National
Qualifications
SPECIMEN ONLY

S857/76/02

Physics
Section 1 — Questions

Date — Not applicable

Duration — 2 hours 30 minutes

Instructions for the completion of Section 1 are given on *page 02* of your question and answer booklet S857/76/01.

Record your answers on the answer grid on *page 03* of your question and answer booklet.

Reference may be made to the data sheet on *page 02* of this booklet and to the relationships sheet S857/76/11.

You must leave your answer booklet on your desk; if you do not, you could lose all the marks for this paper.

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DATA SHEET

COMMON PHYSICAL QUANTITIES

Quantity	Symbol	Value	Quantity	Symbol	Value
Speed of light in vacuum	c	3.00×10^{8} m s^{-1}	Planck's constant	h	6.63×10^{-34} J s
Magnitude of the charge on an electron	e	1.60×10^{-19} C	Mass of electron	m_e	9.11×10^{-31} kg
Universal Constant of Gravitation	G	6.67×10^{-11} m^3 kg^{-1} s^{-2}	Mass of neutron	m_n	1.675×10^{-27} kg
Gravitational acceleration on Earth	g	9.8 m s^{-2}	Mass of proton	m_p	1.673×10^{-27} kg
Hubble's constant	H_0	2.3×10^{-18} s^{-1}	Speed of sound in air	v_{air}	3.40×10^{2} m 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 }	Infrared
	10 590 }	
Helium-neon	633	Red

PROPERTIES OF SELECTED MATERIALS

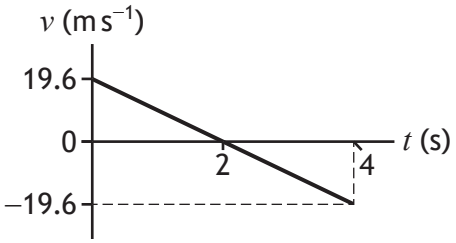
Substance	Density (kg m^{-3})	Melting point (K)	Boiling point (K)
Aluminium	2.70×10^{3}	933	2792
Copper	8.96×10^{3}	1357	2833
Ice	9.20×10^{2}	273	. . . .
Sea Water	1.02×10^{3}	264	377
Water	1.00×10^{3}	273	373
Air	1.29	. . . .	. . . .
Hydrogen	9.0×10^{-2}	14	20

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

SECTION 1 — 20 marks

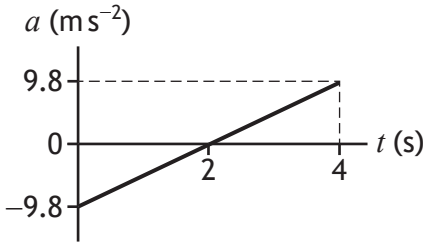
Attempt ALL questions

1. The following velocity-time (v–t) graph represents the vertical motion of a ball.

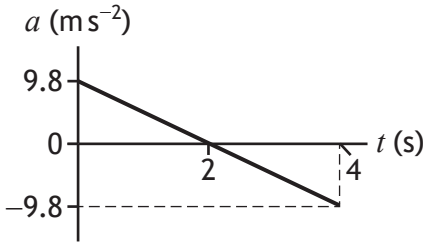


Which of the following acceleration-time (a–t) graphs represents the same motion?

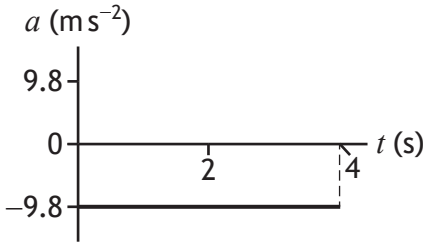
A



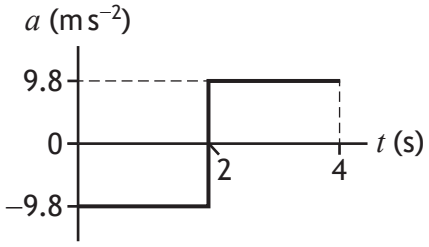
B



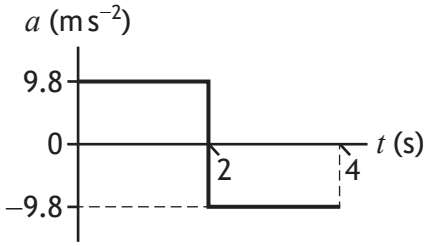
C



D



E



2. A hot air balloon is moving vertically.

At a height of 50 m a sandbag is released.

The sandbag takes 3.0 s to reach the ground.

The effects of air resistance can be ignored.

The initial velocity of the sandbag on release is

A 2.0 $m\,s^{-1}$ upwards

B 2.0 $m\,s^{-1}$ downwards

C 17 $m\,s^{-1}$ upwards

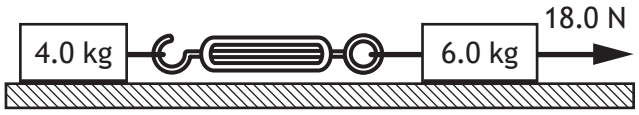
D 17 $m\,s^{-1}$ downwards

E 31 $m\,s^{-1}$ upwards.

3. 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 3.6 N

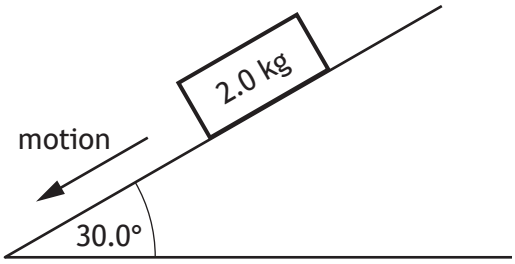
B 7.2 N

C 9.0 N

D 10.8 N

E 18.0 N.

4. A block of wood slides with a constant velocity down a slope. The slope makes an angle of 30.0° with the horizontal as shown. The mass of the block is 2.0 kg.



The magnitude of the force of friction acting on the block is

A 1.0 N

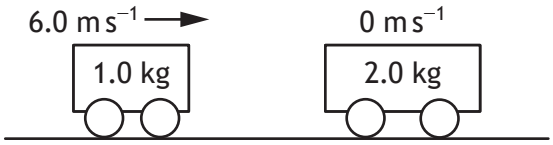
B 1.7 N

C 9.8 N

D 17 N

E 19.6 N.

5. The diagram shows the masses and velocities of two trolleys just before they collide on a level bench.



After the collision, the trolleys move along the bench joined together.

The kinetic energy lost in this collision is

A 0.0 J

B 6.0 J

C 12 J

D 18 J

E 24 J.

[Turn over

6. Two small asteroids are 12 m apart.

The masses of the asteroids are 2.0×10^3 kg and 0.050×10^3 kg.

The gravitational force acting between the asteroids is

A 1.2×10^{-9} N

B 4.6×10^{-8} N

C 5.6×10^{-7} N

D 1.9×10^{-6} N

E 6.8×10^3 N.

7. Evidence supporting the existence of dark energy comes from

A estimations of the mass of galaxies

B the darkness of the sky (Olbers' paradox)

C large numbers of galaxies showing redshift, rather than blueshift

D the accelerating rate of expansion of the Universe

E the abundance of the elements hydrogen and helium in the Universe.

8. The siren on an ambulance is emitting sound with a constant frequency of 900 Hz. The ambulance is travelling at a constant speed of 25 m s^{-1} as it approaches and passes a stationary observer.

Which row in the table shows the frequency of the sound heard by the observer as the ambulance approaches and as it moves away from the observer?

	Frequency as ambulance approaches (Hz)	**Frequency as ambulance moves away (Hz)**
A	971	838
B	971	900
C	900	838
D	838	900
E	838	971

9. A student makes the following statements about particles in electric fields.

I A neutron experiences a force in an electric field.

II When an alpha particle is moved in an electric field work is done.

III An electric field applied to a conductor causes the free electrons in the conductor to move.

Which of the statements is/are correct?

A II only

B III only

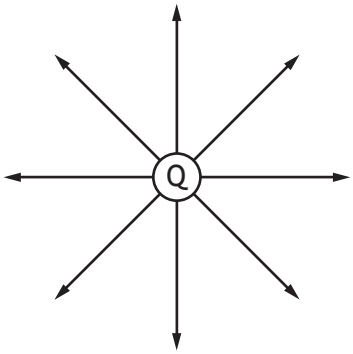
C I and II only

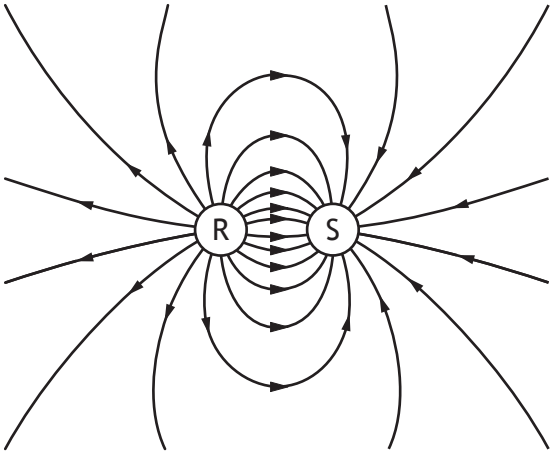
D II and III only

E I, II and III

[Turn over

10. 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

11. A student makes the following statements about an electron.

I An electron is a boson.

II An electron is a lepton.

III An electron is a fermion.

Which of these statements is/are correct?

A I only

B II only

C III only

D I and II only

E II and III only

12. The last two changes in a radioactive decay series are shown below.

A Bismuth nucleus emits a beta particle and its product, a Polonium nucleus, emits an alpha particle.

$$^{P}_{Q}Bi \xrightarrow[\text{decay}]{\beta} {}^{R}_{S}Po \xrightarrow[\text{decay}]{\alpha} {}^{208}_{82}Pb$$

Which numbers are represented by P, Q, R, and S?

	P	Q	R	S
A	210	83	208	81
B	210	83	210	84
C	211	85	207	86
D	212	83	212	84
E	212	85	212	84

[Turn over

13. A photon of energy 6.40×10^{-19} J is incident on a metal plate.

This causes photoemission to take place.

The work function of the metal is 4.20×10^{-19} J.

The maximum speed of the photoelectron is

A 1.19×10^{6} m s^{-1}

B 9.60×10^{5} m s^{-1}

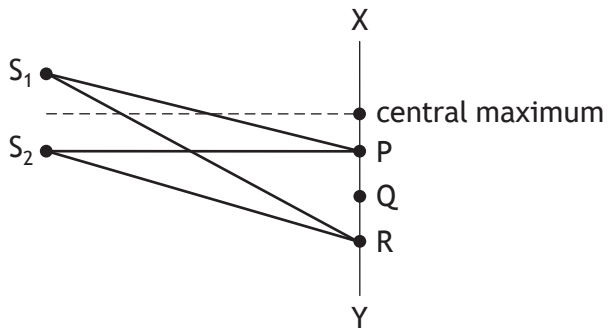
C 6.95×10^{5} m s^{-1}

D 6.79×10^{5} m s^{-1}

E 4.91×10^{5} m s^{-1}.

14. S_1 and S_2 are sources of coherent waves.

An interference pattern is obtained between X and Y.



The first order maximum occurs at P, where S_1P = 200 mm and S_2P = 180 mm.

For the third order maximum at R, the path difference (S_1R–S_2R) is

A 20 mm

B 30 mm

C 40 mm

D 50 mm

E 60 mm.

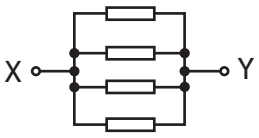
15. A ray of red light travels from air into water.

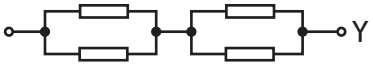
Which row in the table describes the change, if any, in speed and frequency of a ray of red light as it travels from air into water?

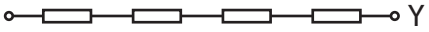
	Speed	**Frequency**
A	stays constant	decreases
B	increases	increases
C	increases	stays constant
D	decreases	stays constant
E	decreases	decreases

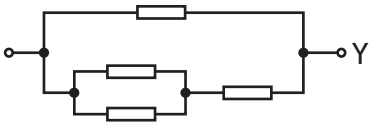
16. In the diagrams below, each resistor has the same resistance.

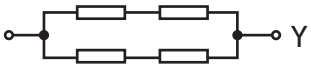
Which combination has the least value of the effective resistance between the terminals X and Y?

