X272/12/02

NATIONAL QUALIFICATIONS 2012

MONDAY, 28 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 33)

11 Answer the questions numbered 21 to 33 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 33.

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

REFRACTIVE INDICES

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

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

SPECTRAL LINES

Element	*Wavelength*/nm	*Colour*
Hydrogen	656	Red
	486	Blue-green
	434	Blue-violet
	410	Violet
	397	Ultraviolet
	389	Ultraviolet
Sodium	589	Yellow

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

Lasers		
Element	*Wavelength*/nm	*Colour*
Carbon dioxide	9550 } 10590 }	Infrared
Helium-neon	633	Red

PROPERTIES OF SELECTED MATERIALS

Substance	*Density*/kg m^{-3}	*Melting Point*/K	*Boiling Point*/K
Aluminium	$2{\cdot}70 \times 10^{3}$	933	2623
Copper	$8{\cdot}96 \times 10^{3}$	1357	2853
Ice	$9{\cdot}20 \times 10^{2}$	273	. . . .
Sea Water	$1{\cdot}02 \times 10^{3}$	264	377
Water	$1{\cdot}00 \times 10^{3}$	273	373
Air	1·29	. . . .	. . . .
Hydrogen	$9{\cdot}0 \times 10^{-2}$	14	20

The gas densities refer to a temperature of 273 K and a pressure of $1{\cdot}01 \times 10^{5}$ Pa.

SECTION A

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

EXAMPLE

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

A kilowatt-hour

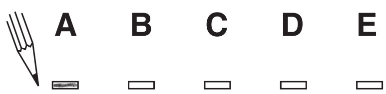
B ampere

C watt

D coulomb

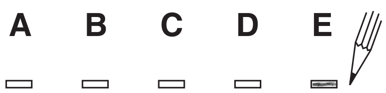
E volt.

The correct answer is **A**—kilowatt-hour. The answer **A** has been clearly marked in **pencil** with a horizontal line (see below).



Changing an answer

If you decide to change your answer, carefully erase your first answer and, using your pencil, fill in the answer you want. The answer below has been changed to **E**.



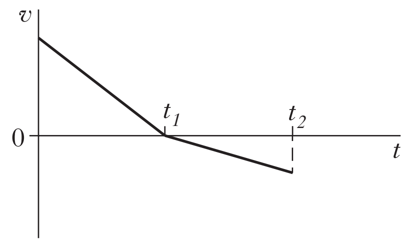
[Turn over

SECTION A

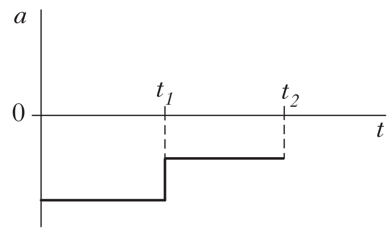
Answer questions 1–20 on the answer sheet.

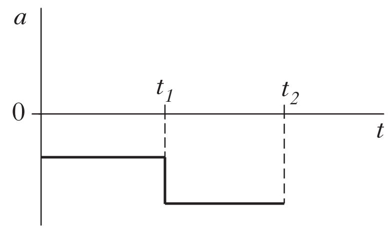
1. A trolley travels along a straight track.

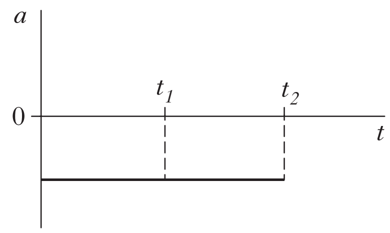
The graph shows how the velocity v of the trolley varies with time t.

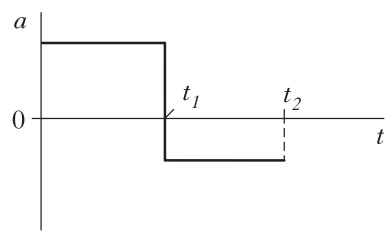


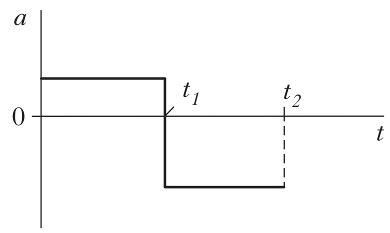
Which graph shows how the acceleration a of the trolley varies with time t?

A


B


C


D


E


2. A rocket of mass 200 kg accelerates vertically upwards from the surface of a planet at $2{\cdot}0\,\mathrm{m\,s^{-2}}$.

The gravitational field strength on the planet is $4{\cdot}0\,\mathrm{N\,kg^{-1}}$.

What is the size of the force being exerted by the rocket's engines?

A 400 N

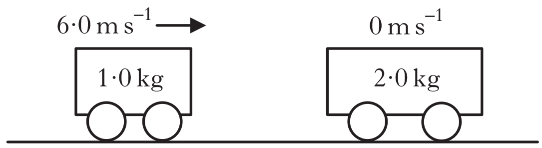
B 800 N

C 1200 N

D 2000 N

E 2400 N

3. 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.

How much kinetic energy is lost in this collision?

A 0 J

B 6·0 J

C 12 J

D 18 J

E 24 J

4. A satellite orbits a planet at a distance of $5{\cdot}0 \times 10^7$ m from the centre of the planet.

The mass of the satellite is $2{\cdot}5 \times 10^4$ kg.

The mass of the planet is $4{\cdot}0 \times 10^{24}$ kg.

The gravitational force acting on the satellite due to the planet is

A $1{\cdot}7 \times 10^{-6}$ N

B $2{\cdot}7 \times 10^{3}$ N

C $1{\cdot}3 \times 10^{11}$ N

D $2{\cdot}7 \times 10^{14}$ N

E $2{\cdot}7 \times 10^{32}$ N.

5. The length of a spaceship at rest is *L*.

This spaceship passes a planet at a speed of $0{\cdot}95c$.

Which row in the table gives the measured lengths of the spaceship according to an observer on the spaceship and an observer on the planet?

