X272/12/02

NATIONAL QUALIFICATIONS 2013

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

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 $\mathrm{m^{-3}}$	*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

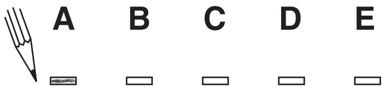
B ampere

C watt

D coulomb

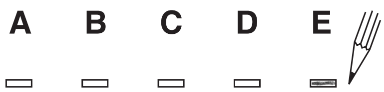
E volt.

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 train accelerates uniformly from $5{\cdot}0\ \mathrm{m\,s^{-1}}$ to $12{\cdot}0\ \mathrm{m\,s^{-1}}$ while travelling a distance of 119 m along a straight track. The acceleration of the train is

A $0{\cdot}50\ \mathrm{m\,s^{-2}}$

B $0{\cdot}70\ \mathrm{m\,s^{-2}}$

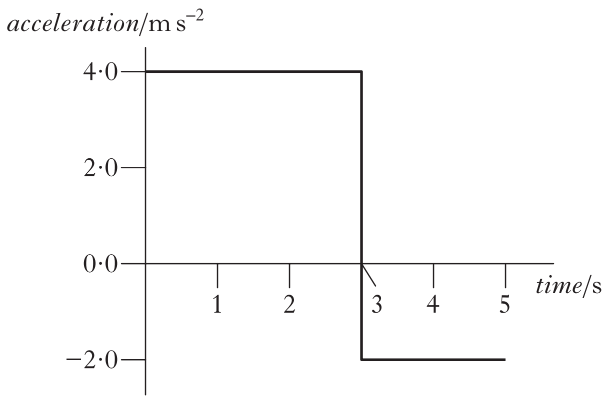
C $1{\cdot}2\ \mathrm{m\,s^{-2}}$

D $7{\cdot}0\ \mathrm{m\,s^{-2}}$

E $14\ \mathrm{m\,s^{-2}}$.

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

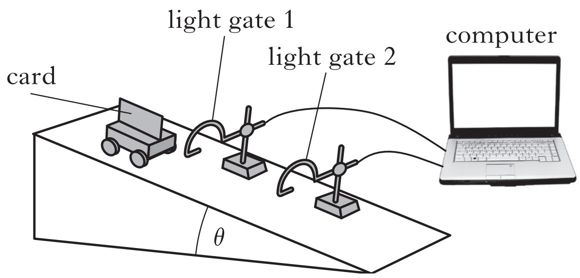
B $8\ \mathrm{m\,s^{-1}}$

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

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

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

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,
$d = 0{\cdot}020 \pm 0{\cdot}001\ \mathrm{m}$

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

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

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

Which quantity has the largest percentage uncertainty?

A θ

B d

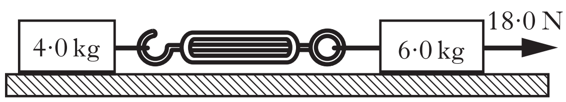
C t_1

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

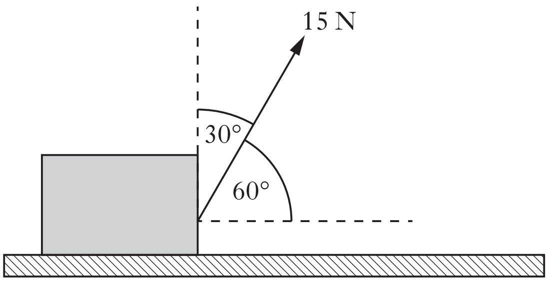
C 10·8 N

D 18·0 N

E 40·0 N.

5. A box is placed on a horizontal surface.

A force of 15 N acts on the box as shown.



Which entry in the table shows the horizontal and vertical components of the force?

	Horizontal component/N	*Vertical component*/N
A	15 sin 60°	15 sin 30°
B	15 cos 60°	15 sin 30°
C	15 sin 60°	15 cos 60°
D	15 cos 30°	15 sin 30°
E	15 cos 60°	15 sin 60°

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 50·0 m s^{-1}.

The speed of the cannon immediately after firing is

A 0·125 m s^{-1}

B 8·00 m s^{-1}

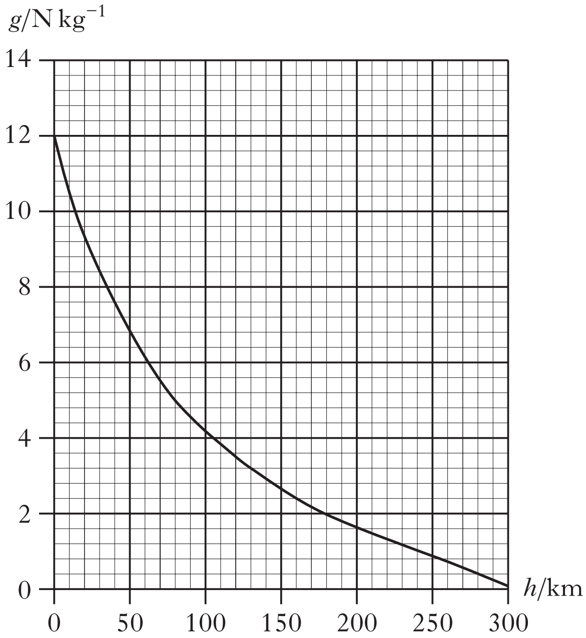
C 39·9 m s^{-1}

D 40·1 m s^{-1}

E 200 m s^{-1}.

7. A rock of mass 0·80 kg falls towards the surface of a planet.

The graph shows how the gravitational field strength, g, of the planet varies with height, h, above the surface of the planet.



At one point during its fall the weight of the rock is 4·0 N. The height of this point above the surface of the planet is

A 15 km

B 80 km

C 105 km

D 130 km

E 255 km.