A 

B 

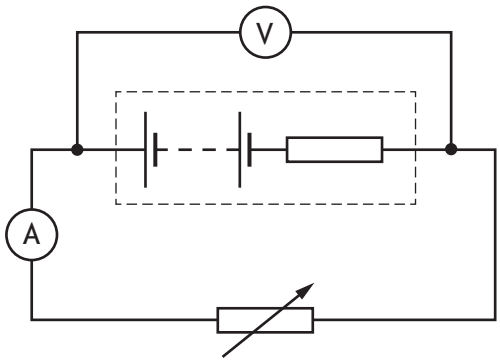
C 

D 

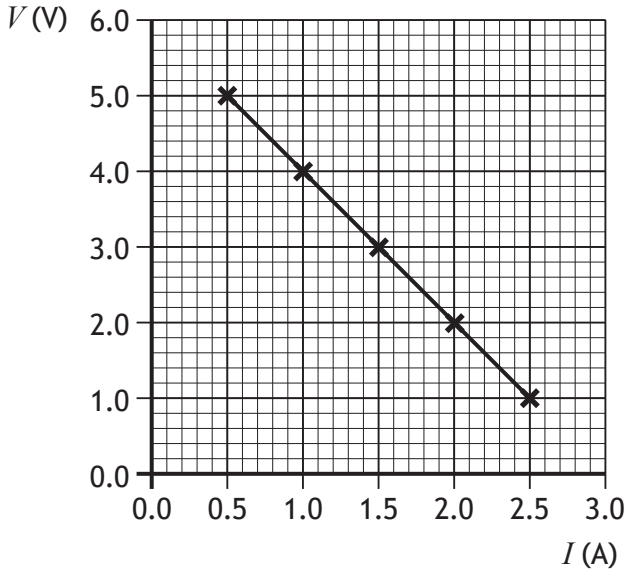
E 

[Turn over

17. A student carries out an experiment to determine the EMF and internal resistance of a battery using the circuit shown.



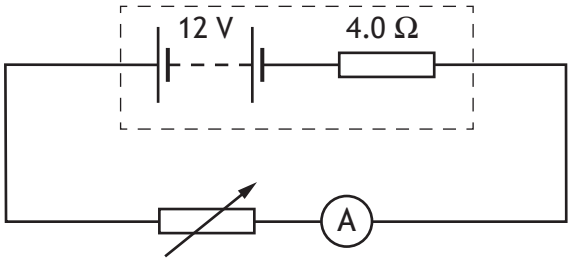
The resistance of the variable resistor is altered and readings of voltage V and current I are taken. These readings are used to produce the following graph.



Which row in the table shows the EMF and internal resistance of the battery?

	EMF (V)	**Internal resistance (Ω)**
A	2.0	6.0
B	5.0	0.50
C	5.0	2.0
D	6.0	0.50
E	6.0	2.0

18. A circuit is set up as shown.



The resistance of the variable resistor is set to 6.0 Ω.

The lost volts due to the internal resistance of the battery is

A 1.2 V

B 4.8 V

C 6.0 V

D 7.2 V

E 8.0 V.

19. A student makes the following statements about red and blue LEDs.

I Red LEDs emit photons of longer wavelength than blue LEDs.

II The gap between the valence band and the conduction band is larger for red LEDs than blue LEDs.

III The potential difference across an LED determines the wavelength of the photons emitted.

Which of these statements is/are correct?

A I only

B II only

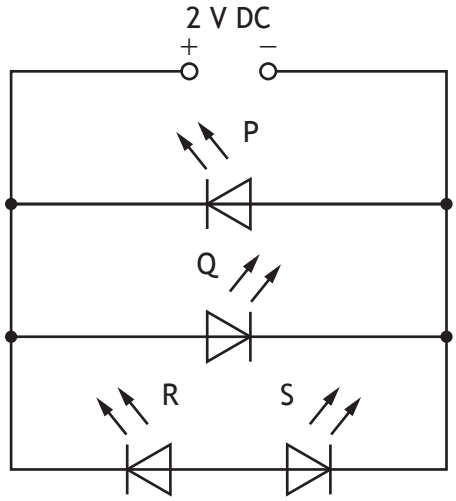
C III only

D I and II only

E I, II and III

[Turn over

20. A student connects four identical light emitting diodes (LEDs) to a 2 V DC supply as shown.



Which of the LEDs P, Q, R, and S will light?

A P only

B Q only

C P and Q only

D P and R only

E Q and S only

[END OF SECTION 1. NOW ATTEMPT THE QUESTIONS IN SECTION 2 OF YOUR QUESTION AND ANSWER BOOKLET]

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National Qualifications SPECIMEN ONLY

Mark

S857/76/01

Physics
Section 1 — Answer grid and Section 2

Date — Not applicable

Duration — 2 hours 30 minutes

S8577601

Fill in these boxes and read what is printed below.

Full name of centre

Town

Forename(s)

Surname

Number of seat

Date of birth

Day Month Year

Scottish candidate number

Total marks — 130

SECTION 1 — 20 marks
Attempt ALL questions.
Instructions for the completion of Section 1 are given on *page 02*.

SECTION 2 — 110 marks
Attempt ALL questions.

You may use a calculator.
Reference may be made to the data sheet on *page 02* of the question paper S857/76/02 and to the relationships sheet S857/76/11.
Care should be taken to give an appropriate number of significant figures in the final answers to calculations.
Write your answers clearly in the spaces provided in this booklet. Additional space for answers and rough work is provided at the end of this booklet. If you use this space you must clearly identify the question number you are attempting. Any rough work must be written in this booklet. Score through your rough work when you have written your final copy.
Use **blue** or **black** ink.
Do not remove any exam materials. You must leave this booklet on your desk; if you do not, you could lose all the marks for this paper.

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SECTION 1 — 20 marks

The questions for Section 1 are contained in the question paper S857/76/02.

Read these and record your answers on the answer grid on *page 03*.

Use **blue** or **black** ink. Do NOT use gel pens or pencil.

1. The answer to each question is **either** A, B, C, D or E. Decide what your answer is, then fill in the appropriate bubble (see sample question below).

2. There is **only one correct** answer to each question.

3. Any rough work must be written in the additional space for answers and rough work at the end of this booklet.

Sample question

The energy unit measured by the electricity meter in your home is the

A ampere

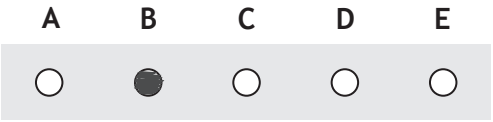
B kilowatt-hour

C watt

D coulomb

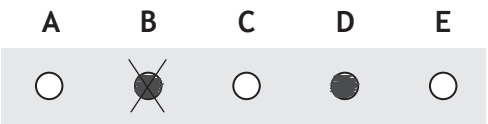
E volt.

The correct answer is **B** — kilowatt-hour. The answer **B** bubble has been clearly filled in (see below).

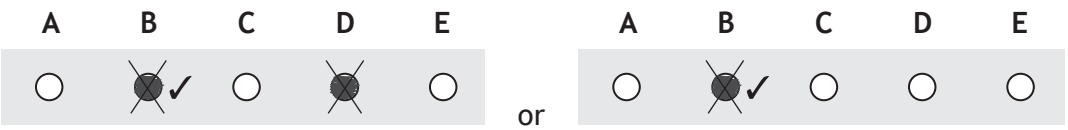


Changing an answer

If you decide to change your answer, cancel your first answer by putting a cross through it (see below) and fill in the answer you want. The answer below has been changed to **D**.



If you then decide to change back to an answer you have already scored out, put a tick (✓) to the **right** of the answer you want, as shown below:



SECTION 1 — Answer grid

0BJ20AE1

	A	B	C	D	E
1	○	○	○	○	○
2	○	○	○	○	○
3	○	○	○	○	○
4	○	○	○	○	○
5	○	○	○	○	○
6	○	○	○	○	○
7	○	○	○	○	○
8	○	○	○	○	○
9	○	○	○	○	○
10	○	○	○	○	○
11	○	○	○	○	○
12	○	○	○	○	○
13	○	○	○	○	○
14	○	○	○	○	○
15	○	○	○	○	○
16	○	○	○	○	○
17	○	○	○	○	○
18	○	○	○	○	○
19	○	○	○	○	○
20	○	○	○	○	○

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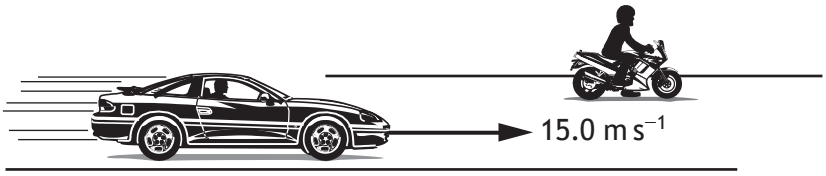
SECTION 2 — 110 marks

Attempt ALL questions

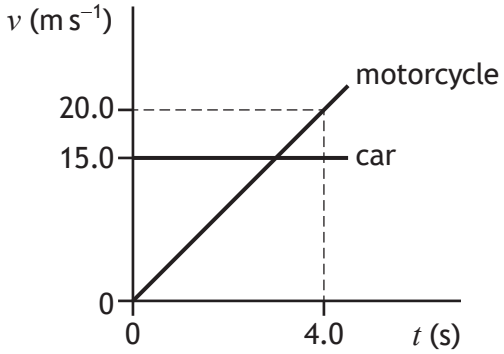
1. A car is travelling at a constant speed of 15.0 m s^{-1} along a straight, level road.

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) Calculate the initial acceleration of the motorcycle. **3**

Space for working and answer

1. (continued)

(b) Determine the distance between the car and motorcycle at 4.0 s. **4**

Space for working and answer

(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) Determine the frictional force acting on the motorcycle at this time. **4**

Space for working and answer

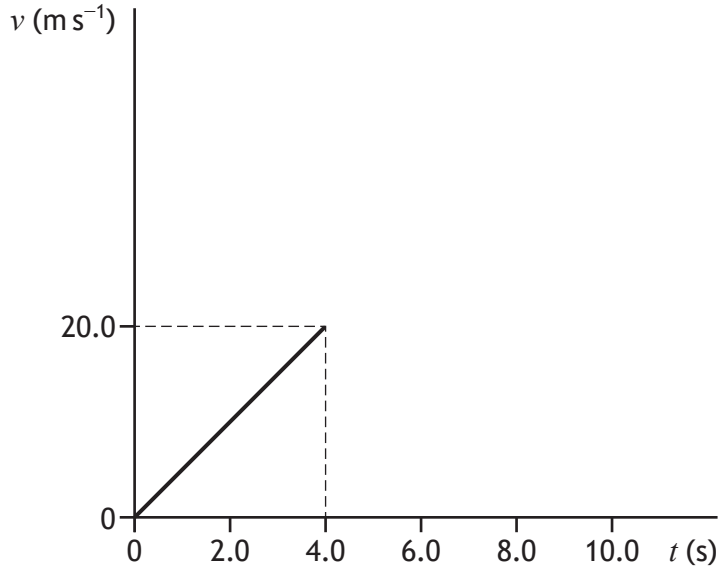
(ii) State whether the driving force must be increased, decreased or kept constant to maintain a constant acceleration.

Justify your answer. **2**

1. (continued)

(d) The driving force on the motorcycle reaches its maximum value at 5.0 s and then remains constant.

The velocity-time graph for the motorcycle during the first 4.0 s is shown below.



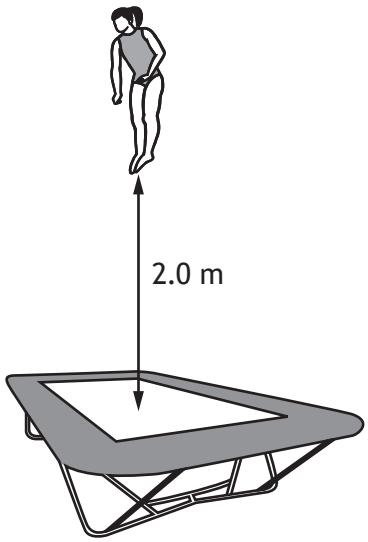
Extend the graph to show how the velocity of the motorcycle varies between 4.0 s and 10.0 s.

Additional numerical values on the velocity axis are **not** required. **1**

(An additional graph, if required, can be found on *page 42*.)

[Turn over

2. (a) A gymnast of mass 42 kg is practising on a trampoline.



(i) At maximum height, the gymnast's feet are 2.0 m above the trampoline.

Show that the speed of the gymnast, as they land on the trampoline, is 6.3 m s^{-1}. **2**

Space for working and answer

(ii) The gymnast rebounds with a speed of 5.3 m s^{-1}.

Calculate the magnitude of the change in momentum of the gymnast. **3**

Space for working and answer

2. (a) (continued)

(iii) The gymnast was in contact with the trampoline for 0.50 s.