	Length measured by observer on spaceship	*Length measured by observer on planet*
A	*L*	*L*
B	*L*	less than *L*
C	less than *L*	*L*
D	less than *L*	less than *L*
E	greater than *L*	less than *L*

6. A spacecraft travels at a constant speed of $0{\cdot}70c$ relative to the Earth.

A clock on the spacecraft records a flight time of 3·0 hours.

A clock on Earth records this flight time to be

A 1·6 hours

B 2·1 hours

C 4·2 hours

D 5·5 hours

E 5·9 hours.

7. A galaxy is moving away from the Earth at a velocity of $1{\cdot}20 \times 10^7$ m s^{-1}.

Light of wavelength 450 nm is emitted from this galaxy.

When detected and measured on Earth this light has a wavelength of

A 425 nm

B 432 nm

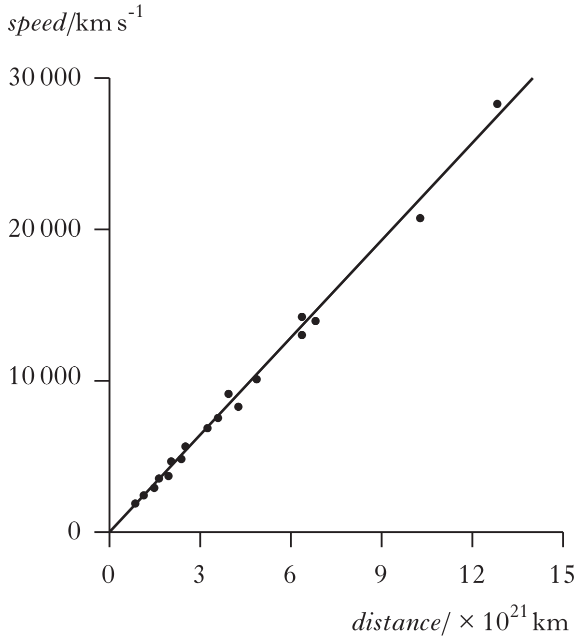
C 468 nm

D 475 nm

E 630 nm.

8. Galaxies at different distances from the Earth have been found to have different speeds.

The graph shows data for some distant galaxies.



A student studies this graph and makes the following statements.

I The speed of distant galaxies varies inversely with their distance from the Earth.

II The gradient of the line gives the value of Hubble's constant.

III The unit for Hubble's constant is s^{-1}.

Which of these statements is/are correct?

A I only

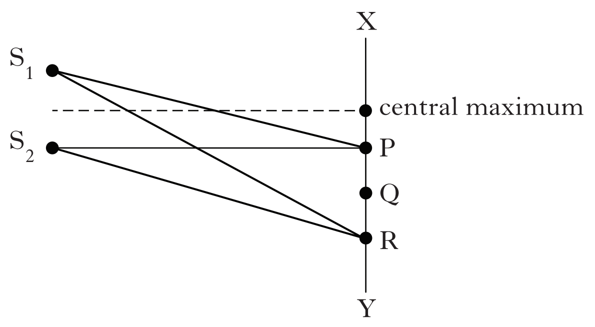
B II only

C III only

D I and II only

E II and III only

9. 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

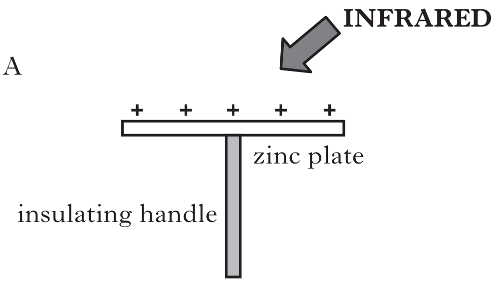
E 60 mm.

10. Clean zinc plates are mounted on insulating handles and then charged.

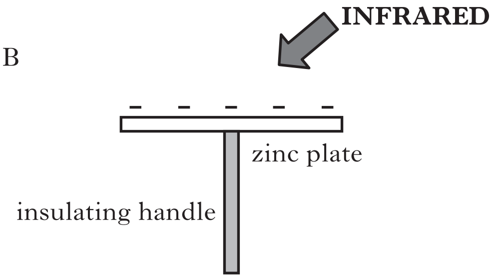
Different types of electromagnetic radiation are now incident on the plates as shown.

Which of the zinc plates is most likely to discharge due to photoelectric emission?

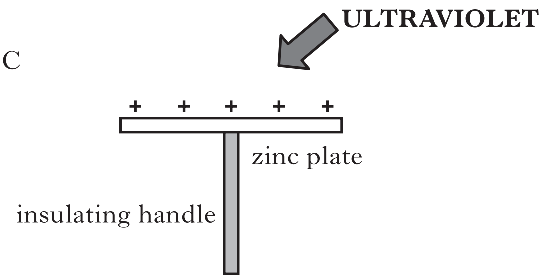
A



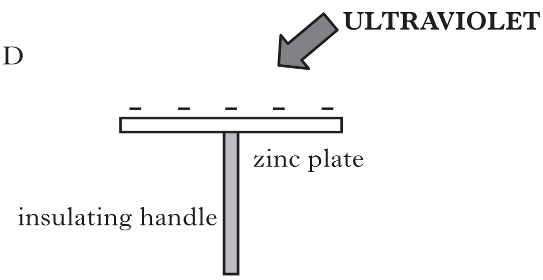
B



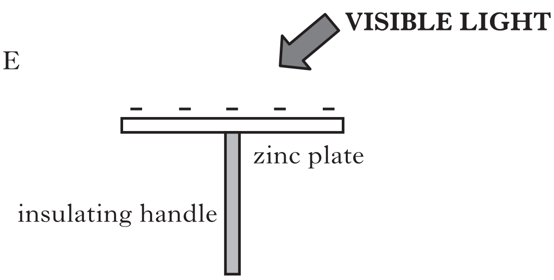
C



D



E



11. Electromagnetic radiation of frequency $9{\cdot}0 \times 10^{14}$ Hz is incident on a clean metal surface.

The work function of the metal is $5{\cdot}0 \times 10^{-19}$ J.

