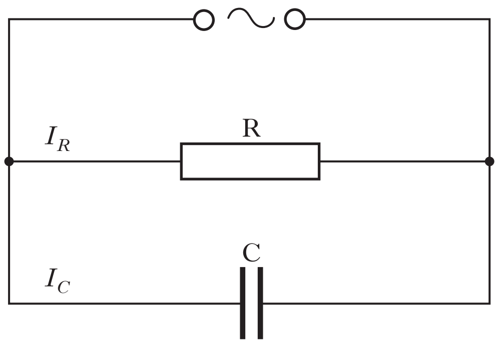
B II only

C III only

D I and II only

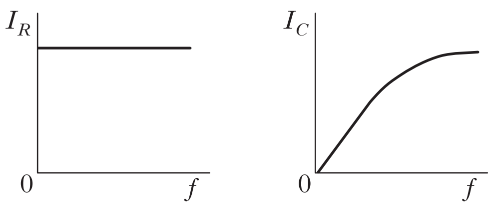
E I, II and III

12. The following circuit shows a constant voltage a.c. supply connected to a resistor and capacitor in parallel.

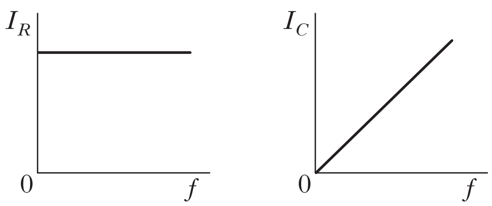


Which pair of graphs shows how the r.m.s. currents I_R and I_C vary as the frequency, f, of the supply is increased?

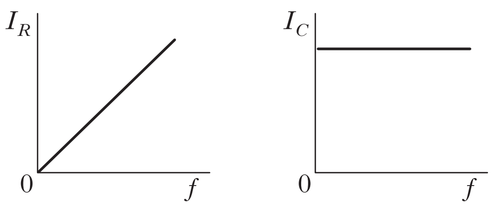
A



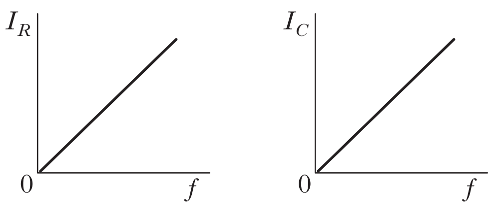
B



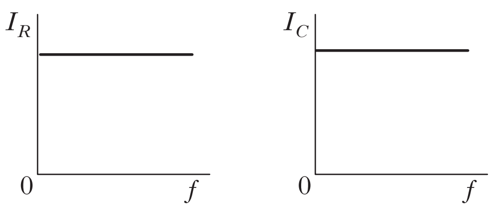
C



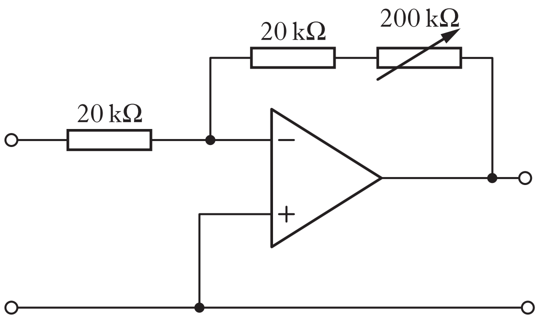
D



E



13. A physicist designs the amplifier circuit shown.



In this circuit, adjustment of the resistance of the variable resistor from zero to 200 kΩ allows the voltage gain to be altered over the range

A zero to one

B zero to ten

C zero to eleven

D one to ten

E one to eleven.

14. The energy of a water wave depends on its

A amplitude

B period

C phase

D speed

E wavelength.

15. Light travels from air into glass.

Which row in the table describes what happens to the speed, frequency and wavelength of the light?

	Speed	*Frequency*	*Wavelength*
A	increases	decreases	stays constant
B	decreases	stays constant	decreases
C	stays constant	decreases	decreases
D	increases	stays constant	increases
E	decreases	decreases	stays constant

16. The irradiance of light can be measured in

A W

B $W\,m^{-1}$

C $W\,m$

D $W\,m^{-2}$

E $W\,m^2$.

17. Ultraviolet radiation causes the emission of photoelectrons from a zinc plate.

The irradiance of the ultraviolet radiation on the zinc plate is increased.

Which row in the table shows the effect of this change?

	Maximum kinetic energy of a photoelectron	*Number of photoelectrons emitted per second*
A	increases	no change
B	no change	increases
C	no change	no change
D	increases	increases
E	decreases	increases

18. A student reads the following passage in a physics dictionary.

"*. . . is a solid state device in which positive and negative charge carriers are produced by the action of light on a p-n junction*."

The passage describes

A a thermistor

B a MOSFET

C a photodiode

D a laser

E an LED.

19. A student makes the following statements about Rutherford's model of the atom.

I The nucleus has a relatively small diameter compared with that of the atom.

II Most of the mass of the atom is concentrated in the nucleus.

III The nucleus consists of positive and negative charges.

Which of these statements is/are correct?