Calculate the magnitude of the average force exerted by the trampoline on the gymnast. **3**

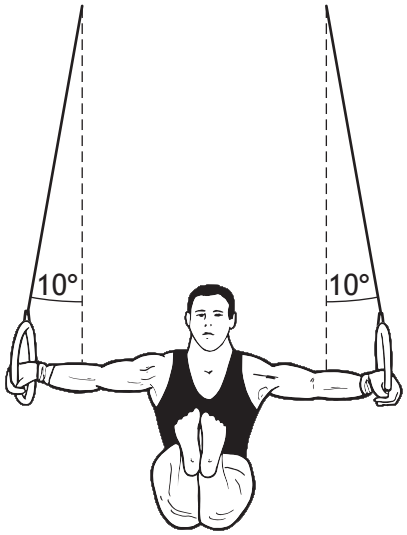
Space for working and answer

[Turn over

2. (continued)

(b) Another gymnast is practising on a piece of equipment called the rings. The gymnast grips two wooden rings suspended above the gym floor by strong vertical ropes, as shown.

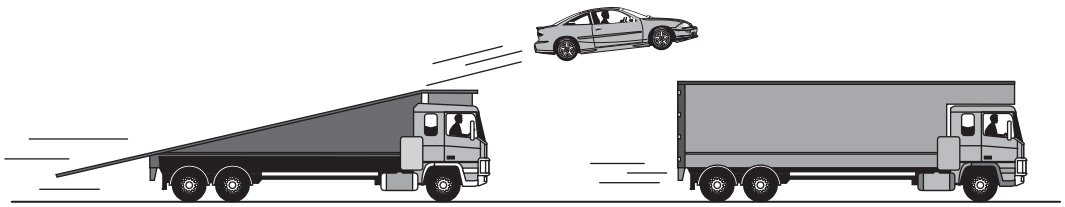
The gymnast now stretches out their arms until each rope makes an angle of 10° with the vertical, as shown.



Explain why the tension in each rope increases as the gymnast stretches out their arms. **1**

3. A stunt is being carried out during the making of a film.

A car is to be driven up a ramp on a moving lorry by a stunt driver, who will attempt to land the car safely on the roof of a second moving lorry. The car is to stop on the roof of the second lorry while this lorry is still moving.



Using your knowledge of physics, comment on the challenges involved in carrying out the stunt successfully. **3**

[Turn over

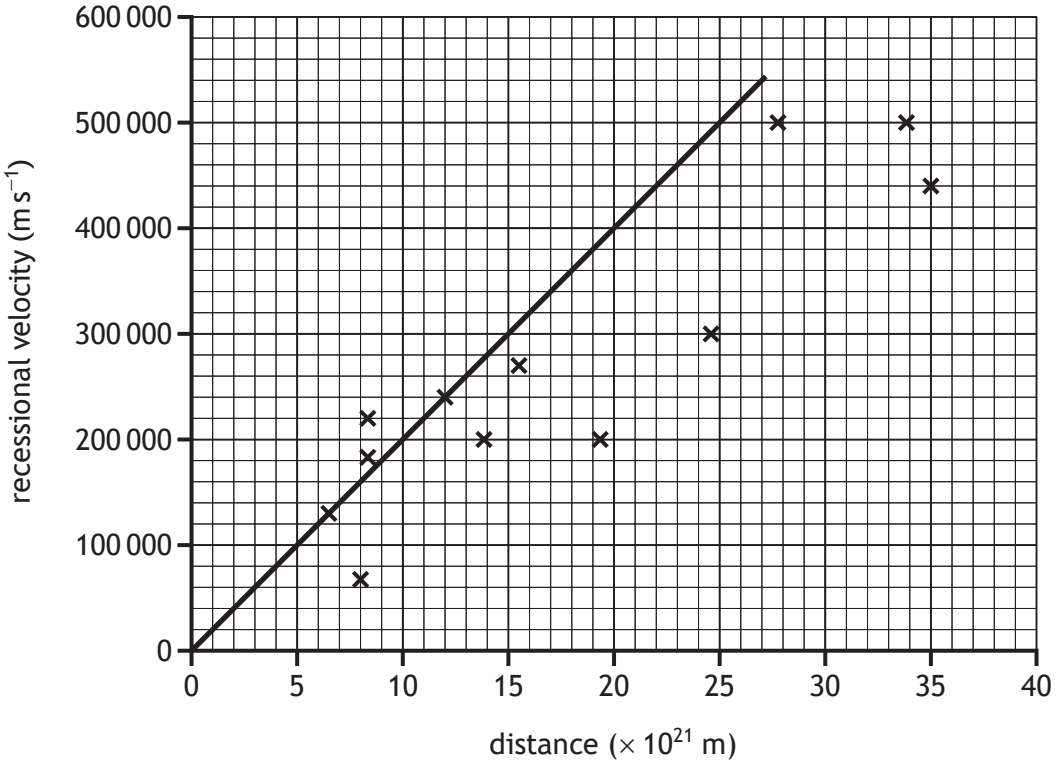
DO NOT WRITE IN THIS MARGIN

3. (continued)

4. The Hubble-Lemaître Law states that the Universe is expanding. The expanding Universe is one piece of evidence that supports the Big Bang theory.

(a) State one other piece of evidence that supports the Big Bang theory. **1**

(b) A student plots some of the original data from the 1929 paper by Edwin Hubble and adds the line shown in order to determine a value for the Hubble constant H_0.



The student calculates the gradient of their line and obtains a value for the Hubble constant of 2.0×10^{-17} s^{-1}.

The age of the Universe can be calculated using the relationship

$$\text{age of Universe} = \frac{1}{H_0}$$

[Turn over

4. (b) (continued)

(i) Calculate the age of the Universe, in years, obtained when using the student's value for the Hubble constant. **2**

Space for working and answer

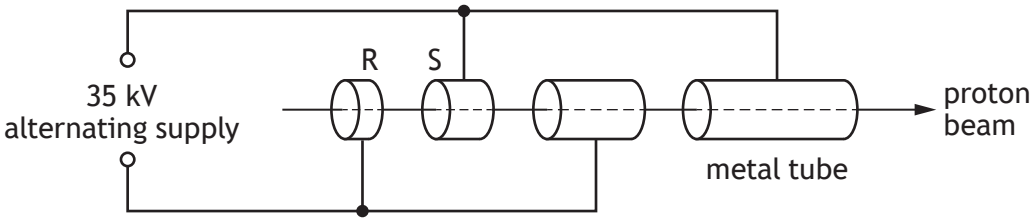
(ii) The current estimate for the age of the Universe is 13.8×10^9 years.

(A) State why the value obtained in (b) (i) is different from the current estimate for the age of the Universe. **1**

(B) Suggest a change that the student could make to their graph to obtain a value closer to the current estimate for the age of the Universe. **1**

5. A linear accelerator is used to accelerate protons.

The accelerator consists of hollow metal tubes placed in a vacuum.



The diagram shows the path of the protons through the accelerator.

Protons are accelerated across the gaps between the tubes by a potential difference of 35 kV.

(a) The protons are travelling at 1.2×10^{6} m s^{-1} at point R.

(i) Show that the work done on a proton as it accelerates from R to S is 5.6×10^{-15} J. **2**

Space for working and answer

(ii) Determine the speed of the proton as it reaches S. **5**

Space for working and answer

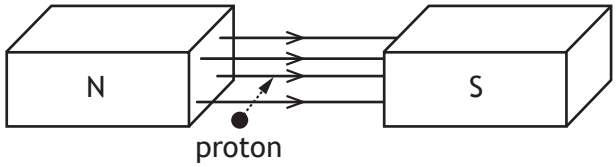
5. (continued)

(b) (i) Explain why an alternating supply is used in the linear accelerator. **1**

(ii) Suggest one reason why the lengths of the tubes increase along the accelerator. **1**

(c) In the Large Hadron Collider (LHC) beams of hadrons travel in opposite directions inside a circular accelerator and then collide. The accelerating particles are guided along the collider using strong magnetic fields.

The diagram shows a proton entering a magnetic field.



State the direction of the force acting on the proton as it enters the magnetic field. **1**

6. The Standard Model explains how the basic building blocks of matter interact, governed by four fundamental forces.

(a) Name the type of particle that is composed of a quark–antiquark pair. **1**

(b) A particle known as a positive kaon (K^+) is composed of an up quark and an anti-strange quark.

(i) The negative kaon particle (K^-) is the antiparticle of the K^+ particle.

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

(ii) The W-boson is the force-mediating particle associated with the decay of kaons.

Name the fundamental force involved in the decay of kaons. **1**

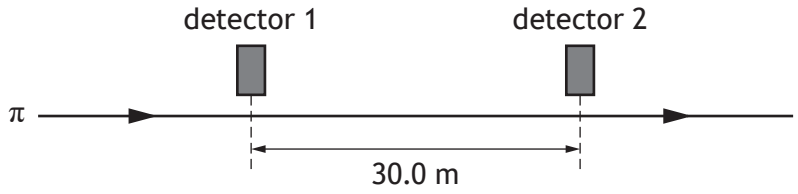
[Turn over

6. (continued)

(c) Another particle, known as a pion (π), is a product of kaon decay.

A beam of pions, travelling in a straight line at a speed of $0.95c$, passes between two detectors.

The detectors are 30.0 m apart as measured by a stationary observer.



(i) Calculate the time taken for a pion to travel between the two detectors in the frame of reference of the stationary observer. **3**

Space for working and answer

(ii) Calculate the distance between the two detectors in the frame of reference of the pions. **3**

Space for working and answer

6. (continued)

(d) Pions have a mean lifetime of 26 ns in their frame of reference.

Explain why a greater number of pions are detected at the second detector than would be expected if relativistic effects are **not** taken into account. **1**

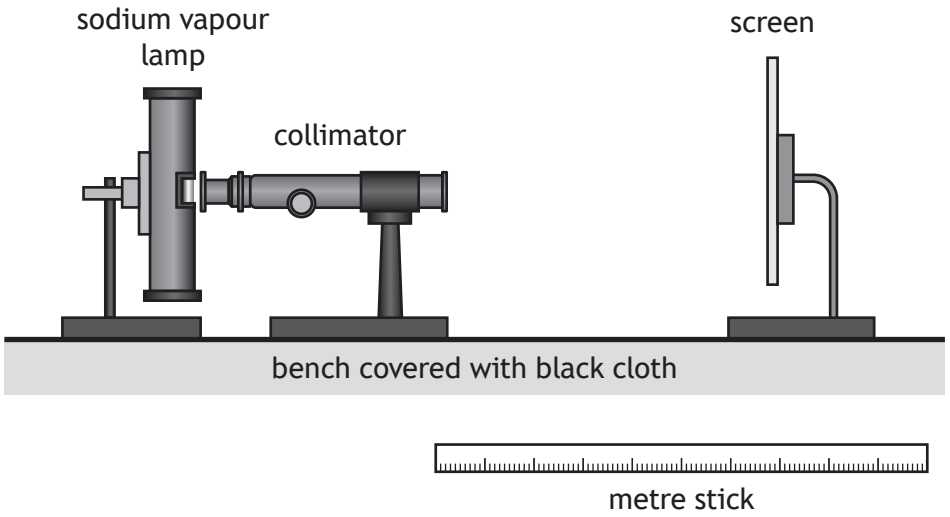
[Turn over

DO NOT WRITE IN THIS MARGIN

7. A student investigates light from a sodium vapour lamp. Sodium vapour lamps emit yellow light.

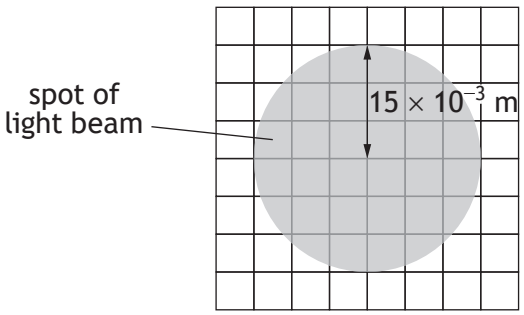
The light from the lamp is passed through a collimator. The collimator is used to produce a parallel beam of light.

The apparatus is set up in a darkened laboratory.



(a) The parallel beam is shone onto a screen. The distance between the end of the collimator and the screen is 0.40 m.

The beam produces a uniformly lit spot of radius 15×10^{-3} m as shown.



7. (a) (continued)

(i) The irradiance of the spot of light on the screen is 17 W m^{-2}.

Determine the power of the beam of light. **4**

Space for working and answer

(ii) The distance between the screen and the end of the collimator is now increased.

The spot produced on the screen has the same radius as before.

Explain why **this** experimental setup is not suitable for investigating the inverse square law. **1**

[Turn over

7. (continued)

(b) The student now looks at the beam of light through a spectroscope and views a bright yellow spectral line with a wavelength of 589.0 nm.

This light is emitted when electrons make a transition from one energy level to another within sodium atoms.