The maximum kinetic energy of a photoelectron released from the metal surface is

A $1{\cdot}0 \times 10^{-19}$ J

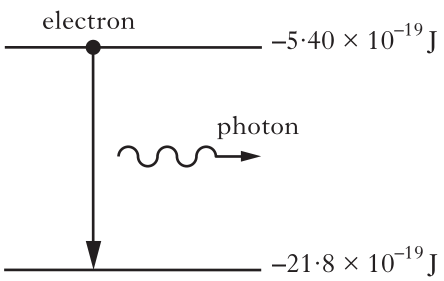
B $4{\cdot}0 \times 10^{-19}$ J

C $5{\cdot}0 \times 10^{-19}$ J

D $6{\cdot}0 \times 10^{-19}$ J

E $9{\cdot}0 \times 10^{-19}$ J.

12. In an atom, a photon of radiation is emitted when an electron makes a transition from a higher energy level to a lower energy level as shown.



The wavelength of the radiation emitted due to an electron transition between the two energy levels shown is

A $1{\cdot}2 \times 10^{-7}$ m

B $7{\cdot}3 \times 10^{-8}$ m

C $8{\cdot}2 \times 10^{6}$ m

D $1{\cdot}4 \times 10^{7}$ m

E $2{\cdot}5 \times 10^{15}$ m.

13. Which of the following statements describes a spontaneous nuclear fission reaction?

A $^{235}_{92}U + ^{1}_{0}n \rightarrow ^{144}_{56}Ba + ^{90}_{36}Kr + 2\,^{1}_{0}n$

B $^{7}_{3}Li + ^{1}_{1}H \rightarrow ^{4}_{2}He + ^{4}_{2}He$

C $^{3}_{1}H + ^{2}_{1}H \rightarrow ^{4}_{2}He + ^{1}_{0}n$

D $^{226}_{88}Ra \rightarrow ^{222}_{86}Rn + ^{4}_{2}He$

E $^{216}_{84}Po \rightarrow ^{216}_{84}Po + \gamma$

14. The statement below represents a nuclear reaction.

$$^{3}_{1}H + ^{2}_{1}H \rightarrow ^{4}_{2}He + ^{1}_{0}n$$

The total mass on the left hand side is $8{\cdot}347 \times 10^{-27}$ kg.

The total mass on the right hand side is $8{\cdot}316 \times 10^{-27}$ kg.

The energy released during one nuclear reaction of this type is

A $9{\cdot}30 \times 10^{-21}$ J

B $2{\cdot}79 \times 10^{-12}$ J

C $7{\cdot}51 \times 10^{-10}$ J

D $1{\cdot}50 \times 10^{-9}$ J

E $2{\cdot}79 \times 10^{15}$ J.

15. Which of the following lists the particles in order of size from smallest to largest?

A helium nucleus; electron; proton

B helium nucleus; proton; electron

C proton; helium nucleus, electron

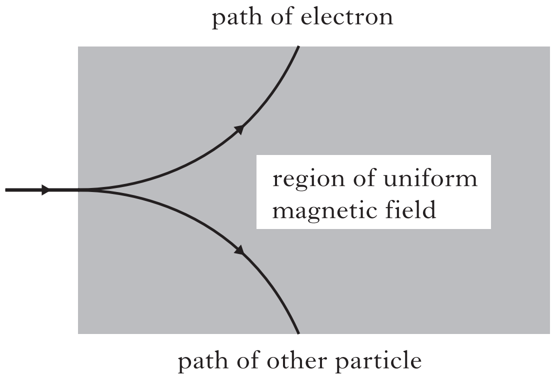
D electron; helium nucleus, proton

E electron; proton; helium nucleus

[Turn over

16. An electron and another particle of identical mass pass through a uniform magnetic field.

Their paths are shown in the diagram.



This observation provides evidence for the existence of

A neutrinos

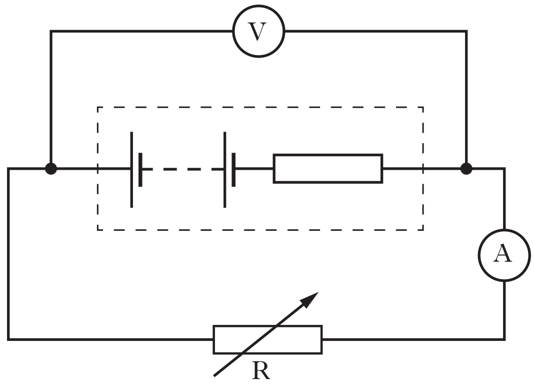
B antimatter

C quarks

D protons

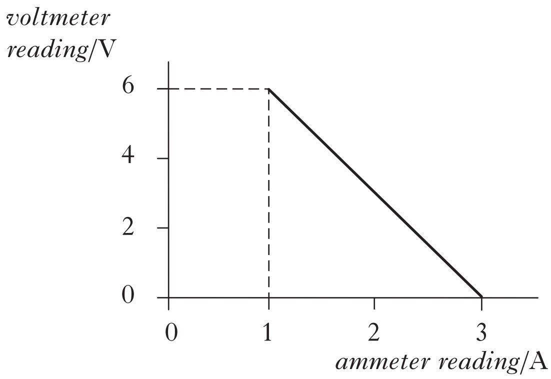
E force mediating particles.

17. A circuit is set up as shown.



The variable resistor R is adjusted and a series of readings taken from the voltmeter and ammeter.

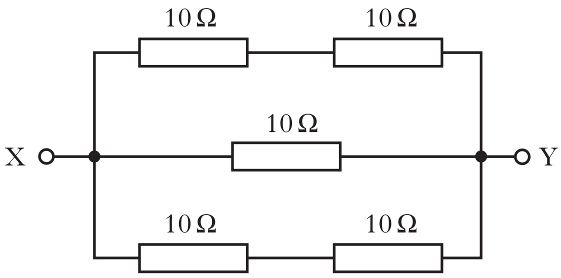
The graph shows how the voltmeter reading varies with the ammeter reading.



Which row in the table shows the values for the e.m.f. and internal resistance of the battery in the circuit?

	e.m.f./V	*internal resistance*/Ω
A	6	2
B	6	3
C	9	2
D	9	3
E	9	6

18. The diagram shows part of an electrical circuit.



What is the resistance between X and Y?