A I only

B II only

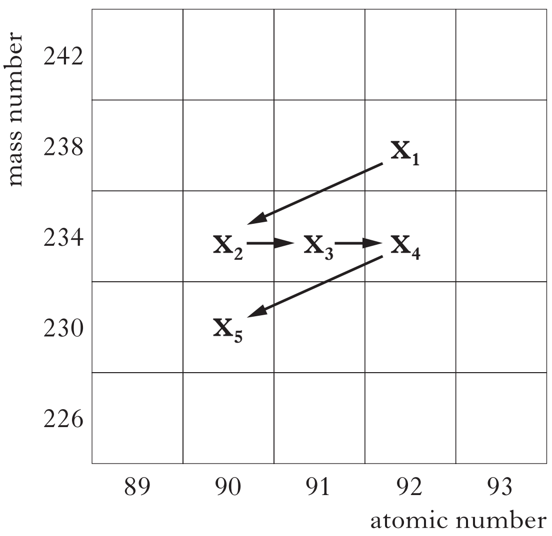
C III only

D I and II only

E I, II and III

20. Part of a radioactive decay series is shown in the diagram.

The symbols $\mathbf{X_1}$ to $\mathbf{X_5}$ represent nuclides in this series.



A student makes the following statements about the decay series.

I Nuclides $\mathbf{X_2}$ and $\mathbf{X_3}$ contain the same number of protons.

II Nuclide $\mathbf{X_1}$ decays into nuclide $\mathbf{X_2}$ by emitting an alpha particle.

III Nuclide $\mathbf{X_3}$ decays into nuclide $\mathbf{X_4}$ by emitting a beta particle.

Which of these statements is/are correct?

A I only

B II only

C III only

D II and III only

E I, II and III

[Turn over

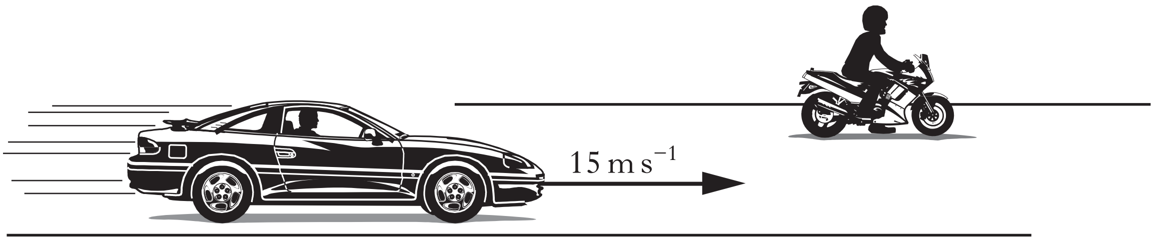
SECTION B

Marks

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

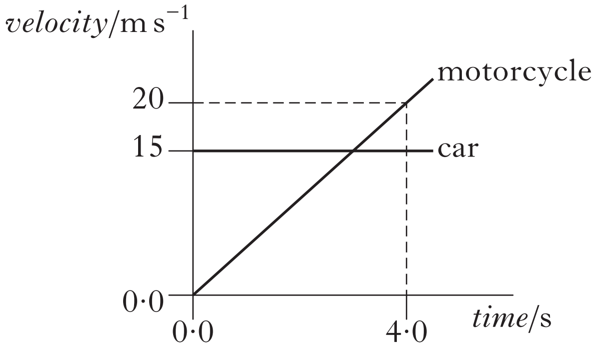
21. A car is travelling at a constant speed of $15\,m\,s^{-1}$ along a straight, level road.

It passes a motorcycle which is stationary at the roadside.



At the instant the car passes, the motorcycle starts to move in the same direction as the car.

The graph shows the motion of each vehicle from the instant the car passes the motorcycle.



(*a*) Show that the initial acceleration of the motorcycle is $5{\cdot}0\,m\,s^{-2}$. **1**

(*b*) Calculate the distance between the car and the motorcycle at 4·0 s. **2**

(*c*) The total mass of the motorcycle and rider is 290 kg. At a time of 2·0 s the driving force on the motorcycle is 1800 N.

(i) Calculate the frictional force acting on the motorcycle at this time. **2**

(ii) Explain why the driving force must be increased with time to maintain a constant acceleration. **1**

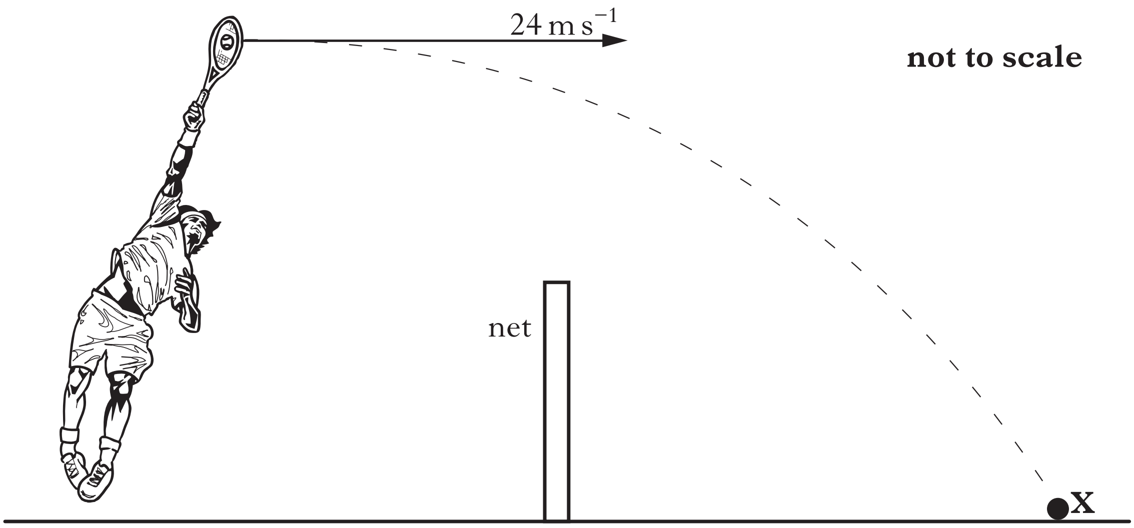
(6)

Marks

22. A tennis player strikes a ball at a height of 2·5 m above the ground.

The ball leaves the racquet travelling horizontally at $24\,\mathrm{m\,s^{-1}}$.