(i) State whether electrons are moving to a higher or a lower energy level when this light is emitted. **1**

(ii) Determine the difference in energy between the two energy levels in the sodium atoms that produce this yellow light. **5**

Space for working and answer

7. (b) (continued)

(iii) The student observes a second yellow spectral line at a wavelength of 589.6 nm.

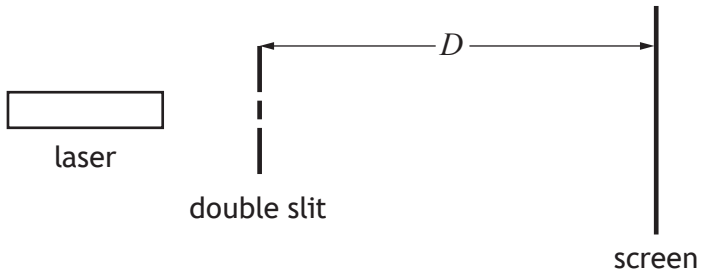
The student observes that the line at 589.0 nm is brighter than the line at 589.6 nm.

Explain the student's observation. **2**

[Turn over

8. A helium-neon laser produces a beam of monochromatic light.

A student directs this laser beam onto a double slit arrangement as shown in the diagram.



A pattern of bright red fringes is observed on the screen.

(a) Explain, in terms of waves, how bright fringes are produced. **1**

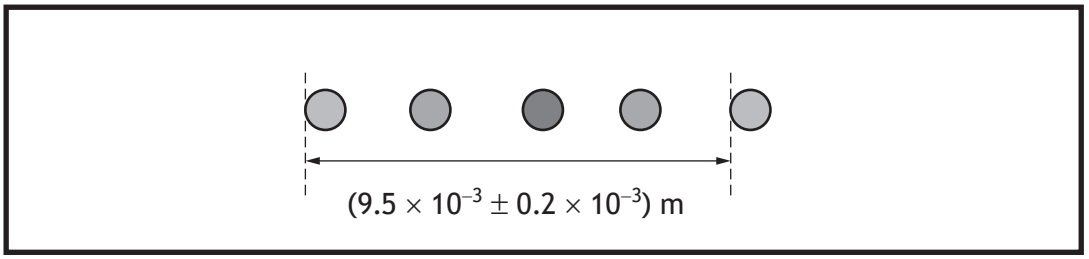
8. (continued)

(b) The average separation Δx between adjacent fringes is given by the relationship

$$\Delta x = \frac{\lambda D}{d}$$

where: λ is the wavelength of the light
D is the distance between the double slit and the screen
d is the distance between the two slits.

The diagram shows the value measured by the student of the distance between a series of fringes and the uncertainty in this measurement.



The student measures the distance D between the double slit and the screen as (0.750 ± 0.001) m.

(i) Determine the best estimate of the distance between the two slits.

An uncertainty in the calculated value is not required. **3**

Space for working and answer

8. (b) (continued)

(ii) The student wishes to determine more precisely the value of the distance between the two slits d.

Show, by calculation, which of the student's measurements should be taken more precisely in order to achieve this.

You must indicate clearly which measurement you have identified. **3**

Space for working and answer

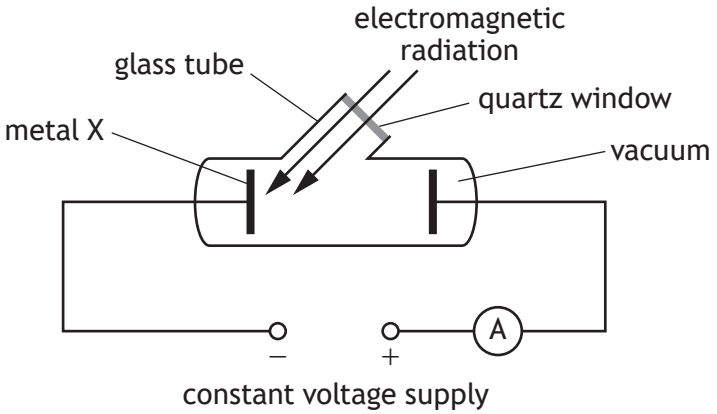
(c) The helium-neon laser is replaced by a laser emitting green light. No other changes are made to the experimental set-up.

State the effect this change has on the separation of the fringes observed on the screen.

You must justify your answer. **2**

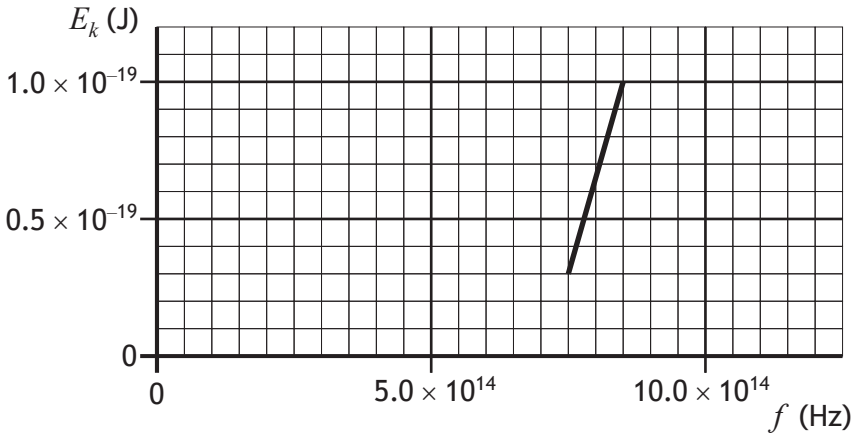
9. The apparatus shown is used to investigate photoemission.

Electromagnetic radiation is incident on metal X.



(a) The frequency of the electromagnetic radiation is varied. The maximum kinetic energy of the photoelectrons emitted from metal X is determined for a range of frequencies.

The graph shows how the maximum kinetic energy E_k of the photoelectrons varies with frequency f.



Using the graph, determine the threshold frequency f_0 of metal X. **1**

[Turn over

9. (continued)

(b) The work function of different metals is shown in the table.

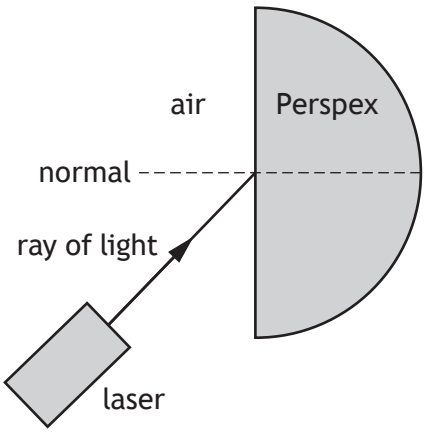
Metal	Work function (J)
Potassium	3.7×10^{-19}
Calcium	4.6×10^{-19}
Zinc	5.8×10^{-19}
Gold	8.5×10^{-19}

Identify which of these metals is metal X.

Justify your answer by calculation. **4**

Space for working and answer

10. A student is investigating refraction of light using the apparatus shown.



(a) The student measures a number of different angles of incidence θ_i and the corresponding angles of refraction θ_r.

Suggest how the student's measurements should be processed to find a reliable value for the refractive index of Perspex for the light from the laser. **2**

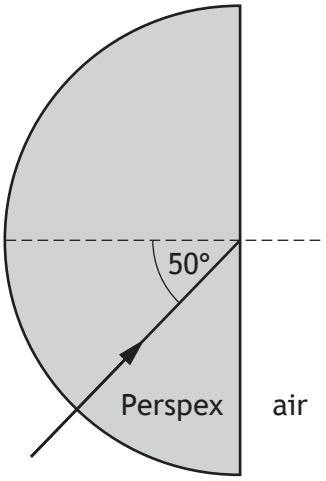
(b) The student determines the refractive index of the Perspex block for this light to be 1.50.

Calculate the critical angle of Perspex for this light. **3**

Space for working and answer

10. (continued)

(c) The student now directs the ray of light into the Perspex block as shown.



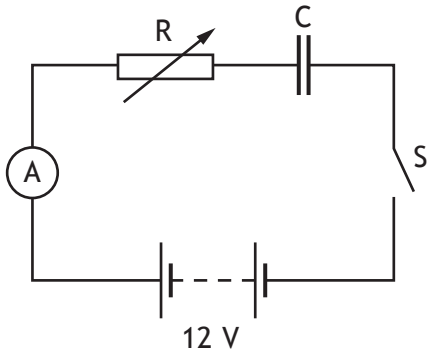
Complete the diagram to show the path of the ray of light after it is incident on this Perspex-air boundary.

Mark on the diagram the values of any relevant angles. **2**

(An additional diagram, if required, can be found on *page 43*.)

11. A 220 μF capacitor is charged using the circuit shown.

The 12 V battery has negligible internal resistance.



The capacitor is initially uncharged.

The switch S is closed. The charging current is kept constant at 3.0×10^{-5} A by adjusting the resistance of variable resistor R.

(a) Calculate the resistance of the variable resistor R just after the switch is closed. **3**

Space for working and answer

(b) (i) Calculate the charge on the capacitor 25 s after switch S is closed. **3**

Space for working and answer

11. (b) (continued)

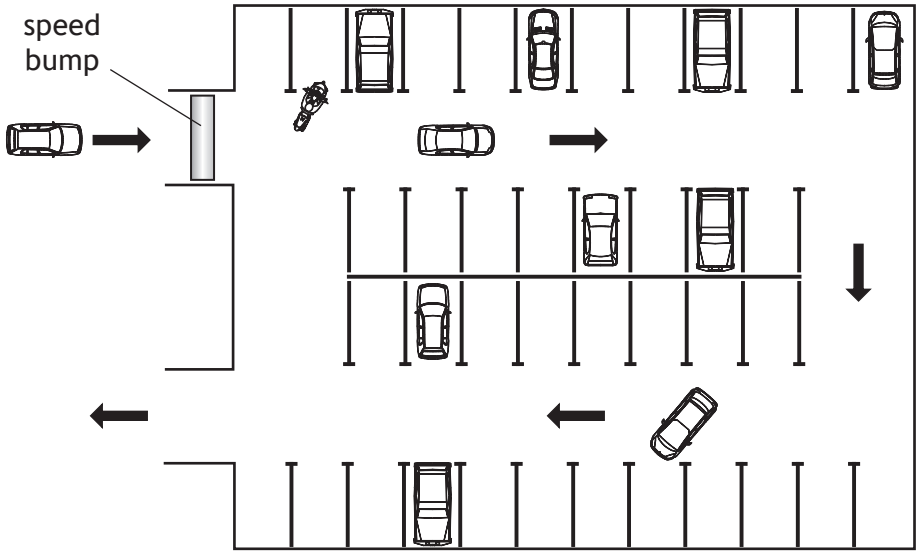
(ii) Determine the potential difference across R at this time. **4**

Space for working and answer

11. (continued)

(c) The use of analogies from everyday life can help improve the understanding of physics concepts.

Vehicles using a car park may be taken as an analogy for the charging of a capacitor.



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

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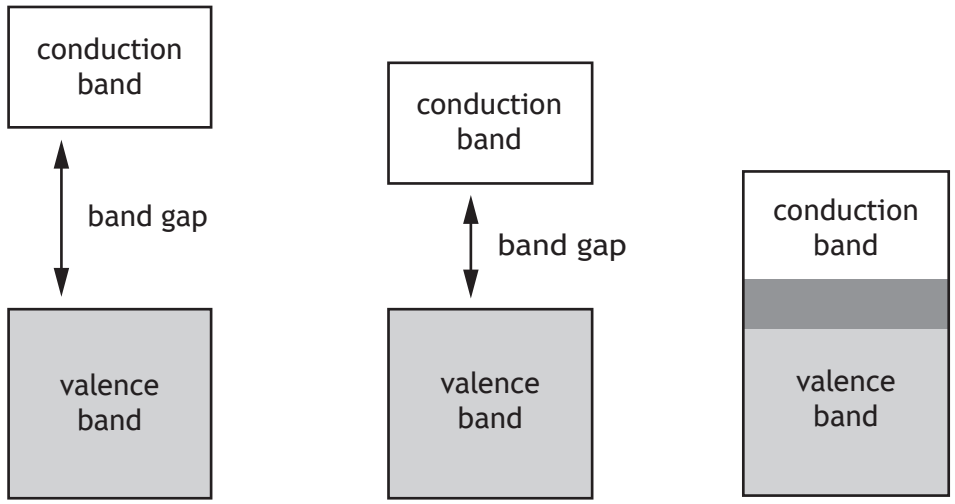
11. (c) (continued)

12. The electrical conductivity of solids can be explained using band theory.

The diagrams below show the distributions of the valence and conduction bands of materials classified as conductors, insulators and semiconductors.

Shaded areas represent bands occupied by electrons.