A 0·2 Ω

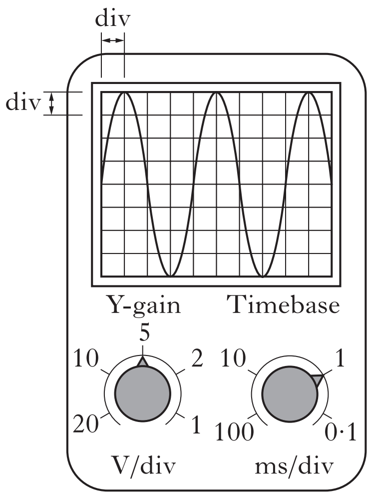
B 5 Ω

C 10 Ω

D 20 Ω

E 50 Ω

19. An alternating voltage is displayed on an oscilloscope screen. The Y-gain and the timebase settings are shown.



Which row in the table gives the values for the peak voltage and frequency of the signal?

	Peak voltage/V	*Frequency*/Hz
A	10	100
B	10	250
C	20	250
D	10	500
E	20	1000

20. The letters **X**, **Y** and **Z** represent missing words in the following passage.

Solids can be categorised as conductors, semiconductors or insulators.

In . . . **X** *. . . the energy gap between the valence band and the conduction band is . . .* **Y** *. . . , allowing . . .* **Z** *. . . conduction to take place at room temperature.*

Which row in the table shows the missing words?

	X	**Y**	**Z**
A	conductors	large	no
B	semiconductors	small	no
C	conductors	large	some
D	semiconductors	small	some
E	insulators	small	no

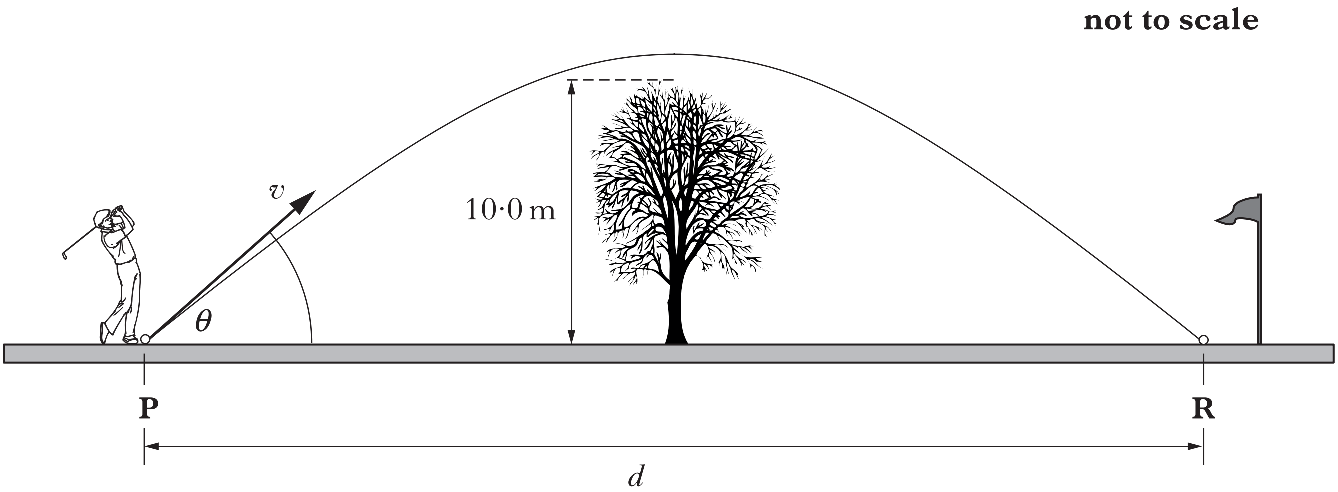
[Turn over

Write your answers to questions 21 to 33 in the answer book.

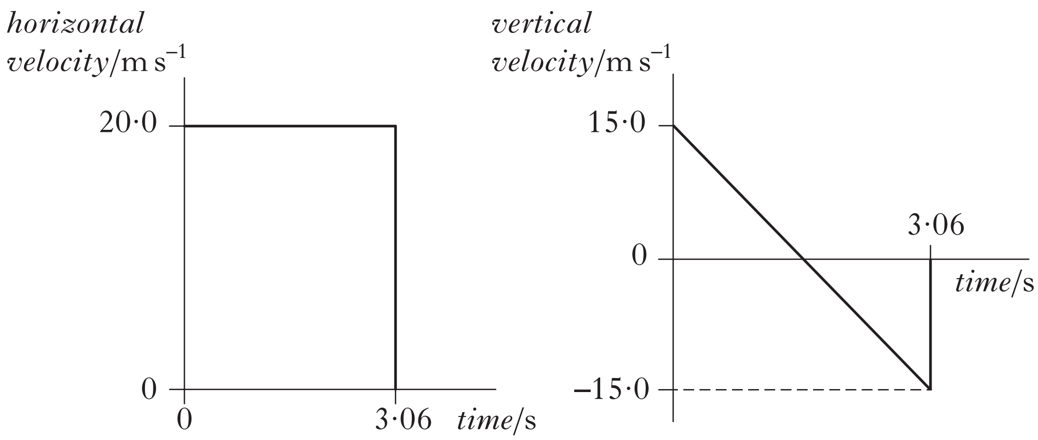
21. A golfer hits a ball from point **P**. The ball leaves the club with a velocity v at an angle of θ to the horizontal.

The ball travels through the air and lands at point **R**.

Midway between **P** and **R** there is a tree of height 10·0 m.



(*a*) The horizontal and vertical components of the ball's velocity during its flight are shown.



The effects of air resistance can be ignored.

Calculate:

(i) the horizontal distance d; **1**

(ii) the maximum height of the ball above the ground. **2**

(*b*) When the effects of air resistance are **not** ignored, the golf ball follows a different path.

Is the ball more or less likely to hit the tree?

You must justify your answer. **2**

Marks

22. All stars emit radiation with a range of wavelengths. The peak wavelength of radiation, λ_{peak}, emitted from a star is related to the surface temperature, T, of the star.

The table gives the surface temperatures, in kelvin, of four different stars and the peak wavelength radiated from each star.