8. An astronomer observes the spectrum of light from a star. The spectrum contains the emission lines for hydrogen.

The astronomer compares this spectrum with the spectrum from a hydrogen lamp. The line which has a wavelength of 656 nm from the lamp is found to be shifted to 663 nm in the spectrum from the star.

The redshift of the light from this star is

A 0·011

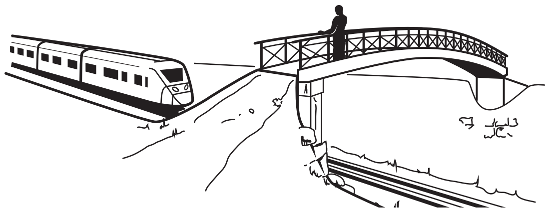
B 0·50

C 0·99

D 2·0

E 94.

9. A train is travelling at a constant speed of $16 \cdot 0 \, m \, s^{-1}$ as it approaches a bridge.



A horn on the train emits sound of frequency 277 Hz.

The sound is heard by a person standing on the bridge.

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

The frequency of the sound heard by the person on the bridge is

A 265 Hz

B 277 Hz

C 291 Hz

D 357 Hz

E 361 Hz.

10. Three students each make a statement about antiparticles.

I An antiparticle has the same mass as its equivalent particle.

II An antiparticle has the same charge as its equivalent particle.

III Every elementary particle has a corresponding antiparticle.

Which of the statements is/are correct?

A I only

B II only

C I and III only

D II and III only

E I, II and III

11. 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

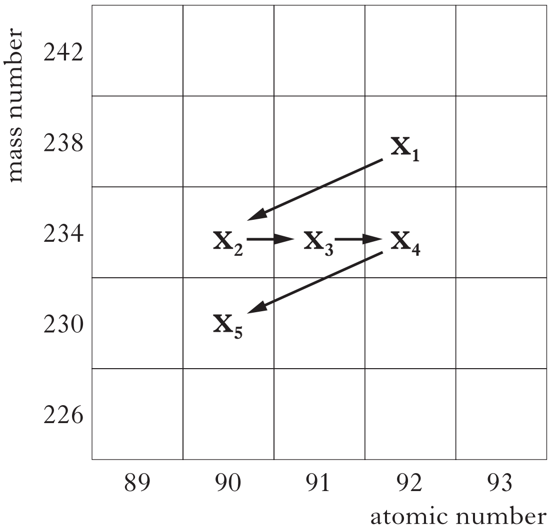
C I and II only

D I and III only

E I, II and III

12. 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

13. 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?

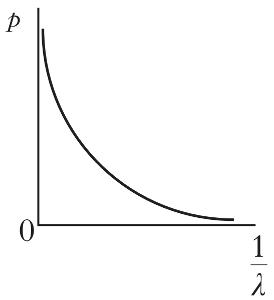
	Maximum kinetic energy of a photoelectron	*Number of photoelectrons emitted per second*
A	increases	no change
B	no change	increases
C	no change	no change
D	increases	increases
E	decreases	increases

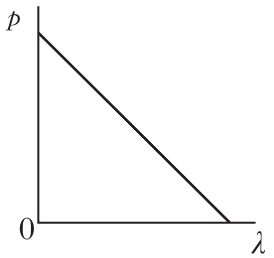
[Turn over

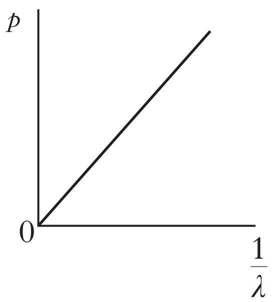
14. All particles exhibit wave properties.

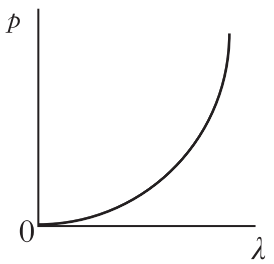
The momentum p of a particle is inversely proportional to its wavelength λ.

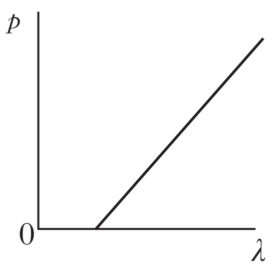
Which of the following graphs shows the relationship between p and λ?

A 

B 

C 

D 

E 

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

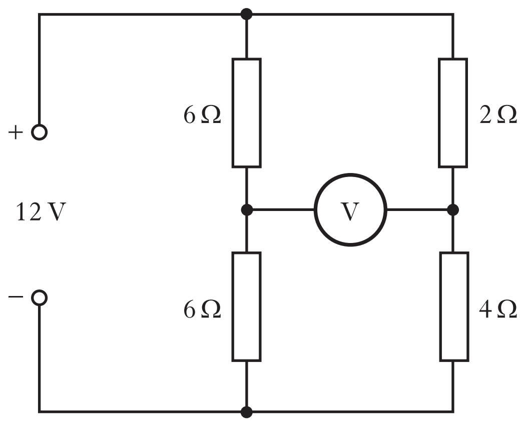
B $W\,m^{-1}$

C $W\,m$

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

E $W\,m^{2}$.

17. The following circuit is set up.



The reading on the voltmeter is

A 0 V

B 2 V

C 6 V

D 8 V

E 12 V.

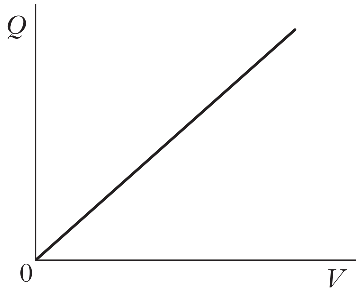
18. The capacitance of a capacitor is 1000 μF. The potential difference (p.d.) across the capacitor is 100 V. The charge stored by the capacitor is 0·10 C.