The band gap is also indicated.



Material 1 **Material 2** **Material 3**

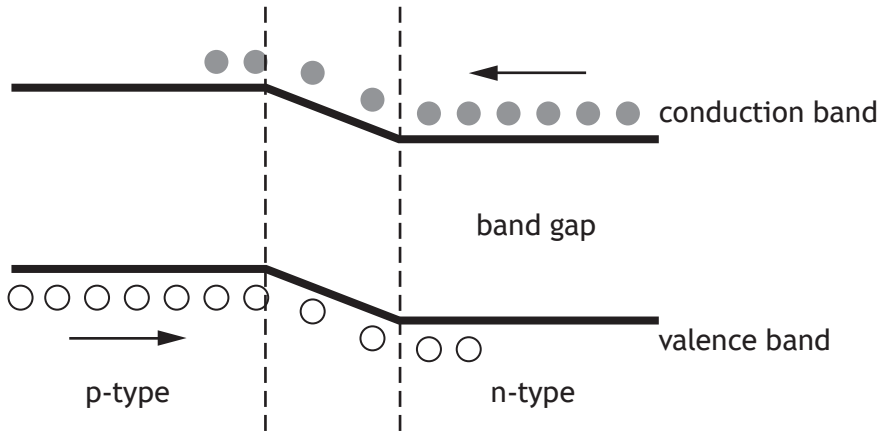
(a) State which material is a semiconductor. **1**

[Turn over

12. (continued)

(b) An LED is made from semiconductor material that has been doped with impurities to create a p-n junction.

The diagram represents the band structure of an LED.



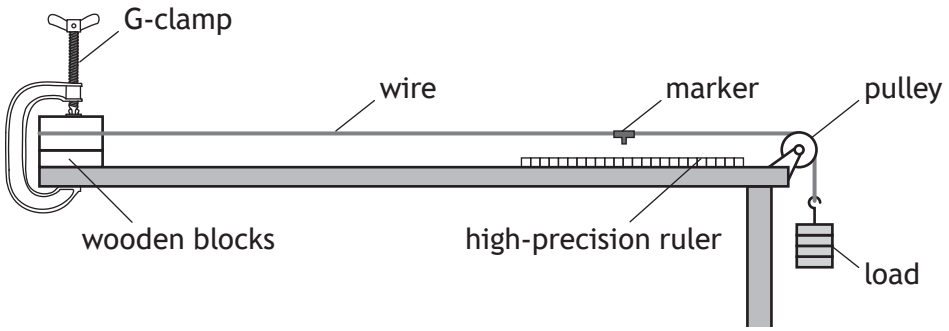
A voltage is applied across an LED so that it is forward biased and emits light.

Using **band theory**, explain how the LED emits light. **3**

[Turn over

13. Young's modulus E of a material is a measure of its stiffness.

A student sets up an experiment to determine Young's modulus of a copper wire.



The student applies a force to the wire, which causes the wire to stretch.

The extension of the wire is the difference between its new length and its original length.

The student varies the force F applied to the wire and measures the corresponding extension e of the wire.

The student records the following information.

F (N)	e ($\times 10^{-3}$ m)
2.0	0.5
3.9	1.0
5.9	1.6
7.8	2.1
9.8	2.7
10.8	3.2

(a) (i) Using the square-ruled paper on *page 39*, draw a graph of F against e. **3**

(The table of results is also shown on *page 40*, after the square-ruled paper.)

(ii) Calculate the gradient of the line of best fit on your graph. **2**

Space for working and answer

13. (a) (continued)

(iii) Young's modulus can be determined using the relationship

$$F = \frac{EA}{L}e$$

where: E is Young's modulus in Pa

F is the force applied to the wire by the load in N

L is the original length of the wire in m

A is the cross-sectional area of the wire in m^2

e is the extension of the wire in m.

The original length of the copper wire is 1.500 m and the cross-sectional area is 5.9×10^{-8} m^2.

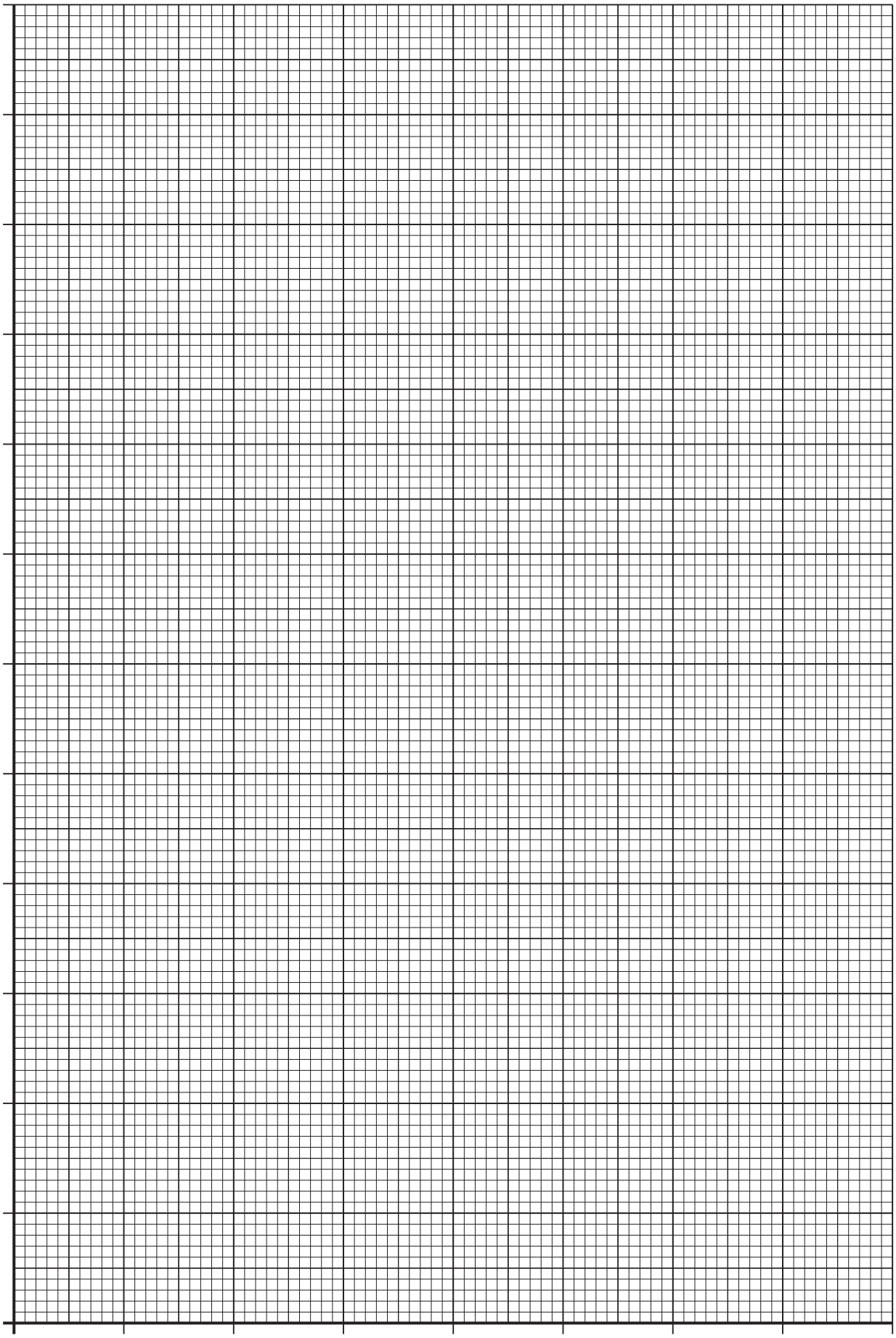
Using the gradient of your line of best fit, determine Young's modulus of the copper wire. **2**

Space for working and answer

(b) The student plots a graph of the data and concludes that there is a systematic uncertainty associated with this data.

Suggest why the student reached this conclusion. **1**

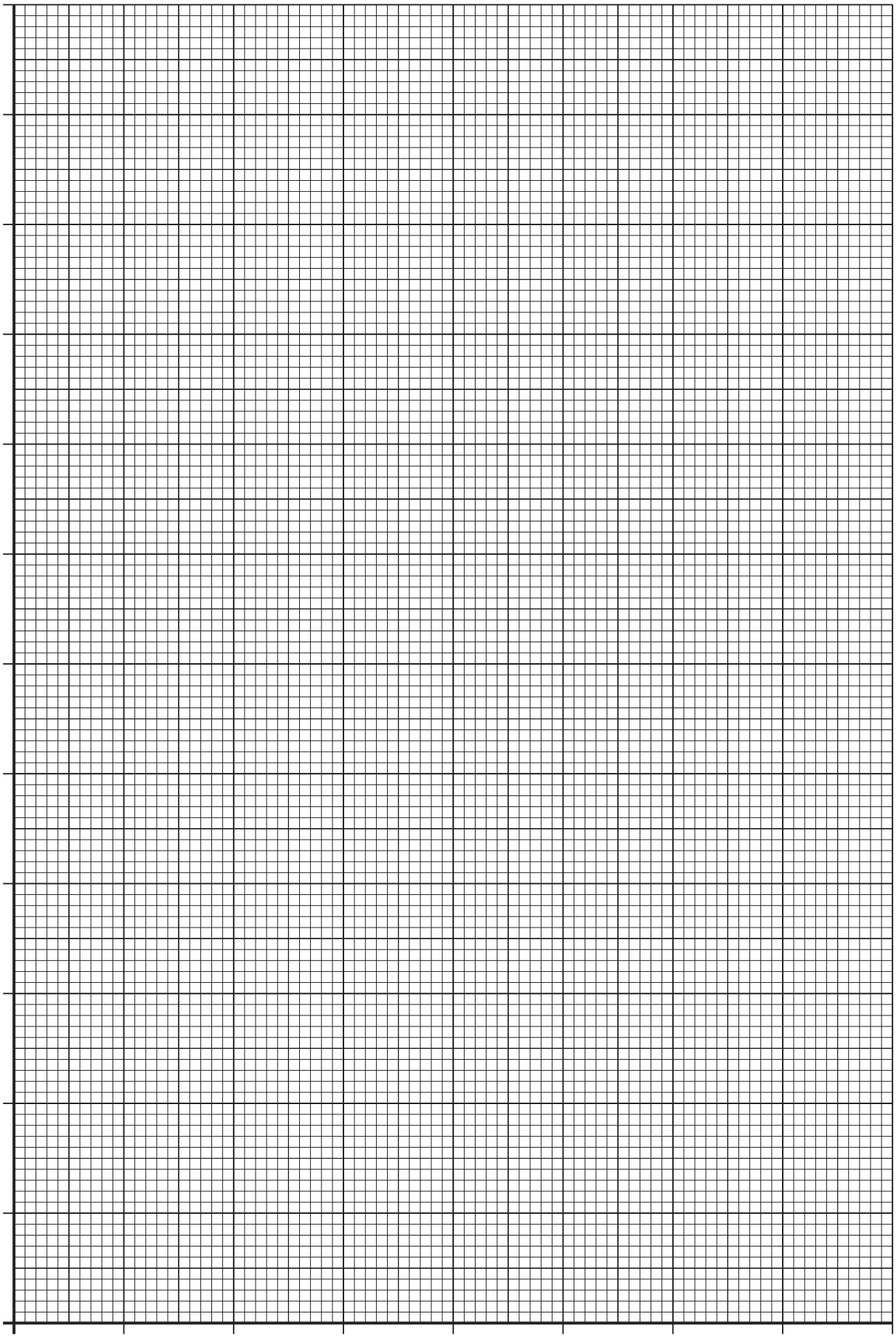
[END OF SPECIMEN QUESTION PAPER]



ADDITIONAL SPACE FOR ANSWERS AND ROUGH WORK

Additional table for use with question 13 (a) (i)

F (N)	e ($\times 10^{-3}$ m)
2.0	0.5
3.9	1.0
5.9	1.6
7.8	2.1
9.8	2.7
10.8	3.2



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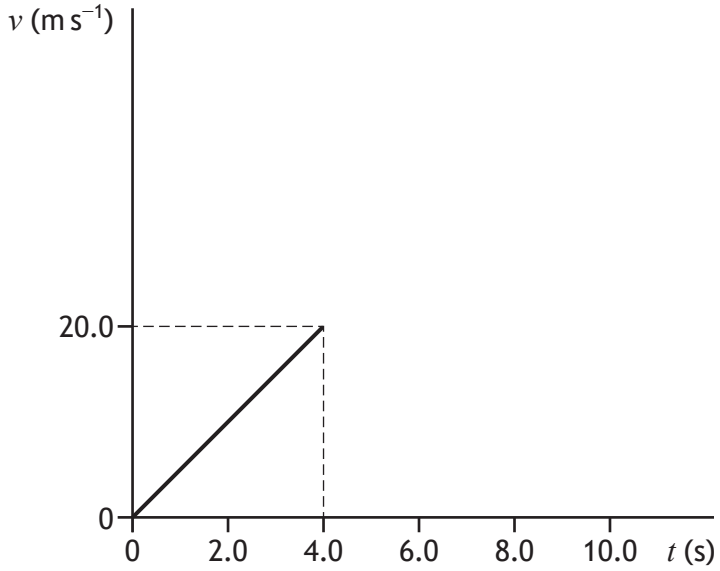
ADDITIONAL SPACE FOR ANSWERS AND ROUGH WORK