Surface temperature of star T/K	*Peak wavelength radiated* λ_{peak}/m
4200	$6{\cdot}90 \times 10^{-7}$
5800	$5{\cdot}00 \times 10^{-7}$
7900	$3{\cdot}65 \times 10^{-7}$
12 000	$2{\cdot}42 \times 10^{-7}$

(*a*) Use **all** the data in the table to show that the relationship between the surface temperature, T, of a star and the peak wavelength radiated, λ_{peak}, from the star is

$$T = \frac{2{\cdot}9 \times 10^{-3}}{\lambda_{peak}}$$ **2**

(*b*) The blue supergiant star Eta Carinae is one of the largest and most luminous stars in our galaxy. It emits radiation with a peak wavelength of 76 nm.

Calculate the surface temperature, in kelvin, of this star. **2**

(*c*) Radiation of peak wavelength 1·06 mm can be detected on Earth coming from all directions in space.

(i) What name is given to this radiation? **1**

(ii) Give a reason why the existence of this radiation supports the Big Bang Theory. **1**

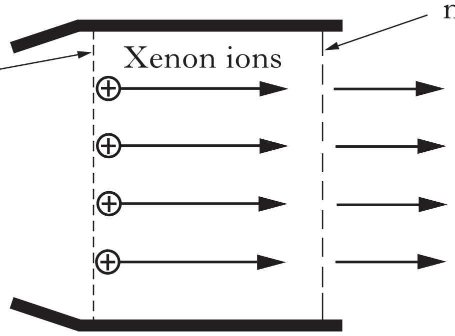
(6)

[Turn over

Marks

23. An ion propulsion engine can be used to propel spacecraft to areas of deep space.

A simplified diagram of a Xenon ion engine is shown.



The Xenon ions are accelerated as they pass through an electric field between the charged metal grids. The emitted ion beam causes a force on the spacecraft in the opposite direction.

The spacecraft has a total mass of 750 kg.

The mass of a Xenon ion is $2{\cdot}18 \times 10^{-25}$ kg and its charge is $1{\cdot}60 \times 10^{-19}$ C. The potential difference between the charged metal grids is $1{\cdot}22$ kV.

(*a*) (i) Show that the work done on a Xenon ion as it moves through the electric field is $1{\cdot}95 \times 10^{-16}$ J. **1**

(ii) Assuming the ions are accelerated from rest, calculate the speed of a Xenon ion as it leaves the engine. **2**

(*b*) The ion beam exerts a constant force of $0{\cdot}070$ N on the spacecraft. Calculate the change in speed of the spacecraft during a 60 second period of time. **2**

(*c*) A different ion propulsion engine uses Krypton ions which have a smaller mass than Xenon ions. The Krypton engine emits the same number of ions per second at the same speed as the Xenon engine.

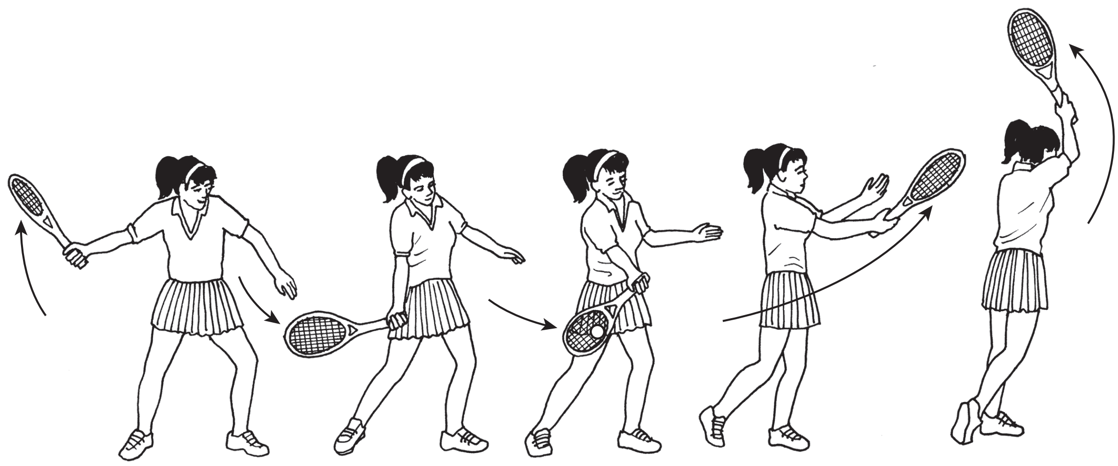
Which of the two engines produces a greater force?

Justify your answer. **2**

(7)

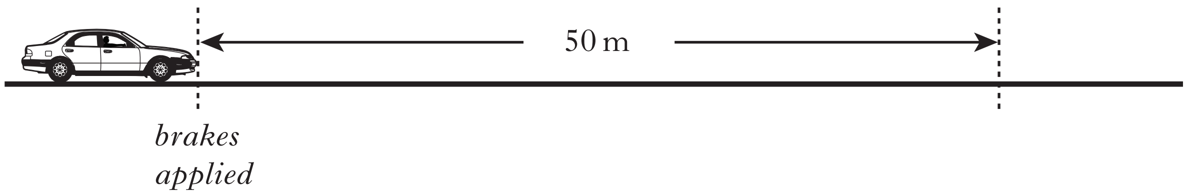
Marks

24. Tennis players are coached to swing "through the ball" when striking it rather than stopping the tennis racquet suddenly.



Use your knowledge of physics to comment on why this causes the ball to leave the racquet with a greater speed. **(3)**

25. A car is travelling along a straight, level road. The brakes are then applied and the car comes to rest in a distance of 50 m.



The work done in stopping the car is 75 kJ and the average external frictional force exerted on the car is 300 N.

The total mass of the car and driver is 1100 kg.

(*a*) Calculate the average force exerted by the brakes on the car. **3**

(*b*) A second car of smaller total mass is travelling at the same speed along the same road. Its brakes are applied and it stops in the same distance of 50 m.

The same average external frictional force is exerted on this car.