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

19. 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

20. A crystal of silicon is "doped" with arsenic. This means that a small number of the silicon atoms are replaced with arsenic atoms.

The effect of the doping on the crystal is to

A make it into a photodiode

B make it into an insulator

C increase its resistance

D decrease its resistance

E allow it to conduct in only one direction.

[Turn over

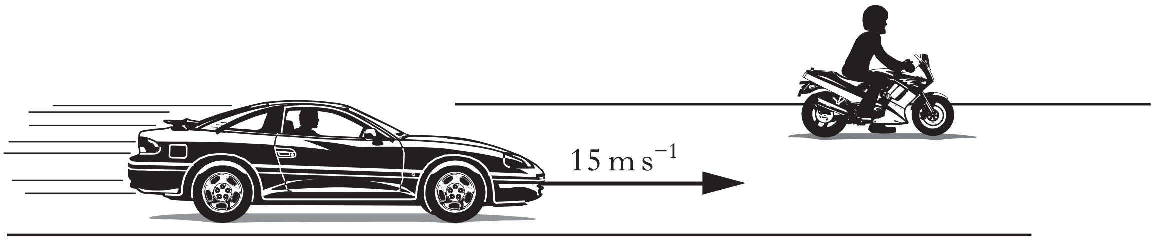
SECTION B

Marks

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

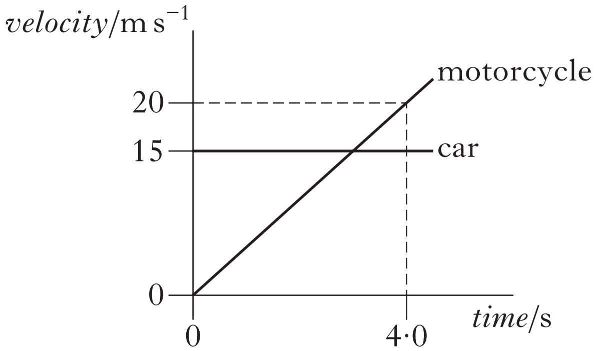
21. A car is travelling at a constant speed of 15 m s^{-1} along a straight, level road.

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 5·0 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**

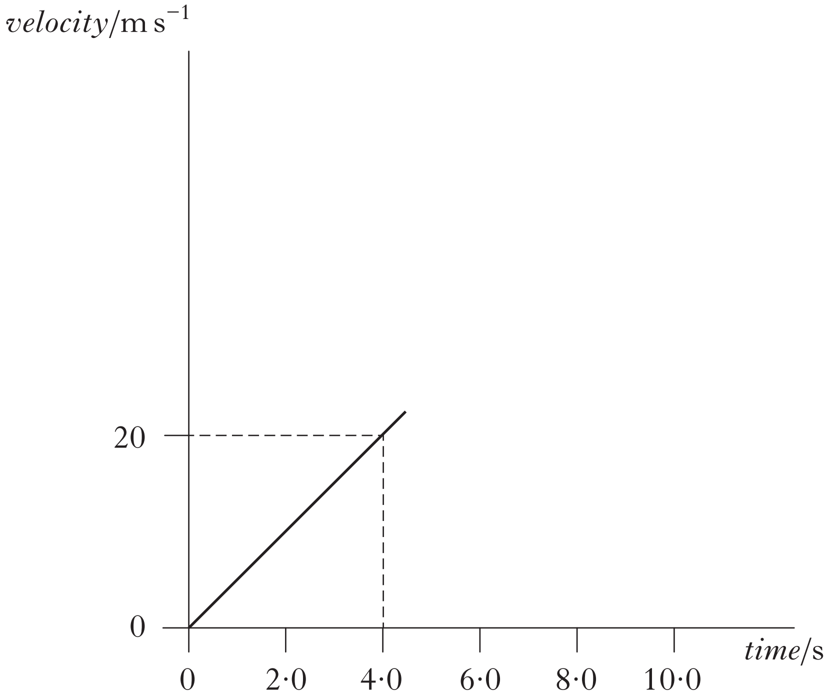
Marks

21. (continued)

(*d*) The driving force on the motorcycle reaches its maximum value at 5·0 s and then remains constant.

Sketch the velocity-time graph shown below and extend the graph to show how the velocity of the motorcycle varies with time between 4·0 s and 10·0 s.

Additional numerical values on the velocity axis are **not** required.



1

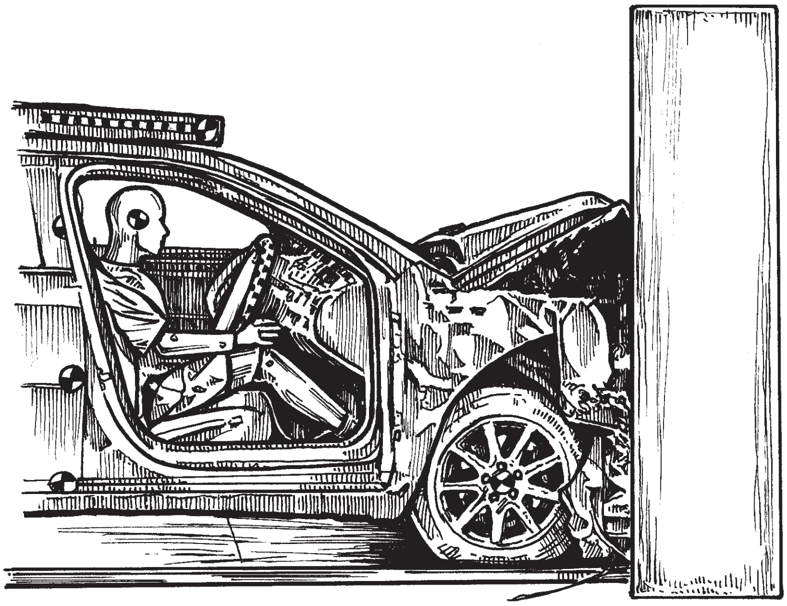
(7)

[Turn over

Marks

22. 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 0·48 m while coming to rest.