Additional graph for use with question 1 (d)



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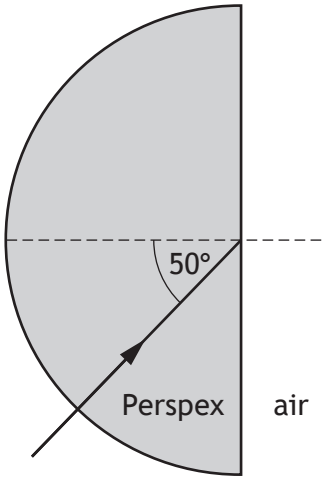
ADDITIONAL SPACE FOR ANSWERS AND ROUGH WORK

Additional diagram for use with question 10 (c)



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S857/76/11

Physics
Paper 1 — Relationships sheet

Date — Not applicable

Duration — 2 hours 30 minutes

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Qualifications Scotland
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Relationships required for Physics Higher

$d = \bar{v}t$

$s = \bar{v}t$

$v = u + at$

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

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

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

$F = ma$

$W = mg$

$E_w = Fd$, or $W = Fd$

$E_p = mgh$

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

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

$p = mv$

$Ft = mv - mu$

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

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

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

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

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

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

$v = H_0 d$

$W = QV$

$E = mc^2$

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

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

$I_1 d_1^2 = I_2 d_2^2$

$E = hf$

$E_k = hf - hf_0$

$v = f\lambda$

$E_2 - E_1 = hf$

$d \sin\theta = m\lambda$

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

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

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

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

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

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

$V = IR$

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

$R_T = R_1 + R_2 + \ldots$

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

$V_1 = \left(\dfrac{R_1}{R_1 + R_2}\right)V_S$

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

$E = V + Ir$

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

$Q = It$

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

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

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

or

$\Delta R = \dfrac{R_{\max} - R_{\min}}{n}$

Additional relationships

Circle

circumference $= 2\pi r$

area $= \pi r^2$

Sphere

area $= 4\pi r^2$

volume $= \frac{4}{3}\pi r^3$

Trigonometry

$$\sin\theta = \frac{\text{opposite}}{\text{hypotenuse}}$$

$$\cos\theta = \frac{\text{adjacent}}{\text{hypotenuse}}$$

$$\tan\theta = \frac{\text{opposite}}{\text{adjacent}}$$

$$\sin^2\theta + \cos^2\theta = 1$$

Electron arrangements of elements

Group 1 (1)	Group 2 (2)	Group 3 (13)	Group 4 (14)	Group 5 (15)	Group 6 (16)	Group 7 (17)	Group 0 (18)
1 **H** 1 Hydrogen							2 **He** 2 Helium
3 **Li** 2,1 Lithium	4 **Be** 2,2 Beryllium	5 **B** 2,3 Boron	6 **C** 2,4 Carbon	7 **N** 2,5 Nitrogen	8 **O** 2,6 Oxygen	9 **F** 2,7 Fluorine	10 **Ne** 2,8 Neon
11 **Na** 2,8,1 Sodium	12 **Mg** 2,8,2 Magnesium	13 **Al** 2,8,3 Aluminium	14 **Si** 2,8,4 Silicon	15 **P** 2,8,5 Phosphorus	16 **S** 2,8,6 Sulfur	17 **Cl** 2,8,7 Chlorine	18 **Ar** 2,8,8 Argon
19 **K** 2,8,8,1 Potassium	20 **Ca** 2,8,8,2 Calcium	31 **Ga** 2,8,18,3 Gallium	32 **Ge** 2,8,18,4 Germanium	33 **As** 2,8,18,5 Arsenic	34 **Se** 2,8,18,6 Selenium	35 **Br** 2,8,18,7 Bromine	36 **Kr** 2,8,18,8 Krypton
37 **Rb** 2,8,18,8,1 Rubidium	38 **Sr** 2,8,18,8,2 Strontium	49 **In** 2,8,18, 18,3 Indium	50 **Sn** 2,8,18, 18,4 Tin	51 **Sb** 2,8,18, 18,5 Antimony	52 **Te** 2,8,18, 18,6 Tellurium	53 **I** 2,8,18, 18,7 Iodine	54 **Xe** 2,8,18, 18,8 Xenon
55 **Cs** 2,8,18,18, 8,1 Caesium	56 **Ba** 2,8,18,18, 8,2 Barium	81 **Tl** 2,8,18, 32,18,3 Thallium	82 **Pb** 2,8,18, 32,18,4 Lead	83 **Bi** 2,8,18, 32,18,5 Bismuth	84 **Po** 2,8,18, 32,18,6 Polonium	85 **At** 2,8,18, 32,18,7 Astatine	86 **Rn** 2,8,18, 32,18,8 Radon
87 **Fr** 2,8,18,32, 18,8,1 Francium	88 **Ra** 2,8,18,32, 18,8,2 Radium						

Key

Atomic number
Symbol
Electron arrangement
Name

Transition elements

(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
21 **Sc** 2,8,9,2 Scandium	22 **Ti** 2,8,10,2 Titanium	23 **V** 2,8,11,2 Vanadium	24 **Cr** 2,8,13,1 Chromium	25 **Mn** 2,8,13,2 Manganese	26 **Fe** 2,8,14,2 Iron	27 **Co** 2,8,15,2 Cobalt	28 **Ni** 2,8,16,2 Nickel	29 **Cu** 2,8,18,1 Copper	30 **Zn** 2,8,18,2 Zinc
39 **Y** 2,8,18,9,2 Yttrium	40 **Zr** 2,8,18, 10,2 Zirconium	41 **Nb** 2,8,18, 12,1 Niobium	42 **Mo** 2,8,18,13, 1 Molybdenum	43 **Tc** 2,8,18,13, 2 Technetium	44 **Ru** 2,8,18,15, 1 Ruthenium	45 **Rh** 2,8,18,16, 1 Rhodium	46 **Pd** 2,8,18, 18,0 Palladium	47 **Ag** 2,8,18, 18,1 Silver	48 **Cd** 2,8,18, 18,2 Cadmium
57 **La** 2,8,18,18, 9,2 Lanthanum	72 **Hf** 2,8,18,32, 10,2 Hafnium	73 **Ta** 2,8,18, 32,11,2 Tantalum	74 **W** 2,8,18,32, 12,2 Tungsten	75 **Re** 2,8,18,32, 13,2 Rhenium	76 **Os** 2,8,18,32, 14,2 Osmium	77 **Ir** 2,8,18,32, 15,2 Iridium	78 **Pt** 2,8,18,32, 17,1 Platinum	79 **Au** 2,8,18, 32,18,1 Gold	80 **Hg** 2,8,18, 32,18,2 Mercury
89 **Ac** 2,8,18,32, 18,9,2 Actinium	104 **Rf** 2,8,18,32, 32,10,2 Rutherfordium	105 **Db** 2,8,18,32, 32,11,2 Dubnium	106 **Sg** 2,8,18,32, 32,12,2 Seaborgium	107 **Bh** 2,8,18,32, 32,13,2 Bohrium	108 **Hs** 2,8,18,32, 32,14,2 Hassium	109 **Mt** 2,8,18,32, 32,15,2 Meitnerium	110 **Ds** 2,8,18,32, 32,17,1 Darmstadtium	111 **Rg** 2,8,18,32, 32,18,1 Roentgenium	112 **Cn** 2,8,18,32, 32,18,2 Copernicium

Lanthanides	57 **La** 2,8,18, 18,9,2 Lanthanum	58 **Ce** 2,8,18, 20,8,2 Cerium	59 **Pr** 2,8,18,21, 8,2 Praseodymium	60 **Nd** 2,8,18,22, 8,2 Neodymium	61 **Pm** 2,8,18,23, 8,2 Promethium	62 **Sm** 2,8,18,24, 8,2 Samarium	63 **Eu** 2,8,18,25, 8,2 Europium	64 **Gd** 2,8,18,25, 9,2 Gadolinium	65 **Tb** 2,8,18,27, 8,2 Terbium	66 **Dy** 2,8,18,28, 8,2 Dysprosium	67 **Ho** 2,8,18,29, 8,2 Holmium	68 **Er** 2,8,18,30, 8,2 Erbium	69 **Tm** 2,8,18,31, 8,2 Thulium	70 **Yb** 2,8,18,32, 8,2 Ytterbium	71 **Lu** 2,8,18,32, 9,2 Lutetium
Actinides	89 **Ac** 2,8,18,32, 18,9,2 Actinium	90 **Th** 2,8,18,32, 18,10,2 Thorium	91 **Pa** 2,8,18,32, 20,9,2 Protactinium	92 **U** 2,8,18,32, 21,9,2 Uranium	93 **Np** 2,8,18,32, 22,9,2 Neptunium	94 **Pu** 2,8,18,32, 24,8,2 Plutonium	95 **Am** 2,8,18,32, 25,8,2 Americium	96 **Cm** 2,8,18,32, 25,9,2 Curium	97 **Bk** 2,8,18,32, 27,8,2 Berkelium	98 **Cf** 2,8,18,32, 28,8,2 Californium	99 **Es** 2,8,18,32, 29,8,2 Einsteinium	100 **Fm** 2,8,18,32, 30,8,2 Fermium	101 **Md** 2,8,18,32, 31,8,2 Mendelevium	102 **No** 2,8,18,32, 32,8,2 Nobelium	103 **Lr** 2,8,18,32, 32,9,2 Lawrencium

National
Qualifications
SPECIMEN ONLY

S857/76/01 **Physics**

Marking Instructions

These marking instructions have been provided to show how Qualifications Scotland would mark this specimen question paper.

Qualifications Scotland
Teisteanasan Alba

General marking principles for Physics Higher

This information is provided to help you understand the general principles you must apply when marking candidate responses to questions in this paper. These principles must be read in conjunction with the detailed marking instructions, which identify the key features required in candidate responses.

(a) Marks for each candidate response must always be assigned in line with these marking principles, the Physics: general marking principles (GMPs) (Physics: general marking principles - National 3 to Advanced Higher (qualifications.gov.scot)) and the detailed marking instructions for this assessment.

(b) Marking should always be positive. This means that, for each candidate response, marks are accumulated for the demonstration of relevant skills, knowledge and understanding: they are not deducted from a maximum on the basis of errors or omissions.

(c) If a specific candidate response does not seem to be covered by either the principles or detailed marking instructions, and you are uncertain how to assess it, you must seek guidance from your team leader.

(d) Where a candidate answers part of a question incorrectly and carries the incorrect answer forward in the following part, award marks if the incorrect answer has then been used correctly in the subsequent part or 'follow-on'. (GMP 16)

(e) Award marks for non-standard symbols where the symbols are defined and the relationship is correct, or where the substitution shows that the relationship used is correct. This must be clear and unambiguous. (GMP 20)

(f) Award full marks for a correct final answer (including units if required) on its own, unless a numerical question specifically requires evidence of working to be shown, eg in a 'show' question. (GMP 1)

(g) Award marks where a diagram or sketch conveys correctly the response required by the question. It will usually require clear and correct labels (or the use of standard symbols) (GMP 19)

(h) Marks are allocated for knowledge of relevant relationships alone. Do not award a mark when a candidate writes down several relationships and does not select the correct one to continue with, for example by substituting values. (GMP 1c)

(i) Do not award marks if a 'magic triangle' (eg) 

is the only statement in a candidate's response. To gain the mark, the correct relationship must be stated, for example $V = IR$ or $R = \frac{V}{I}$. (GMP 2)

(j) In rounding to an expected number of significant figures, award the mark for responses that have up to two figures more or one figure less than the number in the data with the fewest significant figures. (GMP 6)
(Note: the use of a recurrence dot, eg $0.\dot{6}$, would imply an infinite number of significant figures and would therefore not be acceptable.)