It travels through the air and hits the ground at point **X** on the other side of the net.



The effects of air resistance can be ignored.

(*a*) The ball takes 0·50 s to travel to the net.

Calculate the height of the ball above the ground at this time. **2**

(*b*) By scale drawing, or otherwise, calculate the velocity of the ball as it hits the ground at **X**. **3**

(*c*) After playing with the same ball for a time, the temperature of the gas inside the ball increases.

Using the kinetic model, describe how this increase in temperature affects the pressure of the gas in the ball. Assume that the mass of gas and the volume of the ball remain constant. **2**

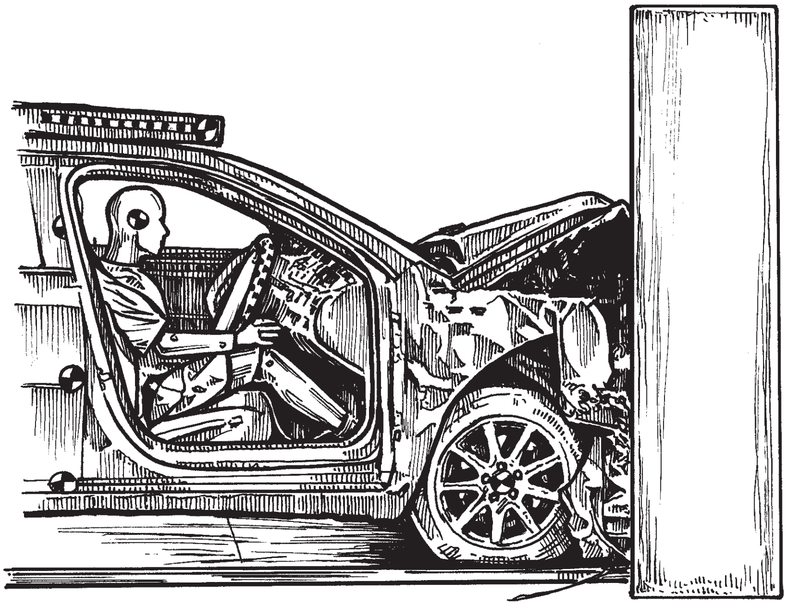
(7)

[Turn over

Marks

23. The force applied by a seat belt on a crash test dummy is being investigated. The crash test dummy is placed in a car.

The car then travels along a test track at a speed of $13 \cdot 4\,\mathrm{m\,s^{-1}}$, collides with a wall and comes to rest.



(*a*) State the law of conservation of linear momentum. **1**

(*b*) The total mass of the car and dummy is 1200 kg.

Calculate the change in momentum of the car and dummy in the collision. **2**

(*c*) The crash test dummy has a mass of 75 kg and is wearing a seat belt.

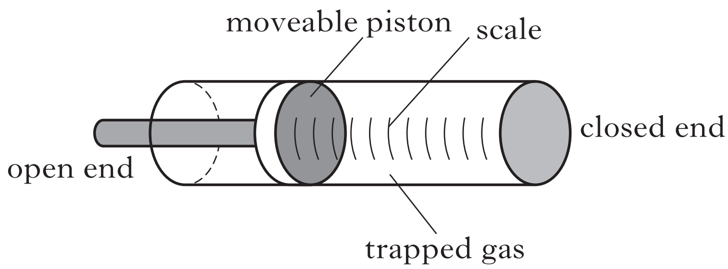
During the collision the dummy travels a distance of $0 \cdot 48\,\mathrm{m}$ while coming to rest.

Calculate the average force exerted on the dummy by the seat belt. **3**

(6)

24. A diver is measuring the pressure at different depths in the sea using a simple pressure gauge. Part of the pressure gauge consists of a cylinder containing gas trapped by a moveable piston.

Marks



At sea level, the atmospheric pressure is $1{\cdot}01 \times 10^5$ Pa and the trapped gas exerts a force of 262 N on the piston.

(*a*) Calculate the area of the piston. **2**

(*b*) The diver now descends to a depth, *h*, where the gauge registers a total pressure of $5{\cdot}13 \times 10^5$ Pa.

The density of the sea water is $1{\cdot}02 \times 10^3\ \text{kg m}^{-3}$.