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

(*d*) This seatbelt is designed to stretch slightly during the collision.

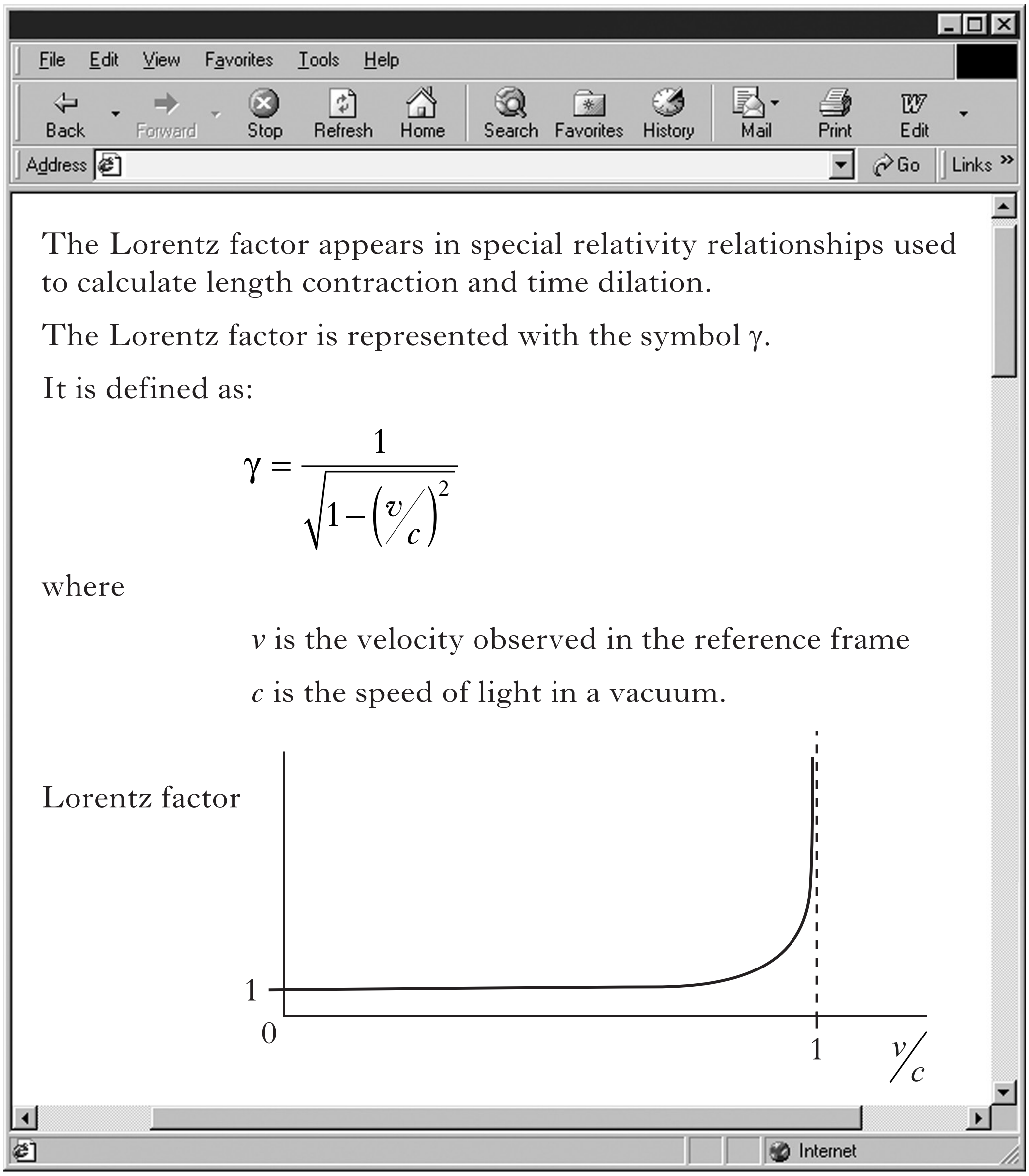
Explain, in terms of forces, an advantage of this design. **2**

(8)

23. Estimate the gravitational force of attraction between two students sitting beside each other.

Clearly show your working for the calculation and any estimates you have made. **(3)**

24. A page from a website on special relativity is shown.



The Lorentz factor appears in special relativity relationships used to calculate length contraction and time dilation.

The Lorentz factor is represented with the symbol γ.

It is defined as:

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

where

v is the velocity observed in the reference frame

c is the speed of light in a vacuum.

(*a*) Explain what is meant by the term *length contraction*. **1**

(*b*) Calculate the Lorentz factor when the ratio $\frac{v}{c} = 0{\cdot}80$. **1**

(*c*) Length contraction calculations use the relationship

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

where the symbols have their usual meanings.

State this relationship in terms of l', l and γ. **1**

(*d*) Explain, in terms of the Lorentz factor, why an observer can ignore relativistic effects for an object which is moving with a velocity much less than c. **2**

(5)

Marks

25. (*a*) Experimental work at CERN has been described as "*recreating the conditions that occurred just after the Big Bang*".