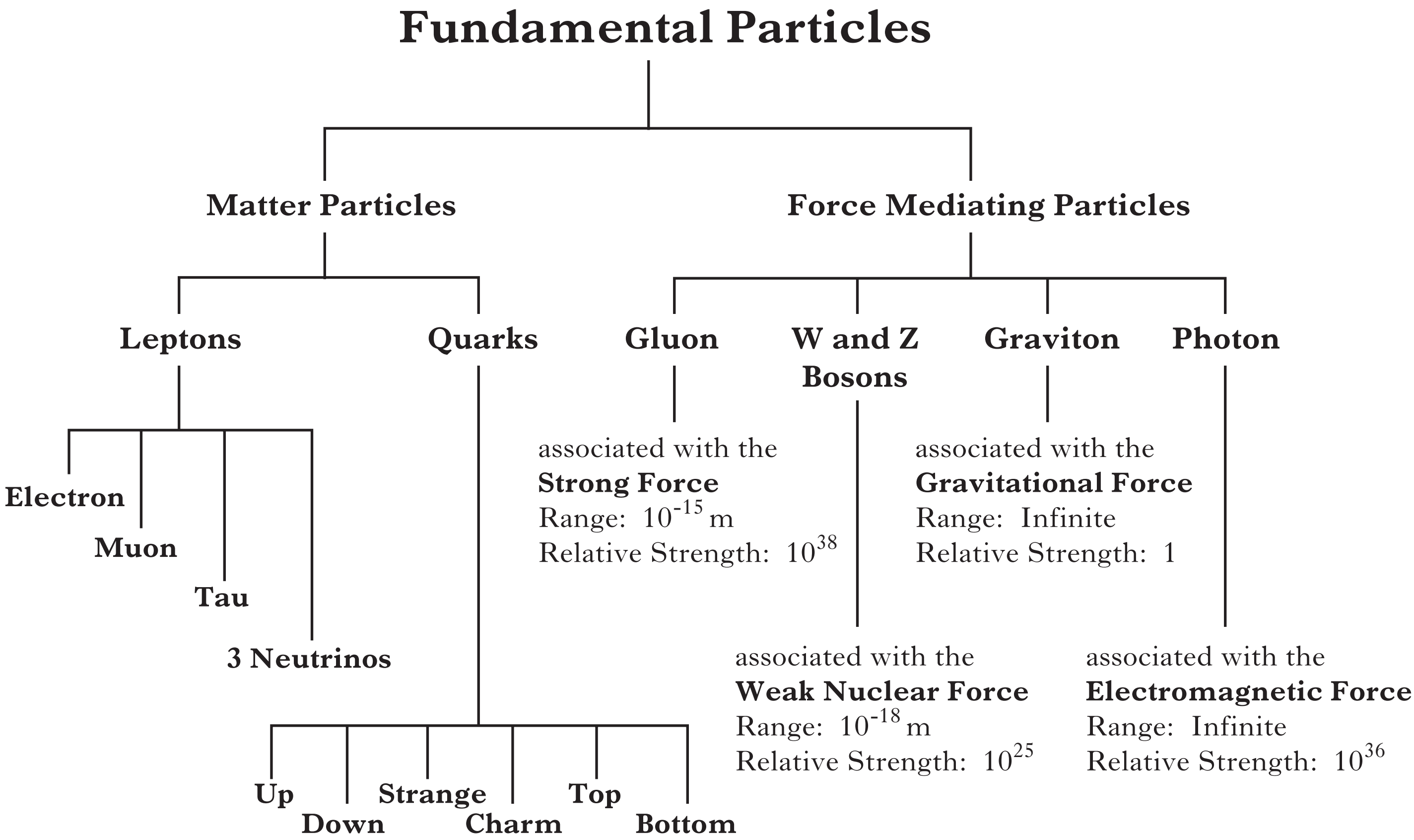
How does the value of the average braking force on this car compare to that of the original car?

You must justify your answer. **2**

(5)

[Turn over

26. The following diagram gives information on the Standard Model of Fundamental Particles and Interactions.



Marks

Use information from the diagram and your knowledge of physics to answer the following questions.

(*a*) Explain why particles such as leptons and quarks are known as *Fundamental Particles*. **1**

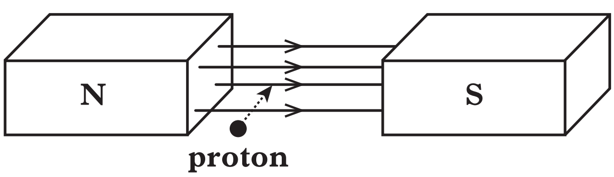
(*b*) A particle called the sigma plus (Σ^+) has a charge of +1. It contains two different types of quark. It has two up quarks each having a charge of $+^2/_3$ and one strange quark.

What is the charge on the strange quark? **1**

(*c*) Explain why the gluon cannot be the force mediating particle for the gravitational force. **1**

(*d*) 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 around the collider using strong magnetic fields.

(i) The diagram shows a proton entering a magnetic field.



In which direction is this proton deflected? **1**

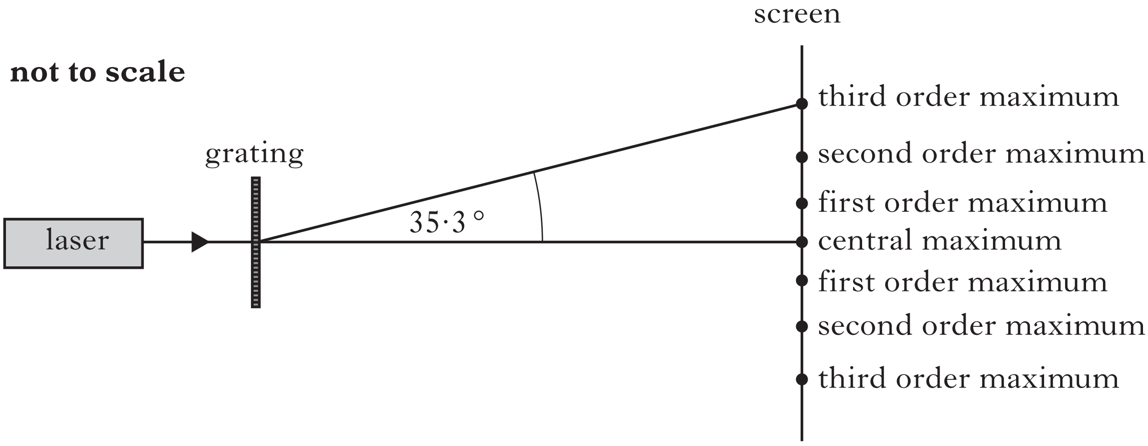
(ii) The neutron is classified as a hadron.