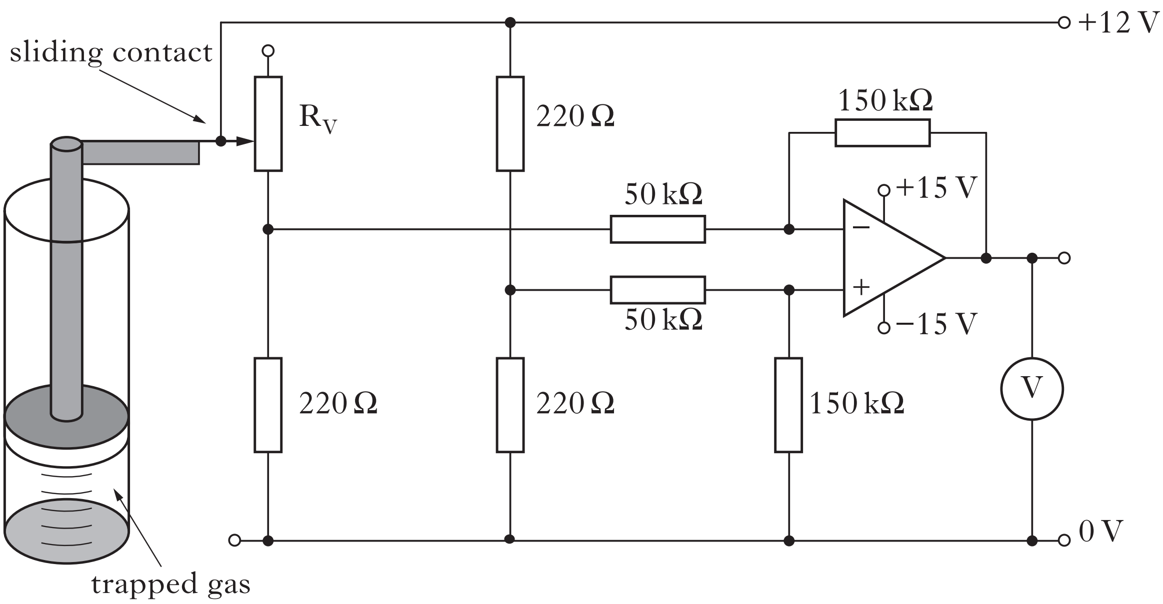
The temperature of the trapped gas remains constant.

(i) Calculate this depth, *h*. **3**

(ii) While at this depth, a bubble of gas is released from the diver's breathing apparatus.

State what happens to the volume of this bubble as it rises to the surface. Justify your answer. **1**

(*c*) The pressure gauge is now used as the sensor in the circuit shown to indicate the depth of a mini-submarine. A variable resistor, R_V, is attached to the moveable piston of the pressure gauge.



The resistance of R_V decreases as the depth of the mini-submarine increases.

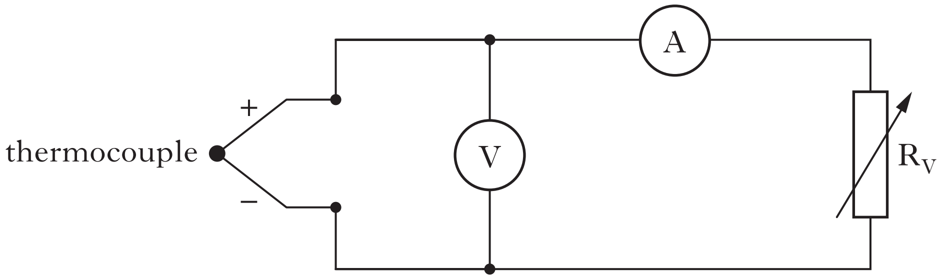
Calculate the reading on the voltmeter when the value of R_V is zero. **3**

(9)

Marks

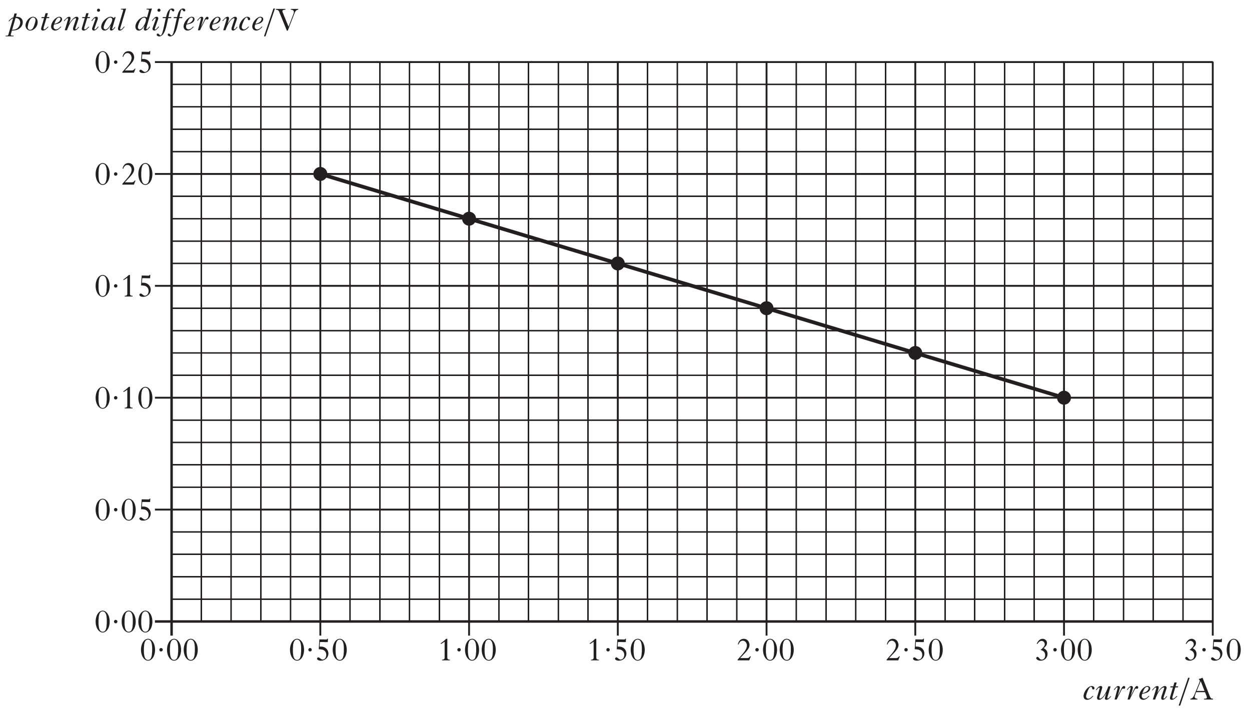
25. A thermocouple is a device that produces an e.m.f. when heated.