Describe what scientists mean by the *Big Bang theory* and give **one** piece of evidence which supports this theory. **2**

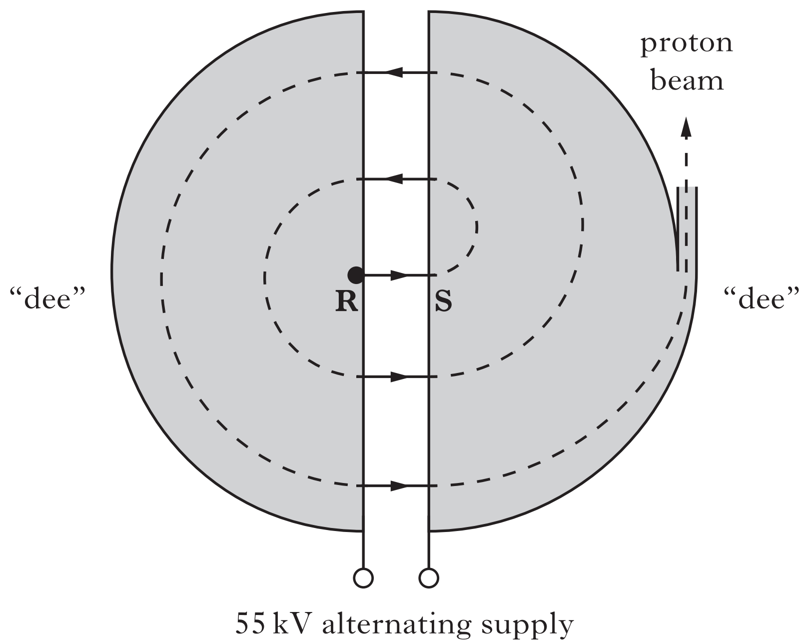
(*b*) During a television programme the presenter states, "*Looking through a telescope at the night sky is like looking back in time*".

Use physics principles to comment on this statement. **3**

(5)

26. A cyclotron is used in a hospital to accelerate protons that are then targeted to kill cancer cells.

The cyclotron consists of two D-shaped, hollow metal structures called "dees", placed in a vacuum. The diagram shows the cyclotron viewed from above.



Protons are released from rest at **R** and are accelerated across the gap between the "dees" by a voltage of 55 kV.

(*a*) (i) Show that the work done on a proton as it accelerates from **R** to **S** is $8{\cdot}8 \times 10^{-15}$ J. **1**

(ii) Calculate the speed of a proton as it reaches **S**. **2**

(*b*) Inside the "dees" a uniform magnetic field acts on the protons.

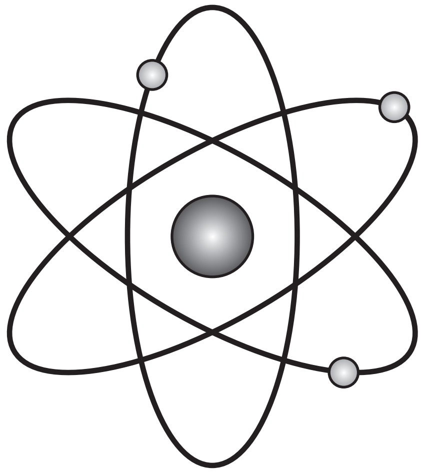
Determine the direction of this magnetic field. **1**

(*c*) Explain why an alternating voltage is used in the cyclotron. **2**

(6)

Marks

27. A science textbook contains the following diagram of an atom.

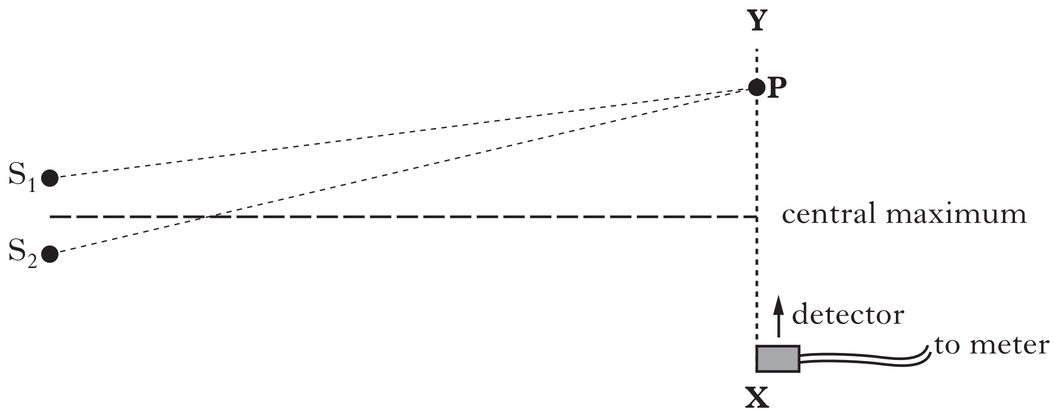


Use your knowledge of physics to comment on this diagram. **(3)**

[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**

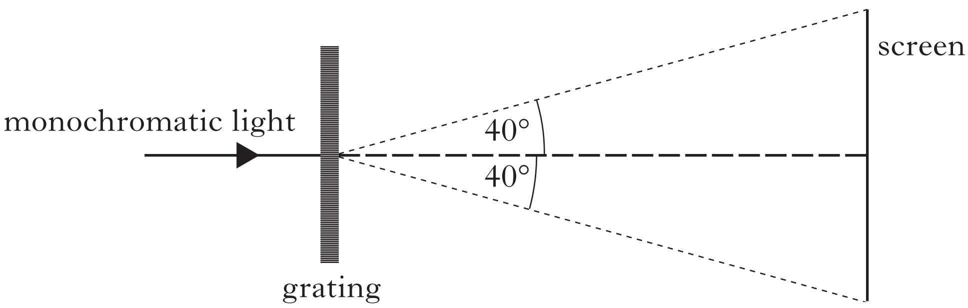
(ii) The **third** maximum from the central maximum is located at P.