Explain why neutrons are **not** used for collision experiments in the LHC. **1**

(5)

Marks

27. A manufacturer claims that a grating consists of $3{\cdot}00 \times 10^5$ lines per metre and is accurate to $\pm\, 2{\cdot}0\%$. A technician decides to test this claim. She directs laser light of wavelength 633 nm onto the grating.



She measures the angle between the central maximum and the third order maximum to be 35·3 °.

(*a*) Calculate the value she obtains for the slit separation for this grating. **2**

(*b*) What value does she determine for the number of lines per metre for this grating? **1**

(*c*) Does the technician's value for the number of lines per metre agree with the manufacturer's claim of $3{\cdot}00 \times 10^5$ lines per metre $\pm\, 2{\cdot}0\%$?

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

(5)

28. One of the most important debates in scientific history asked the question:

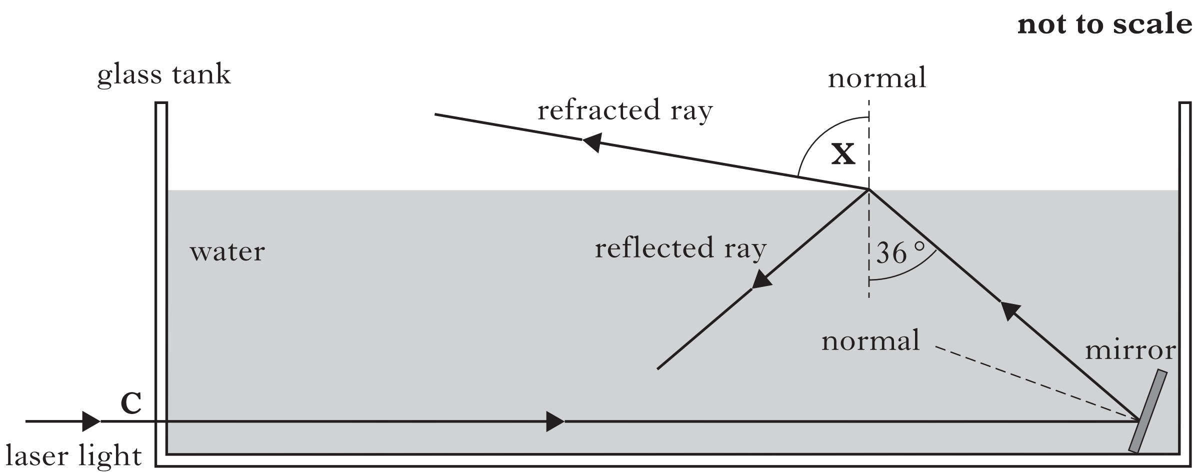
"Is light a wave or a particle?"

Use your knowledge of physics to comment on our understanding of this issue. **(3)**

[Turn over

Marks

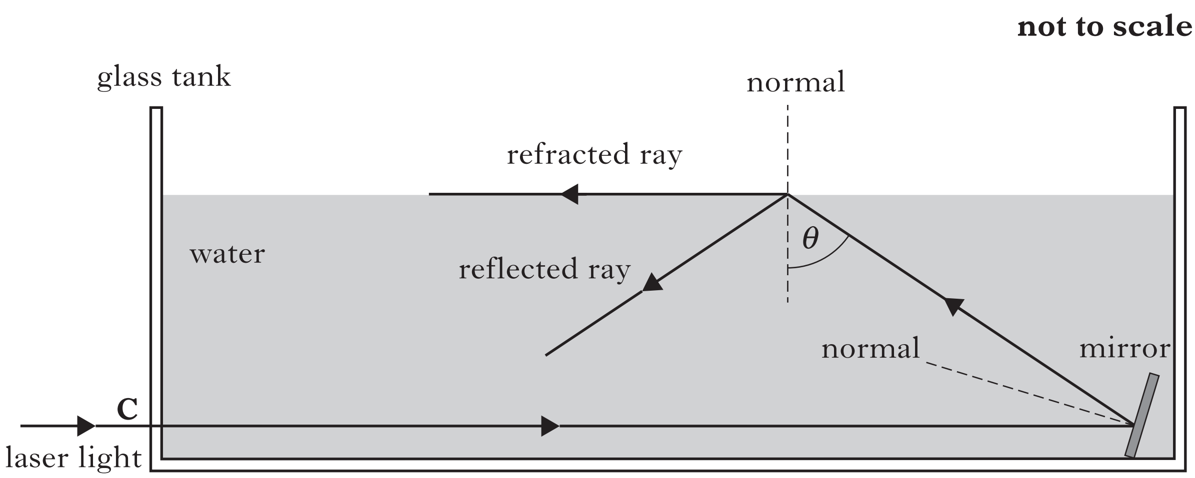
29. A technician investigates the path of laser light as it passes through a glass tank filled with water. The light enters the glass tank along the normal at **C** then reflects off a mirror submerged in the water.



The refractive index of water for this laser light is 1·33.

(*a*) Calculate angle **X**. **2**

(*b*) The mirror is now adjusted until the light follows the paths shown.



(i) State why the value of θ is equal to the critical angle for this laser light in water. **1**

(ii) Calculate angle θ. **2**

(*c*) The water is now replaced with a liquid which has a greater refractive index. The mirror is kept at the same angle as in part (*b*) and the incident ray again enters the tank along the normal at **C.**

Draw a sketch which shows the path of the light ray after it has reflected off the mirror.