(*a*) A technician uses the circuit shown to investigate the operation of a thermocouple when heated in a flame.



Readings of current and potential difference (p.d.) are recorded for different settings of the variable resistor R_V.

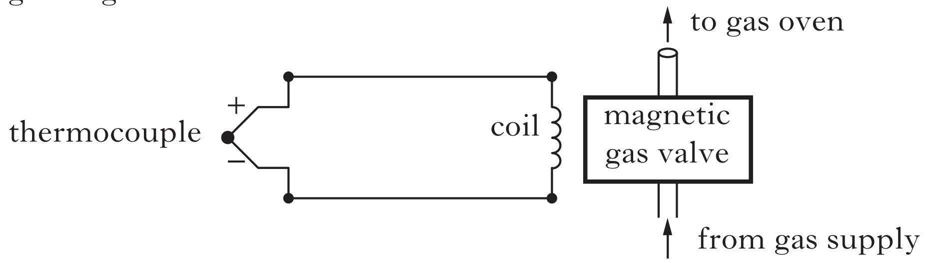
The graph of p.d. against current is shown.



Use information from the graph to find:

(i) the e.m.f. produced by the thermocouple; **1**

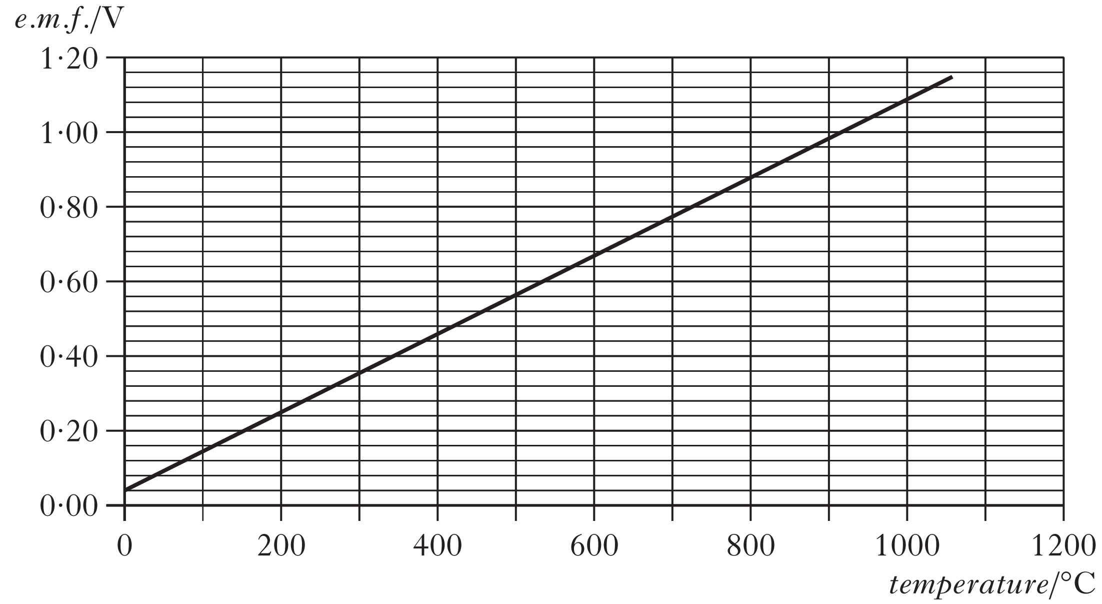
(ii) the internal resistance of the thermocouple. **2** (*b*) A **different** thermocouple is to be used as part of a safety device in a gas oven. The safety device turns off the gas supply to the oven if the flame goes out. The thermocouple is connected to a coil of resistance 0·12 Ω which operates a magnetic gas valve.