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*) (i) 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**

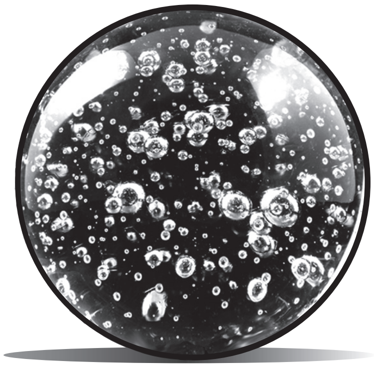
(ii) The experiment is now repeated using a source of monochromatic red light.

How does the total number of maxima visible on the screen compare to the answer to part (*b*)(i)?

Justify your answer. **2**

(8)

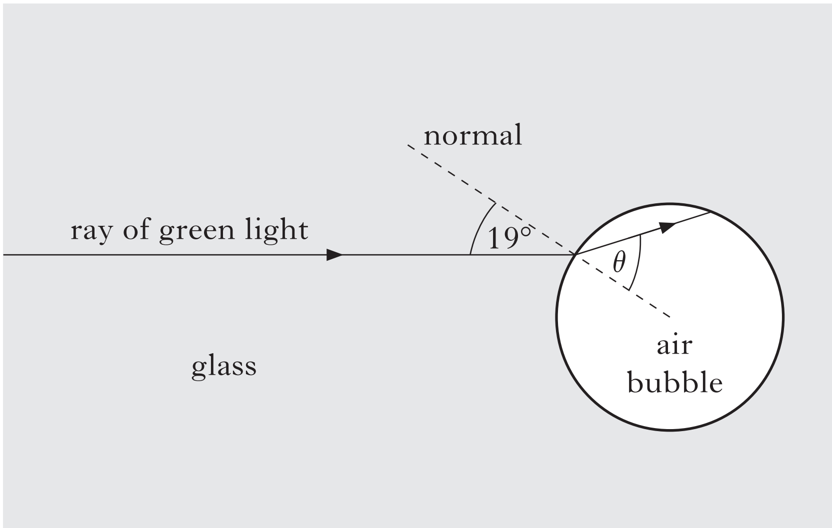
29. A student places a glass paperweight containing air bubbles on a sheet of white paper.



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**

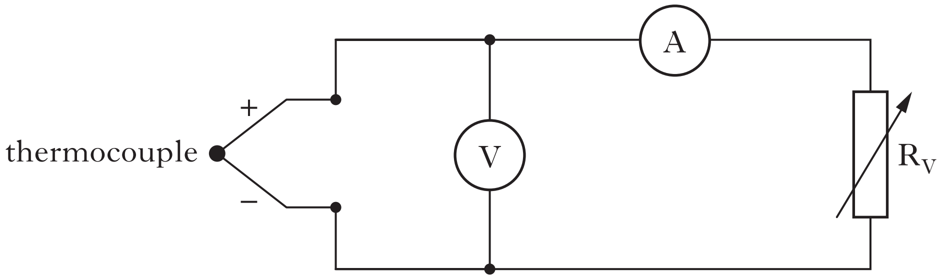
(5)

[Turn over

Marks

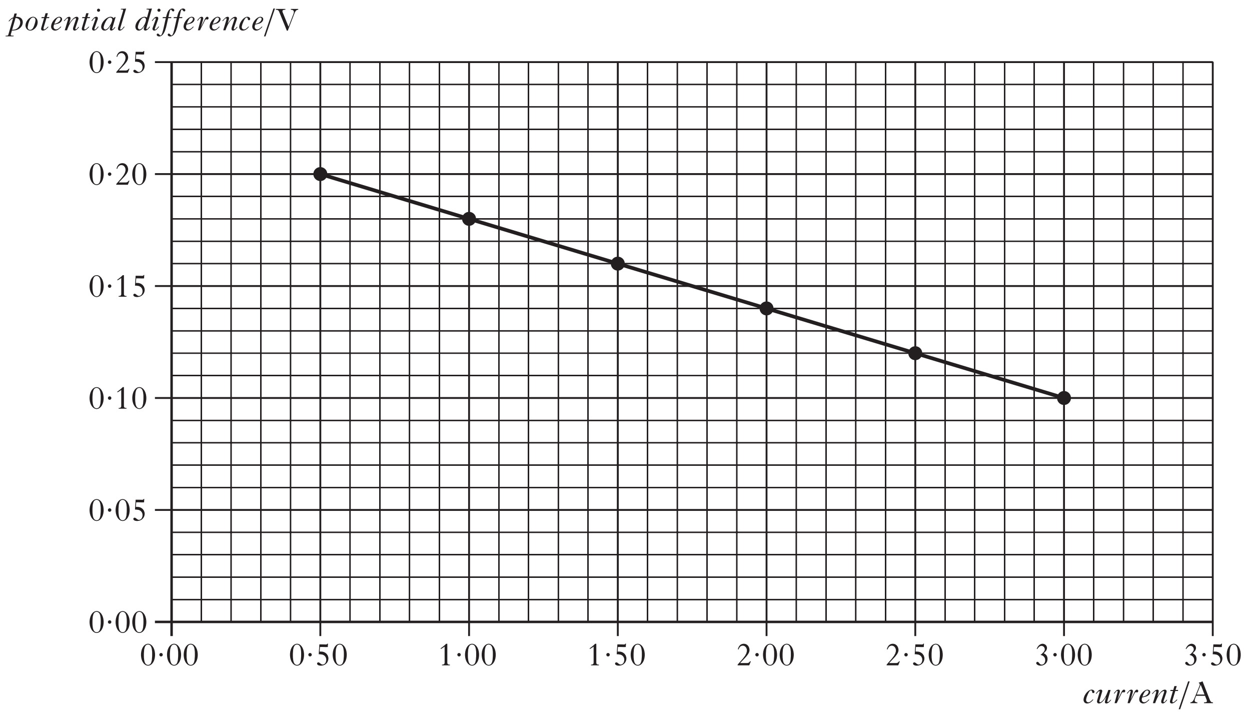
30. A thermocouple is a device that produces an e.m.f. when heated.