(k) The incorrect spelling of technical terms should usually be ignored and candidates should be awarded the relevant mark, provided that answers can be interpreted and understood without any doubt as to the meaning.
Where there is ambiguity, do not award the mark. Two specific examples of this would be when the candidate uses a term:

- that might be interpreted as *reflection*, *refraction* or *diffraction*, eg 'defraction'
- that might be interpreted as either *fission* or *fusion*, eg 'fussion'

The spelling of these words is similar, but the words have totally different meanings. If the spelling (or handwriting) in an answer makes it difficult for you to interpret a candidate's intention, then do not award the mark. (GMP 22)

(l) Marks are awarded only for a valid response to the question asked. For example, in response to questions that ask candidates to:

- **identify**, **name**, **give**, or **state**, they need only name or present in brief form.
- **describe**, they must provide a statement or structure of characteristics and/or features.
- **explain**, they must relate cause and effect and/or make relationships between things clear.
- **determine** or **calculate**, they must determine a number from given facts, figures or information.
- **estimate**, they must determine an approximate value for something.
- **justify**, they must give reasons to support their suggestions or conclusions. For example this might be by identifying an appropriate relationship and the effect of changing variables.
- **show that**, they must use physics [and mathematics] to prove something, for example a given value – *all steps, including the stated answer, must be shown*.
- **predict**, they must suggest what may happen based on available information.
- **suggest**, they must apply their knowledge and understanding of physics to a new situation. A number of responses are acceptable: award marks for any suggestions that are supported by knowledge and understanding of physics.
- **use their knowledge of physics or aspect of physics to comment on**, they must apply their skills, knowledge and understanding to respond appropriately to the problem/ situation presented (for example by making a statement of principle(s) involved and/or a relationship or equation, and applying these to respond to the problem/situation). Candidates are given credit for the breadth and/or depth of their conceptual understanding.

Standard three marker
The examples over the page set out how to apportion marks to answers requiring calculations. These are the 'standard three marker' type of questions.

Award full marks for a correct answer to a numerical question, even if the steps are not shown explicitly, **unless** it specifically requires evidence of working to be shown.

For some questions requiring numerical calculations, there may be alternative methods (eg alternative relationships) that would lead to a correct answer.

Sometimes, a question requires a calculation that does not fit into the 'standard three marker' type of response. In these cases, the detailed marking instructions will contain guidance for marking the question.

When marking partially correct answers, apportion individual marks as shown over the page.

Marking in calculations

Example question

The current in a resistor is 1·5 amperes when the potential difference across it is 7·5 volts. Calculate the resistance of the resistor. (3 marks)

	Example response	**Mark and comment**
1.	$V = IR$ $7.5 = 1.5R$ $R = 5.0\ \Omega$	1 mark: relationship 1 mark: substitution 1 mark: correct answer
2.	$5.0\ \Omega$	3 marks: correct answer
3.	5.0	2 marks: unit missing
4.	$4.0\ \Omega$	0 marks: no evidence, wrong answer
5.	$\_\_\ \Omega$	0 marks: no working or final answer
6.	$R = \frac{V}{I} = \frac{7.5}{1.5} = 4.0\ \Omega$	2 marks: arithmetic error
7.	$R = \frac{V}{I} = 4.0\ \Omega$	1 mark: relationship only
8.	$R = \frac{V}{I} = \_\_\ \Omega$	1 mark: relationship only
9.	$R = \frac{V}{I} = \frac{7.5}{1.5} = \_\_\ \Omega$	2 marks: relationship and substitution, no final answer
10.	$R = \frac{V}{I} = \frac{7.5}{1.5} = 4.0$	2 marks: relationship and substitution, wrong answer
11.	$R = \frac{V}{I} = \frac{1.5}{7.5} = 5.0\ \Omega$	1 mark: relationship but wrong substitution
12.	$R = \frac{V}{I} = \frac{75}{1.5} = 5.0\ \Omega$	1 mark: relationship but wrong substitution
13.	$R = \frac{I}{V} = \frac{1.5}{7.5} = 5.0\ \Omega$	0 marks: wrong relationship
14.	$V = IR$ $7.5 = 1.5 \times R$ $R = 0.2\ \Omega$	2 marks: relationship and substitution, arithmetic error
15.	$V = IR$ $R = \frac{I}{V} = \frac{1.5}{7.5} = 0.2\ \Omega$	1 mark: relationship correct but wrong rearrangement of symbols

Section 1

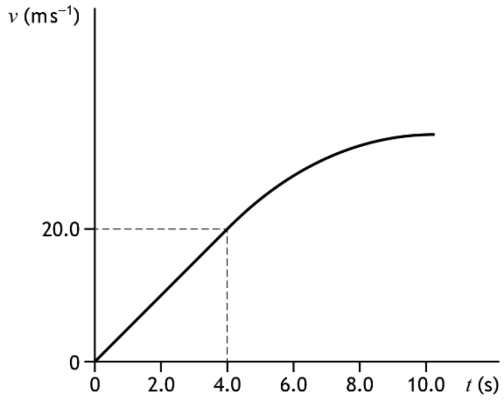
Marking Instructions for each question

Question	Answer	Mark
1.	C	**1**
2.	B	**1**
3.	B	**1**
4.	C	**1**
5.	C	**1**
6.	B	**1**
7.	D	**1**
8.	A	**1**
9.	D	**1**
10.	A	**1**
11.	E	**1**
12.	D	**1**
13.	C	**1**
14.	E	**1**
15.	D	**1**
16.	A	**1**
17.	E	**1**
18.	B	**1**
19.	A	**1**
20.	B	**1**

SECTION 2

Marking instructions for each question

Question			Expected response	Max mark	Additional guidance
1.	(a)		$v = u + at$ **(1)** $20.0 = 0 + a \times 4.0$ **(1)** $a = 5.0\ \text{ms}^{-2}$ **(1)**	**3**	Accept 5, 5.00, 5.000
	(b)		motorcycle $s = area\ under\ graph$ **(1)** $s = \frac{1}{2} \times 4.0 \times 20.0$ **(1)** car $s = area\ under\ graph$ $s = 4.0 \times 15.0$ **(1)** $s_{between} = (4.0 \times 15.0) - (\frac{1}{2} \times 4.0 \times 20.0)$ $s_{between} = 20\ \text{m}$ **(1)**	**4**	Accept 20.0, 20.00 motorcycle $s = ut + \frac{1}{2}at^2$ $s = \frac{1}{2} \times 5.0 \times 4.0^2$ car $d = \overline{v}t$ $d = 15.0 \times 4.0$ $s_{between} = (15.0 \times 4.0) - (\frac{1}{2} \times 5.0 \times 4.0^2)$ $s_{between} = 20\ \text{m}$ **1 mark** for both relationships. **1 mark** for each substitution. **1 mark** for final answer.
	(c)	(i)	$F = ma$ **(1)** $F = 290 \times 5.0$ **(1)** $\left(F = F_{Driving} - F_{Friction}\right)$ $(290 \times 5.0) = 1800 - F_{Friction}$ **(1)** $F_{Friction} = 350\ \text{N}$ **(1)**	**4**	Or consistent with (a) Accept 400, 350.0, 350.00
		(ii)	(Driving force must be) increased. **(1)** Frictional force increases with speed. **(1)**	**2**	JUSTIFY Accept friction, drag, air resistance for frictional force(s)

Question			Expected response	Max mark	Additional guidance
1.	(d)		 graph curves (gradually, away from velocity axis) after 5 s.	**1**	Line can level out but not curve downwards.

Question			Expected response	Max mark	Additional guidance
2.	(a)	(i)	$v^2 = u^2 + 2as$ **(1)** $v^2 = 0 + 2 \times 9.8 \times 2.0$ **(1)** $v = 6.3 \text{ ms}^{-1}$ **OR** $mgh = \frac{1}{2}mv^2$ **(1)** $42 \times 9.8 \times 2.0 = \frac{1}{2} \times 42 \times v^2$ **(1)** $v = 6.3 \text{ ms}^{-1}$	**2**	SHOW question If final line is not shown then a maximum of **1 mark** can be awarded. If using the second method, accept a substitution without the mass providing there is a clear indication that the mass on each side of the relationship cancels.
		(ii)	$\Delta p = mv - mu$ **(1)** $\Delta p = (42 \times 5.3) - (42 \times (-6.3))$ **(1)** $\Delta p = 490 \text{ kgms}^{-1}$ **(1)**	**3**	Accept: 500, 487, 487.2 Accept: alternative sign convention for direction
		(iii)	$Ft = mv - mu$ **(1)** $F \times 0.50 = 490$ **(1)** $F = 980 \text{ N}$ **(1)**	**3**	Or consistent with (a)(ii) Accept: 1000, 980.0
	(b)		Tension (in rope) now has a horizontal component.	**1**	Statement must refer to tension in the rope rather than force applied by the gymnast.

Question			Expected response	Max mark	Additional guidance
3.			**Award 3 marks** where the candidate has demonstrated a good understanding of the physics involved. They show a good comprehension of the physics of the situation and provide a logically correct answer to the question posed. This type of response might include a statement of the principles involved, a relationship or an equation, and the application of these to respond to the problem. The answer does not need to be 'excellent' or 'complete' for the candidate to gain full marks. **Award 2 marks** where the candidate has demonstrated a reasonable understanding of the physics involved. They make some statement(s) that are relevant to the situation, showing that they have understood the problem. **Award 1 mark** where the candidate has demonstrated a limited understanding of the physics involved. They make some statement(s) that are relevant to the situation, showing that they have understood at least a little of the physics within the problem. **Award 0 marks** where the candidate has not demonstrated an understanding of the physics involved. There is no evidence that they have recognised the area of physics involved, or they have not given any statement of a relevant physics principle. Award this mark also if the candidate merely restates the physics given in the question.	**3**	Candidates may use a variety of physics arguments to answer this question. Award marks based on candidates demonstrating overall good, reasonable, limited, or no understanding.

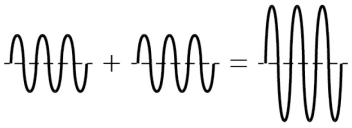
Question			Expected response	Max mark	Additional guidance
4.	(a)		Cosmic Microwave Background Radiation. **OR** Olbers' Paradox. **OR** Abundance of hydrogen and helium in the Universe.	**1**	Do not accept: CMBR on its own. Accept: abundance of light elements in the Universe. Do not accept: any further evidence based on red shift alone.
	(b)	(i)	$\left(Age = \frac{1}{H_0} \right)$ $Age = \frac{1}{2.0 \times 10^{-17}}$ **(1)** $Age = 1.6 \times 10^{9}$ (years) **(1)**	**2**	Accept: 2, 1.58, 1.584 If 365 days has been used, accept 1.585
		(ii) (A)	(Student's) value for H_0 is incorrect/too large. **OR** Incorrect line (of best fit) drawn. **OR** The (student's value for the) gradient of the line (H_0) is too large. **OR** New/more data is available/more accurate. **OR** Not enough data at large distances.	**1**	
		(ii) (B)	The student could draw the (correct) line of best fit. **OR** The student could use a larger sample/all of the 1929 Hubble data/current data.	**1**	Do not accept: 'different line of best fit' alone.

Question			Expected response	Max mark	Additional guidance
5.	(a)	(i)	$W = QV$ **(1)** $W = 1.60\times10^{-19}\times3.5\times10^{4}$ **(1)** $W = 5.6\times10^{-15}$ J	**2**	SHOW question If final line not shown then a maximum of **1 mark** can be awarded.
		(ii)	E_k **at R** $E_k = \frac{1}{2}mv^2$ **(1)** $E_k = 0.5\times1.673\times10^{-27}\times(1.2\times10^{6})^2$ **(1)** E_k **at S** $E_k = \frac{1}{2}mv^2$ $\left(0.5\times1.673\times10^{-27}\times(1.2\times10^{6})^2\right)+5.6\times10^{-15} = 0.5\times1.673\times10^{-27}\times v^2$ **addition** **(1)** **substitution** **(1)** $v = 2.9\times10^{6}$ **ms**$^{-1}$ **(1)**	**5**	Accept: 3, 2.85, 2.852 1 mark for $E_k = \frac{1}{2}mv^2$ anywhere
	(b)	(i)	To ensure the (accelerating) force is in the same direction. **OR** To ensure the protons accelerate in the same direction. **OR** To ensure that the direction of the electric field is correct when the proton passes between the tubes.	**1**	
		(ii)	Alternating voltage has a constant frequency (rather than a frequency which changes). **OR** As the speed of the protons increase, they travel further in the same time.	**1**	
	(c)		Downwards	**1**	Accept: down, (towards the) bottom of the page An arrow drawn pointing down the page is acceptable. If the arrow is drawn in the original diagram, it must be touching the proton.