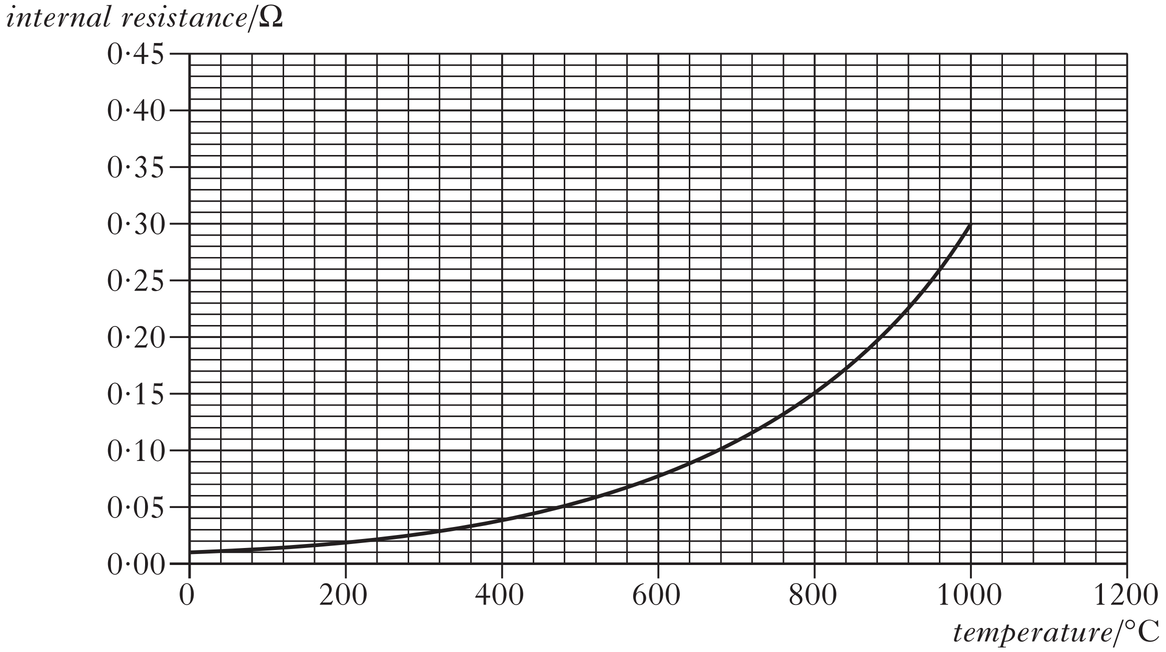


When the current in the coil is less than 2·5 A, the gas valve is closed.

The temperature of the flame in the gas oven is 800 °C.

The manufacturer's data for this thermocouple is shown in the two graphs.



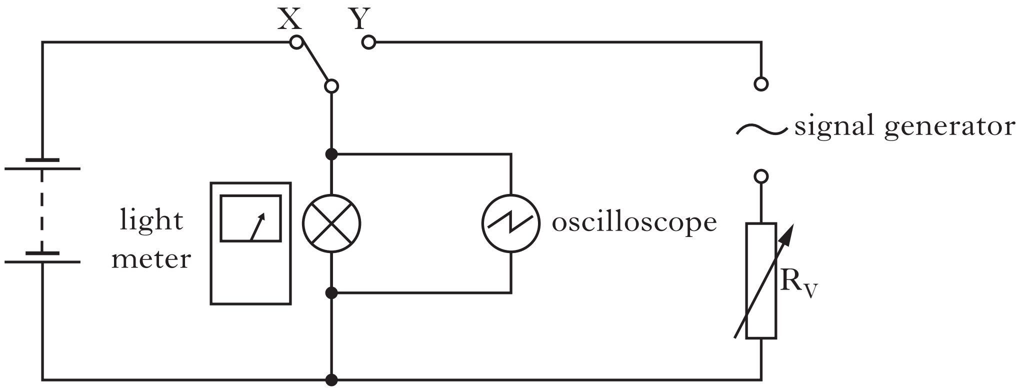


Is this thermocouple suitable as a source of e.m.f. for the gas valve to be open at a temperature of 800 °C?

You must justify your answer. **3**

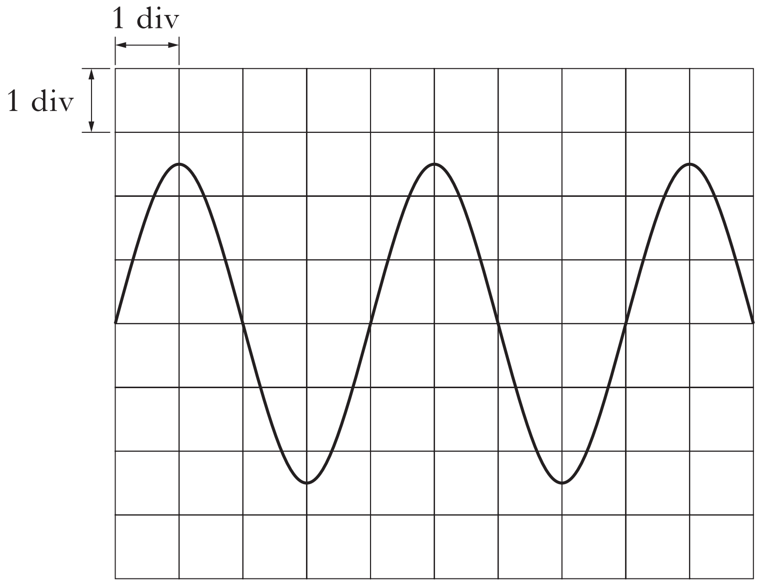
(6)

26. The circuit shown is used to compare the voltage from a battery and the voltage produced by a signal generator.



The switch is connected to X and the voltage across the lamp is 2·30 V. The reading on the light meter is recorded.

The switch is now connected to Y. The resistance of R_V is adjusted until the light meter reading is the same as before. The trace on the oscilloscope screen is shown.



(*a*) The timebase setting is 0·01 s/div.

Calculate the frequency of the output voltage of the signal generator. **2**

(*b*) Calculate the peak value of the voltage displayed on the oscilloscope. **2**

(*c*) With the switch still connected to Y, the signal generator frequency is now doubled without altering the output voltage.

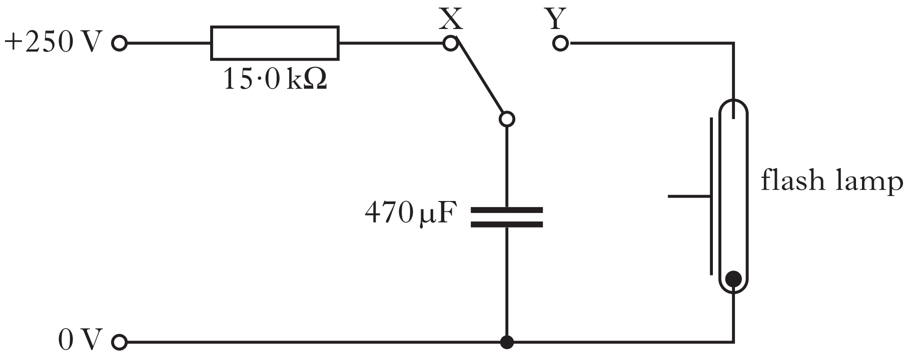
State what happens to the reading on the light meter.