(*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.

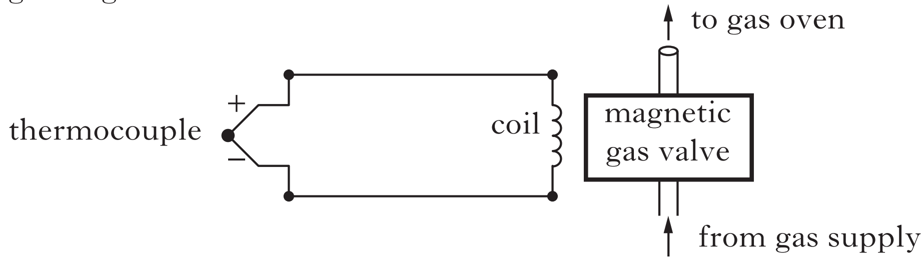
The graph of p.d. against current is shown.



Use information from the graph to find:

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

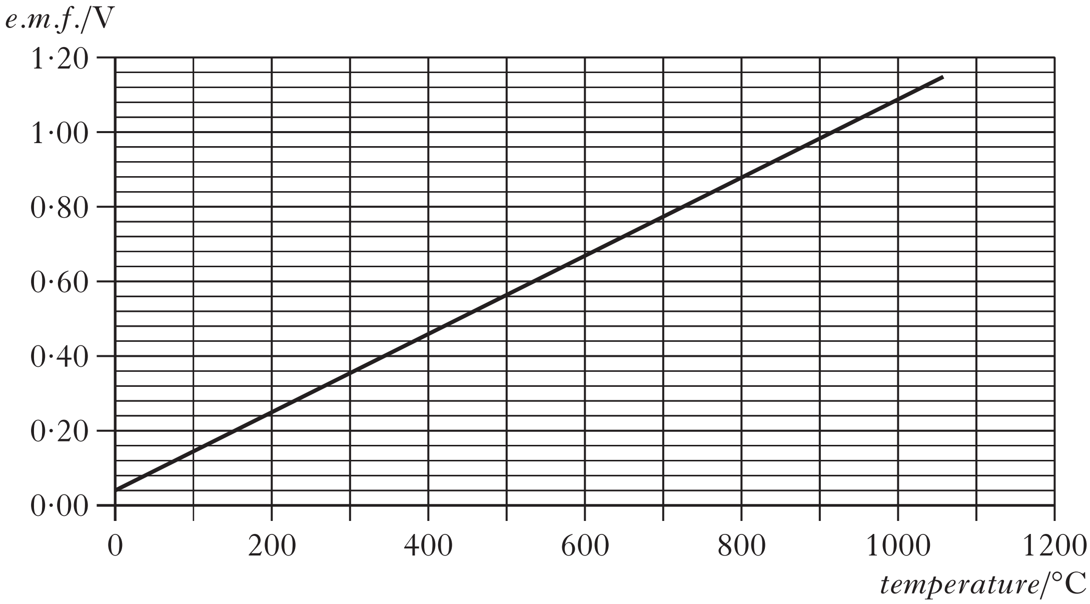
(ii) the internal resistance of the thermocouple. **2** (*b*) A **different** thermocouple is to be used as part of a safety device in a gas oven. The safety device turns off the gas supply to the oven if the flame goes out. The thermocouple is connected to a coil of resistance 0·12 Ω which operates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

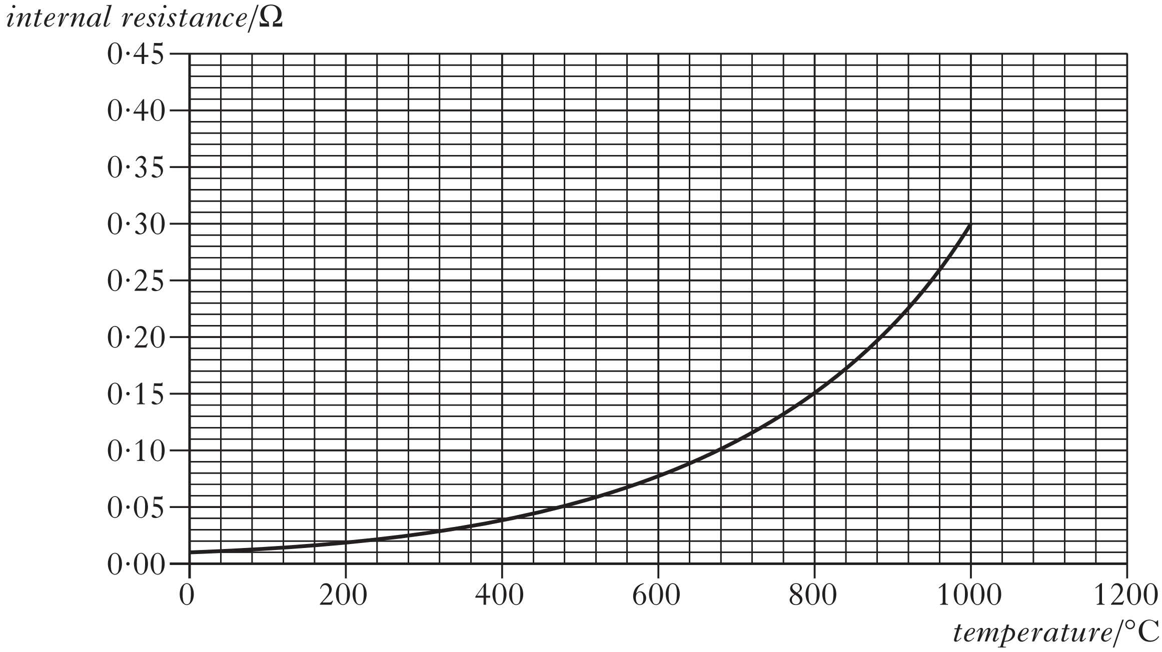


When the current in the coil is less than 2·5 A, the gas valve is closed.