Question			Expected response	Max mark	Additional guidance
6.	(a)		Meson(s)	**1**	
	(b)	(i)	Anti-up Strange	**1**	**Both** required. Do not accept: anti anti-strange.
		(ii)	Weak (nuclear force)	**1**	
	(c)	(i)	$d = \bar{v}t$ **(1)** $30.0 = 0.95 \times 3.00 \times 10^{8} \times t$ **(1)** $t = 1.05 \times 10^{-7}$ s **(1)**	**3**	Accept: 1.1, 1.053, 1.0526
		(ii)	$l' = l\sqrt{1-\left(\frac{v}{c}\right)^2}$ **(1)** $l' = 30.0 \times \sqrt{1-\left(\frac{0.95c}{c}\right)^2}$ **(1)** $l' = 9.37$ m **(1)**	**3**	Accept: 9.4, 9.367, 9.3675 Accept: $l' = 30.0 \times \sqrt{1-(0.95)^2}$
	(d)		For a stationary observer's frame of reference, the mean lifetime of the pion is greater (than 26 ns). **OR** In the pion's frame of reference, the distance is shorter (than 30.0 m).	**1**	The response must involve a statement referring to, or implying, a frame of reference.

Question			Expected response	Max mark	Additional guidance
7.	(a)	(i)	$\left(A = \pi r^2\right)$ $A = \pi \times \left(15 \times 10^{-3}\right)^2$ **(1)** $I = \frac{P}{A}$ **(1)** $17 = \frac{P}{\pi \times \left(15 \times 10^{-3}\right)^2}$ **(1)** $P = 0.012$ W **(1)**	**4**	Accept: 0.01, 0.0120, 0.01202 If 3.14 used for π, accept 0.01201 If no attempt to calculate area, **maximum 1 mark** for irradiance relationship.
		(ii)	(Experimental setup is) not a point source. **OR** Parallel beam so the irradiance does not change with distance.	**1**	Accept: the beam of light does not diverge. Do not accept: sodium lamp is not a point source, on its own.
	(b)	(i)	Lower (energy level)	**1**	
		(ii)	$v = f\lambda$ **(1)** $3.00 \times 10^8 = f \times 589.0 \times 10^{-9}$ **(1)** $E = hf$ **(1)** $E = 6.63 \times 10^{-34} \times \left(\frac{3.00 \times 10^8}{589.0 \times 10^{-9}}\right)$ **(1)** $E = 3.38 \times 10^{-19}$ J **(1)**	**5**	Accept: 3.4, 3.377, 3.3769 Accept: $\Delta E = hf$ **OR** $E_2 - E_1 = hf$ $v = f\lambda$ anywhere **(1)** $E = hf$ anywhere **(1)** Alternative method: $(\Delta) E = \frac{hc}{\lambda}$ **OR** $E_2 - E_1 = \frac{hc}{\lambda}$ Combined relationship **(2)** Substitution for c and λ **(1)** Substitution for h **(1)** Final answer **(1)**

Question			Expected response	Max mark	Additional guidance
7.	(b)	(iii)	There are more electrons (per second) making the transition for the 589.0 nm line. **(1)** So, more photons (per second) are emitted. **(1)** **OR** There are fewer electrons (per second) making the transition for the 589.6 nm line. **(1)** So fewer photons (per second) are emitted. **(1)**	**2**	Do not accept: greater brightness due to greater frequency/energy of the photons.

Question			Expected response	Max mark	Additional guidance
8.	(a)		Waves meet in phase. **OR** Crest meets crest. **OR** Trough meets trough. **OR** $path\ difference = m\lambda$	**1**	Accept: peak for crest. Can be shown by diagram e.g.  Diagram must imply addition of two waves in phase. Do not accept: 'join' or 'merge' alone.
	(b)	(i)	$\left(\Delta x = \frac{\lambda D}{d}\right)$ $\frac{9.5\times10^{-3}}{4} = \frac{633\times10^{-9}\times0.750}{d}$ division by 4 **(1)** substitutions **(1)** $d = 2.0\times10^{-4}$ m **(1)**	**3**	Accept: 2, 2.00, 1.999 The mark for dividing by 4 is independent.
		(ii)	$\%uncertainty$ in $\Delta x = \frac{0.2\times10^{-3}}{9.5\times10^{-3}}\times100$ $\%uncertainty$ in $\Delta x = 2.1\%$ **(1)** $\%uncertainty$ in $D = \frac{0.002}{0.750}\times100$ $\%uncertainty$ in $D = 0.27\%$ **(1)** Improve precision in measurement of Δx **(1)**	**3**	Accept: $\%uncertainty$ in $\Delta x = \frac{0.2}{9.5}\times100$
	(c)		(Fringes are) closer together. **(1)** Green light has a shorter wavelength. **(1)**	**2**	MUST JUSTIFY

Question			Expected response	Max mark	Additional guidance
9.	(a)		$(f_0) = 7.0 \times 10^{14}$ Hz	**1**	Accept: 7×10^{14} Hz Accept: a single value in the range $6.9 \times 10^{14} - 7.1 \times 10^{14}$ Hz
	(b)		$E = hf_0$ **(1)** $E = 6.63 \times 10^{-34} \times 7.0 \times 10^{14}$ **(1)** $E = 4.6 \times 10^{-19}$ (J) **(1)** Calcium/Ca **(1)**	**4**	Or consistent with (a) Suspend significant figure rule for calculated value(s) in this question. If calcium is identified correctly with no calculation, **maximum 1 mark**. If there is a calculation with a value consistent with (a), then the metal chosen must be consistent with their calculated value. If their calculated value does not match a value in the table, then **maximum 3 marks**. A unit is not required, however if a unit is given, it must be correct. If a candidate completes a calculation but does **not** go on to identify a metal, then a unit is required. In this question, if an incorrect metal or no metal is identified, **maximum 3 marks**. Accept: $E = hf$ Alternative method: $E = hf_0$ **(1)** $4.6 \times 10^{-19} = 6.63 \times 10^{-34} \times f_0$ **(1)** $f_0 = 6.9 \times 10^{14}$ (Hz) **(1)** Therefore calcium/Ca **(1)** Where more than one calculation is shown, all substitutions must be correct for substitution mark, and all calculated values must be correct for calculated value mark. Accept: $E_k = hf - hf_0$ **(1)** Substituted values must be consistent with the line or the table depending on the method chosen.

Question			Expected response	Max mark	Additional guidance
10.	(a)		Plot a graph of $\sin\theta_i$ against $\sin\theta_r$. **(1)** Calculate the gradient of (the line of best fit on) the graph. **(1)**	**2**	Accept: $\sin i$ and $\sin r$ Accept: gradient of (the line of best fit on) the graph is n. Accept: reciprocal method: Plot a graph of $\sin\theta_r$ against $\sin\theta_i$. **(1)** Calculate the inverse of the gradient of (the line of best fit on) the graph. **(1)** Do not accept: Calculate n for each angle of incidence and average (as this is an example of invalid averaging).
	(b)		$\sin\theta_c = \frac{1}{n}$ **(1)** $\sin\theta_c = \frac{1}{1.50}$ **(1)** $\theta_c = 41.8^\circ$ **(1)**	**3**	Accept: 42, 41.81, 41.810
	(c)		<u>Total</u> internal reflection **(1)** 50° reflected angle shown on diagram. **(1)**	**2**	Must be consistent with (b) Ray must be passably straight. Any change in direction at curved Perspex-air boundary **maximum 1 mark**. If answer for (b) is greater than 50°, **maximum 1 mark** for a ray that refracts away from the normal.

Question			Expected response	Max mark	Additional guidance
11.	(a)		$V = IR$ **(1)** $12 = 3.0\times10^{-5}\times R$ **(1)** $R = 4.0\times10^{5}\ \Omega$ **(1)**	**3**	Accept: 4, 4.00, 4.000
	(b)	(i)	$Q = It$ **(1)** $Q = 3.0\times10^{-5}\times25$ **(1)** $Q = 7.5\times10^{-4}$ C **(1)**	**3**	Accept: 8, 7.50, 7.500
		(ii)	$C = \frac{Q}{V}$ **(1)** $220\times10^{-6} = \frac{7.5\times10^{-4}}{V}$ **(1)** $\left(V_R = V_S - V_C\right)$ $V_R = 12 - \frac{7.5\times10^{-4}}{220\times10^{-6}}$ **(1)** $V_R = 8.6$ V **(1)**	**4**	Accept: 9, 8.59, 8.591

Question			Expected response	Max mark	Additional guidance
11.	**(c)**		**Award 3 marks** where the candidate has demonstrated a good understanding of the physics involved. They show a good comprehension of the physics of the situation and provide a logically correct answer to the question posed. This type of response might include a statement of the principles involved, a relationship or an equation, and the application of these to respond to the problem. The answer does not need to be 'excellent' or 'complete' for the candidate to gain full marks. **Award 2 marks** where the candidate has demonstrated a reasonable understanding of the physics involved. They make some statement(s) that are relevant to the situation, showing that they have understood the problem. **Award 1 mark** where the candidate has demonstrated a limited understanding of the physics involved. They make some statement(s) that are relevant to the situation, showing that they have understood at least a little of the physics within the problem. **Award 0 marks** where the candidate has not demonstrated an understanding of the physics involved. There is no evidence that they have recognised the area of physics involved, or they have not given any statement of a relevant physics principle. Award this mark also if the candidate merely restates the physics given in the question.	**3**	Candidates may use a variety of physics arguments to answer this question. Award marks based on candidates demonstrating overall good, reasonable, limited, or no understanding.

Question			Expected response	Max mark	Additional guidance
12.	(a)		Material 2	**1**	
	(b)		(Voltage applied causes) electrons to move from the conduction band of the n-type (semiconductor) towards the conduction band of the p-type (semiconductor). **(1)** Electrons 'fall' from the conduction band into the valence band (on either side of the junction). **(1)** Photons are emitted. **(1)**	**3**	Ignore any reference to initial movement of electrons from the valence band of the n-type to the conduction band of the n-type. To access 1st mark, the direction the electrons move must be clear. To access 2nd mark, valence and conduction bands must be included in the answer. Bands must be named correctly, eg do not accept 'valency' or 'conductive'. Final mark is dependent upon having at least one of the first two statements. Any answer using recombination of holes and electrons **on its own**, with no reference to band theory, is worth **0 marks**.

Question			Expected response	Max mark	Additional guidance
13.	(a)	(i)	Axes appropriately labelled (quantity and units) and axes linearly scaled **(1)** [Allow for axes starting at zero or broken axes or an appropriate value] Data points plotted accurately **(1)** Appropriate line of best-fit **(1)**	**3**	If the origin is shown the scale must either be continuous, or the axis must be 'broken'. Otherwise, **maximum 2 marks**. If non-linear scale is used over the range of the data on either axis eg values from the table are used as the scale points, **0 marks**. Do not penalise if candidates plot e against F. Accuracy of plotting should be easily checkable with the scale chosen. An appropriate scale to allow the accuracy of plotting to be checked must be linear over the range of the data.
		(ii)	Choosing 2 points on their line **(1)** Calculate gradient **(1)** (min 1 sig fig, max 4 sig figs) (Gradient works out as approx 3.3×10^3)	**2**	**Must** be consistent with graph drawn for (a)(i). Candidates are asked to calculate the gradient of **their line of best fit**. If relationship to calculate gradient is stated incorrectly (0) marks, eg $\frac{y^2 - y^1}{x^2 - x^1}$ If candidates use values from the table, these points must lie on **their line**. If $(\times 10^{-3})$ is not accounted for in the final answer, **maximum 1 mark** unless this being omitted is consistent with the graph drawn in (a)(i). A unit is not required in the final answer, but if stated it must be correct. If candidate has a non-linear scale over the range of the values used in the substitution, **0 marks**. If candidate has drawn a 'dot to dot' graph or no line, **0 marks**.

Question			Expected response	Max mark	Additional guidance
13.	(a)	(iii)	$\left(gradient = \frac{EA}{L}\right)$ $3.3\times10^{3} = \frac{E\times5.9\times10^{-8}}{1.500}$ **(1)** $E = 8.4\times10^{10}$ Pa **(1)**	**2**	**Must be** consistent with (a)(ii) **Must** substitute the gradient of **their line of best fit**, and not a single data point. If a single data point is substituted into in the calculation, award **0 marks**. Accept: correct alternative units If candidate has plotted extension against force, the formula becomes $\left(gradient = \frac{L}{EA}\right)$ $3.03\times10^{-4} = \frac{1.500}{E\times5.9\times10^{-8}}$ **(1)** $E = 8.4\times10^{10}$ Pa **(1)**
	(b)		There is (a non-zero) y-intercept. **OR** The line of best fit does not go through the origin.	**1**	

[END OF SPECIMEN MARKING INSTRUCTIONS]

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Change since last published:

We've replaced Question Paper 1 and Question Paper 2 with a single question paper that has two sections. The duration has been shortened and the number of marks reduced. Some questions have been removed from the previous specimen question papers, some have been edited or updated, and some have been replaced.