Justify your answer. **1**

(5)

Marks

27. Part of a camera flash circuit operates at 250 V d.c. The circuit includes a 15·0 kΩ resistor and a 470 μF capacitor. The capacitor is initially uncharged.



(*a*) The capacitor is now charged by connecting the switch to X.

(i) Calculate the initial charging current. **2**

(ii) Sketch a graph to show how the voltage across the capacitor varies with time from the moment the switch is connected to X. Numerical values are required on the voltage axis. **1**

(iii) Show that the energy stored in the capacitor is 14·7 J when it is fully charged. **1**

(*b*) When a flash photograph is taken, the switch is connected to Y and the capacitor discharges through the flash lamp in a time of 200 μs.

Calculate the average power output of the flash lamp. **2**

(*c*) The flash cannot be fired again for another photograph until the capacitor has recharged. The time for this to happen is called the recycle time.

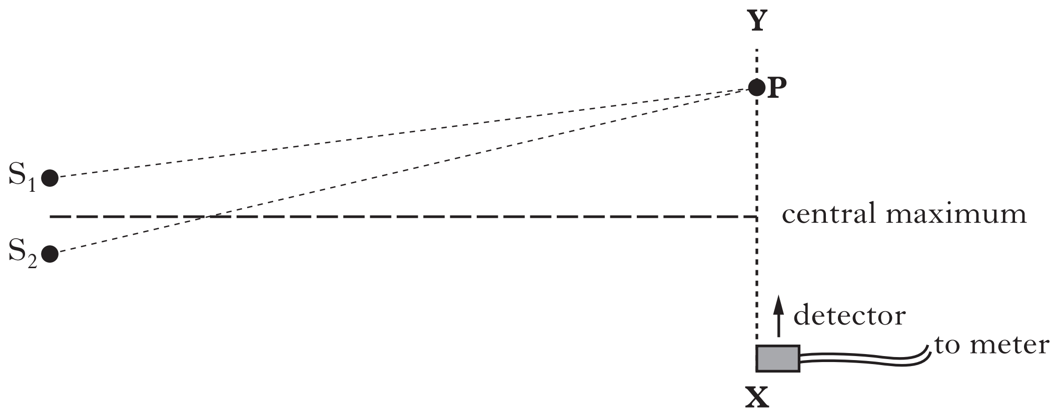
How could the circuit be modified to reduce the recycle time without altering the power output of the flash? **1**

(7)

[Turn over

28. A student is using different types of electromagnetic radiation to investigate interference.

(*a*) In the first experiment, two identical sources of microwaves, S_1 and S_2, are positioned a short distance apart as shown.



(i) The student moves a microwave detector from X towards Y. The reading on the meter increases and decreases regularly.

Explain, in terms of waves, what causes the minimum readings to occur. **1**

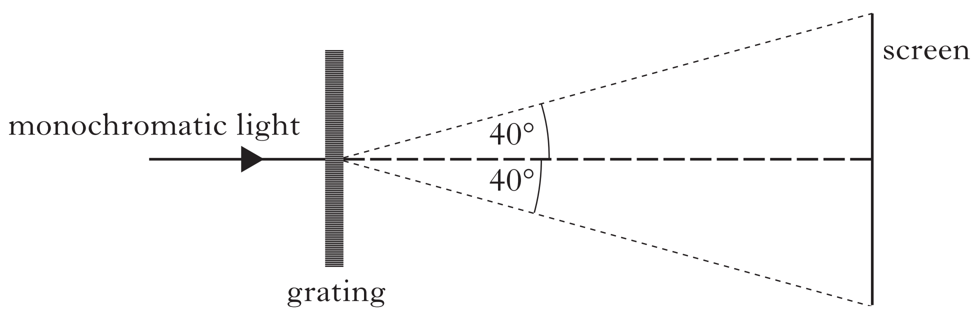
(ii) The **third** maximum from the central maximum is located at P.

The distance from S_1 to P is 620 mm.

The wavelength of the waves is 28 mm.

Calculate the distance from S_2 to P. **2**

(*b*) In the second experiment, a beam of parallel, monochromatic light is incident on a grating. An interference pattern is produced on a screen. The edges of the screen are at an angle of 40° to the centre of the grating as shown.

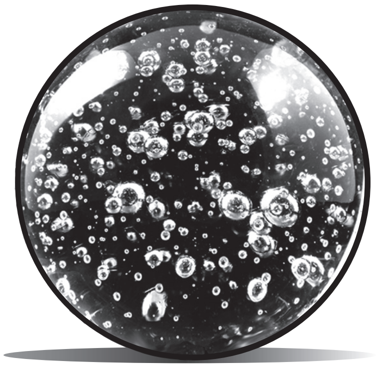


The wavelength of the light is 420 nm and the separation of the slits on the grating is $3{\cdot}27 \times 10^{-6}$ m.