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)

Marks

31. (*a*) Use band theory to explain how electrical conduction takes place in a pure semiconductor such as silicon.

Your explanation should include the terms: *electrons*, *valence band* and *conduction band*. **2**

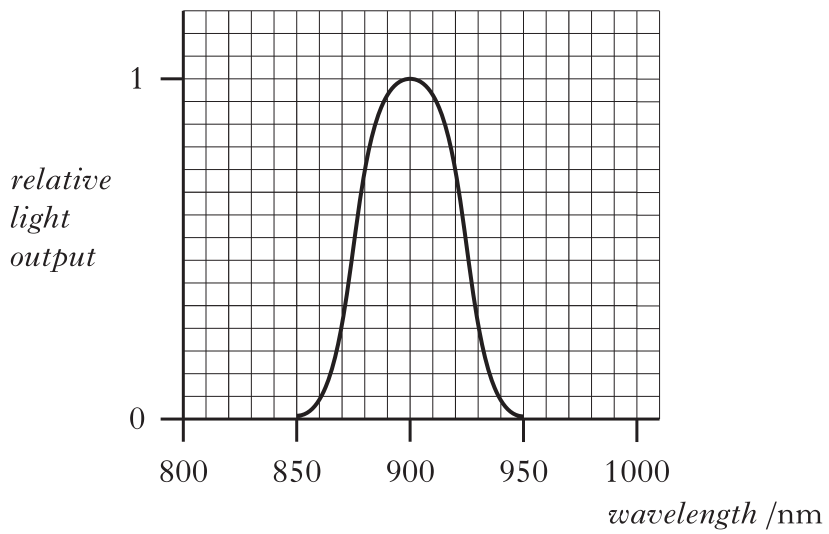
(*b*) A light emitting diode (LED) is a p-n junction which emits light. The table gives the colour of some LEDs and the voltage across the junction required to switch on the LED.

Colour of LED	*Switch on voltage*/V
Green	2·0
Red	1·4
Yellow	1·7

Using this data, suggest a possible value for the switch on voltage of an LED that emits blue light. **1**

(*c*) The remote control for a television contains an LED.

The graph shows the range of wavelengths emitted by the LED and the relative light output.



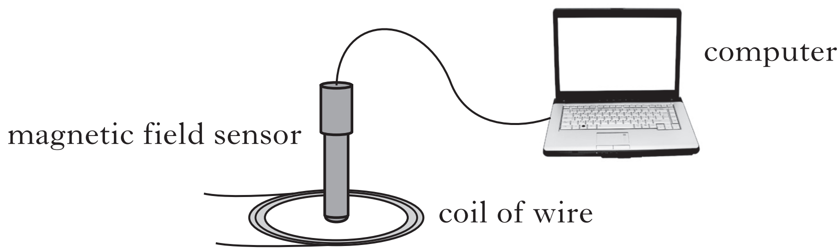
Calculate the maximum energy of a photon emitted from this LED. **3**

(6)

Marks

32. A student is investigating how the magnetic field strength at the centre of a coil of wire depends on the direct current in the coil.

The strength of the magnetic field is measured with a magnetic field sensor placed in the centre of the coil. The sensor is connected to a computer as shown.



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

(*a*) The student designs a circuit to vary and measure the current in the coil of wire.

The circuit symbol for a coil of wire is shown.

Draw a circuit diagram to show how the current in the coil could be varied and measured. **2**

(*b*) The following results are obtained.

Current in coil/A	*Magnetic field strength*/T
0·20	$1 \cdot 4 \times 10^{-4}$
0·40	$2 \cdot 4 \times 10^{-4}$
0·60	$3 \cdot 0 \times 10^{-4}$
0·80	$3 \cdot 6 \times 10^{-4}$
1·00	$4 \cdot 6 \times 10^{-4}$

Using square ruled paper, plot a graph of magnetic field strength against current. **2**

(c) The student concludes that the results show that there is a systematic uncertainty in the measurements.

Suggest a reason why the student has come to this conclusion. **1**

[Turn over for Question 32(*d*) on *Page twenty-two*

32. (continued)

(*d*) The magnetic field strength B at the centre of a coil of wire is given by the relationship

$$B = 6{\cdot}3 \times 10^{-7}\,\frac{NI}{r}$$

where B is the magnetic field strength in tesla

N is the number of turns in the coil

I is the current in the coil in amperes

r is the radius of the coil in metres.

The number of turns in the coil used by the student is 30.

Use this relationship and the gradient of your graph to calculate the radius of the coil. **3**

(8)

[*END OF QUESTION PAPER*]

[BLANK PAGE]

[BLANK PAGE]

$d = \bar{v}t$

$s = \bar{v}t$

$v = u + at$

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

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

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

$W = mg$

$F = ma$

$E_w = Fd$

$E_p = mgh$

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

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

$p = mv$

$Ft = mv - mu$

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

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

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

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

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

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

$v = H_0 d$

$E_w = QV$

$E = mc^2$

$E = hf$

$E_k = hf - hf_0$

$E_2 - E_1 = hf$

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

$v = f\lambda$

$d\sin\theta = m\lambda$

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

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

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

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

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

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

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

$Q = It$

$V = IR$

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

$R_T = R_1 + R_2 + \ldots$

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

$E = V + Ir$

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

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

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

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

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

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

[BLANK PAGE]