Determine the total number of maxima visible on the screen. **3**

(6)

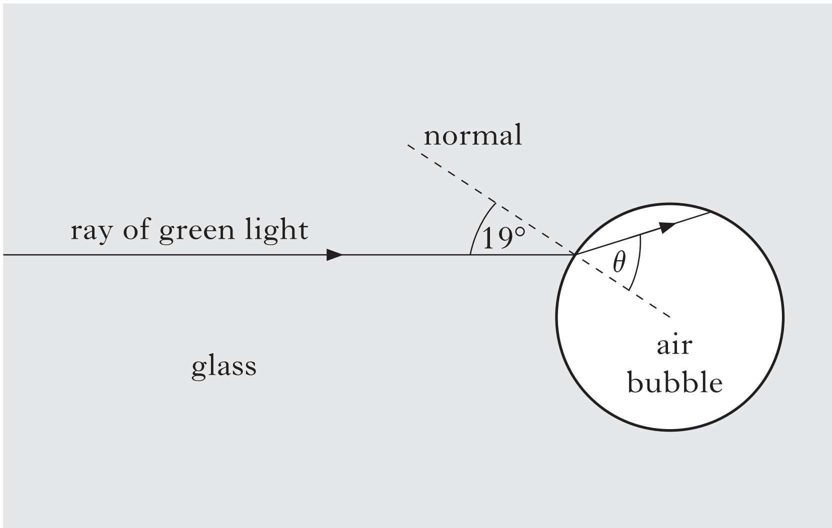
29. A student places a glass paperweight containing air bubbles on a sheet of white paper.



The student notices that when white light passes through the paperweight, a pattern of spectra is produced.

The student decides to study this effect in more detail by carrying out an experiment in the laboratory.

A ray of green light follows the path shown as it enters an air bubble inside glass.



not to scale

The refractive index of the glass for this light is 1·49.

(*a*) Calculate the angle of refraction, θ, inside the air bubble. **2**

(*b*) Calculate the maximum angle of incidence at which a ray of green light can enter the air bubble. **2**

(*c*) The student now replaces the ray of green light with a ray of white light.

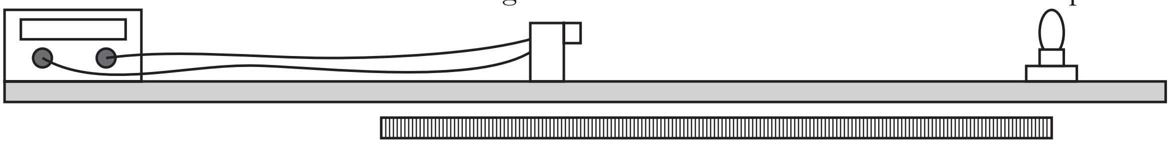
Explain why a spectrum is produced. **1**

(5)

[Turn over

Marks

30. (*a*) A technician uses the following apparatus to investigate the relationship between the irradiance of the light from a lamp and the distance from it.

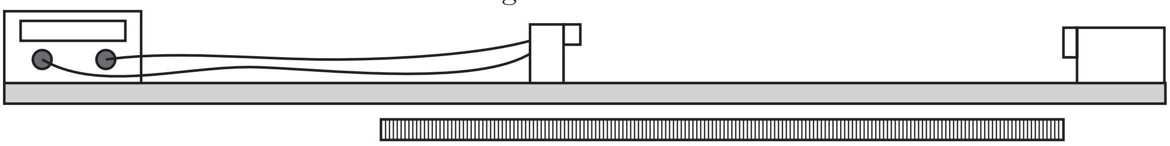


The results of the experiment are shown.

Distance between light sensor and lamp/m	*Irradiance*/units
0·10	242
0·15	106
0·20	60
0·25	39

Use **all** the results to determine whether or not the lamp behaves like a point source of light in this experiment. **2**

(*b*) The experiment is now repeated using a $1{\cdot}00 \times 10^{-4}$ W laser which produces light of wavelength 633 nm.



(i) Explain why the results obtained with the laser differ from those obtained using the lamp. **1**

(ii) Calculate the number of photons emitted by the laser each second. **3**

(iii) Light from the laser is described as *coherent*.

Describe, in terms of photons, two differences between the light from the laser and the light from the lamp used in part (*a*). **1**

(7)

Marks

31. (*a*) The following statement represents a nuclear reaction.

$$^{A}_{Z}\mathbf{X} \quad + \quad ^{2}_{1}\mathrm{H} \quad \longrightarrow \quad 2\,^{4}_{2}\mathrm{He} \quad + \quad ^{1}_{0}\mathrm{n} \quad + \quad \text{energy}$$

The masses of some of the particles involved in this reaction are shown in the table.

Particle	*Mass*/kg
$^{2}_{1}\mathrm{H}$	$3{\cdot}342 \times 10^{-27}$
$^{4}_{2}\mathrm{He}$	$6{\cdot}642 \times 10^{-27}$
$^{1}_{0}\mathrm{n}$	$1{\cdot}675 \times 10^{-27}$

(i) Use the data booklet to identify the element **X**. **1**

(ii) The energy released in this reaction is $2{\cdot}97 \times 10^{-12}$ J.

Calculate the mass of the nucleus $^{A}_{Z}\mathbf{X}$. **3**

(*b*) The crew of an aircraft receives an absorbed dose at a rate of $2{\cdot}0\,\mu\mathrm{Gy\,h^{-1}}$ of gamma rays, $1{\cdot}25\,\mu\mathrm{Gy\,h^{-1}}$ from protons and $0{\cdot}20\,\mu\mathrm{Gy\,h^{-1}}$ from fast neutrons.

The table shows the radiation weighting factor for various types of radiation.

Type	*Radiation weighting factor*
gamma rays	1
protons	2
thermal neutrons	5
fast neutrons	10
alpha particles	20

Calculate the equivalent dose received by a member of the crew during a 12 hour flight. **2**

(6)

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