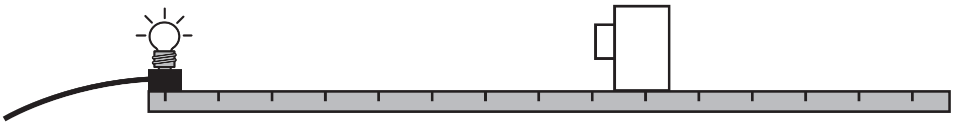
Your sketch should only show what happens at the surface of the liquid. **1**

(6)

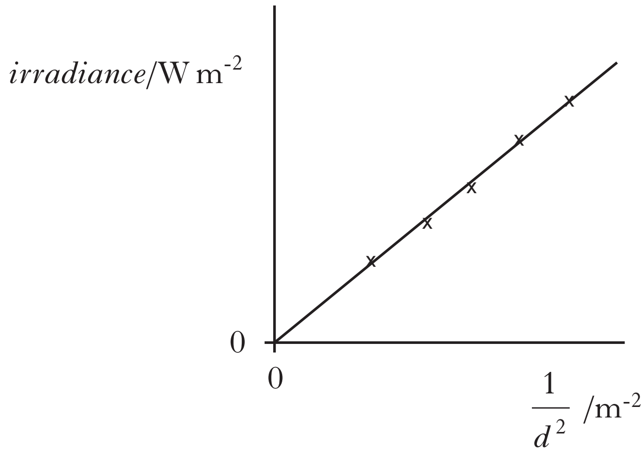
Marks

30. A student investigates how irradiance I varies with distance d from a small lamp.

The following apparatus is set up in a darkened laboratory.



The results are used to produce the following graph.



(*a*) Explain why this graph confirms the relationship $I = \dfrac{k}{d^2}$ **1**

(*b*) The irradiance of light from the lamp at a distance of 1·6 m is 4·0 W m^{-2}.

Calculate the irradiance of the light at a distance of 0·40 m from the lamp. **2**

(*c*) The experiment is repeated with the laboratory lights switched on.

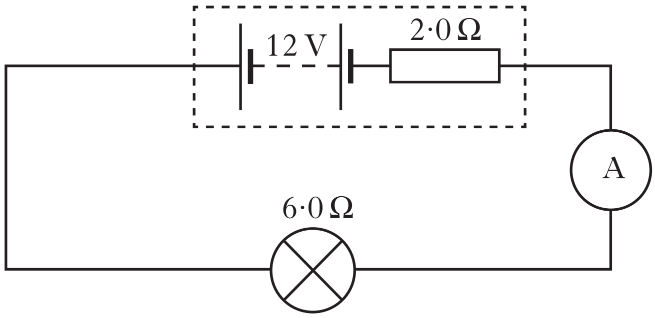
Copy the graph shown and, on the same axes, draw another line to show the results of the second experiment. **1**

(4)

[Turn over

31. A student carries out two experiments using different power supplies connected to a lamp of resistance $6{\cdot}0\,\Omega$.

(*a*) In the first experiment, the lamp is connected to a power supply of e.m.f. 12 V and internal resistance $2{\cdot}0\,\Omega$ as shown.



Calculate:

(i) the reading on the ammeter; **2**

(ii) the lost volts; **1**

(iii) the output power of the lamp. **2**

(*b*) In the second experiment, the lamp is connected to a different power supply. This supply has the same e.m.f. as the supply in part (*a*) but a different value of internal resistance.

The output power of the lamp is now greater.

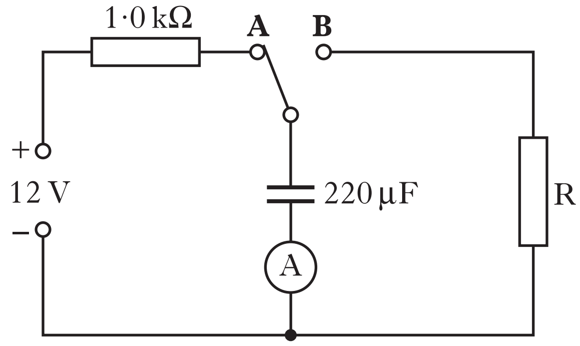
Assuming the resistance of the lamp has not changed, is the internal resistance of the new power supply less than, equal to, or greater than the internal resistance of the original supply?

Justify your answer. **2**

(7)

[Turn over for Question 32 on *Page twenty*

32. The charging and discharging of a capacitor are investigated using the circuit shown.



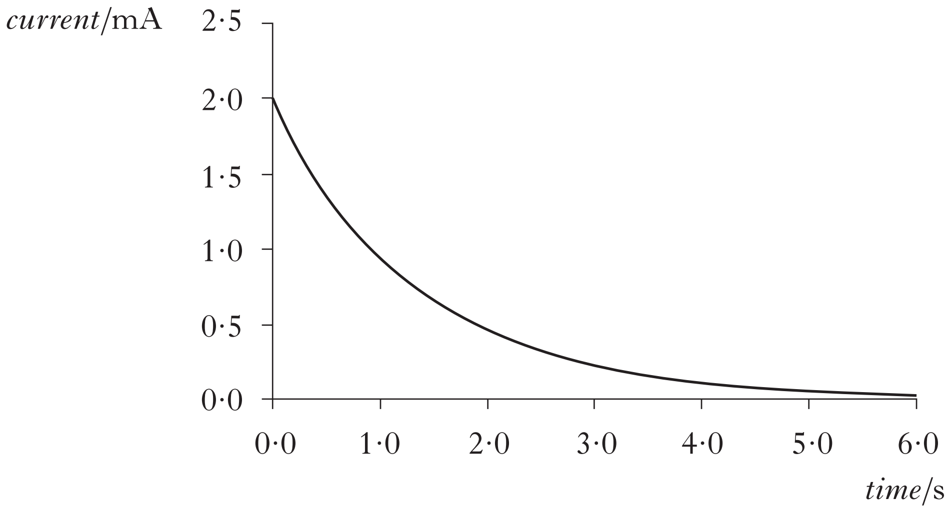
The power supply has an e.m.f. of 12 V and negligible internal resistance. The capacitor is initially uncharged.

(*a*) The switch is connected to **A** and the capacitor starts to charge. Sketch a graph showing how the voltage across the plates of the capacitor varies with time. Your graph should start from the moment the switch is connected to **A** until the capacitor is fully charged.

Numerical values are only required on the voltage axis. **2**

(*b*) The capacitor is now discharged by moving the switch to **B**.

The graph of current against time as the capacitor discharges is shown.

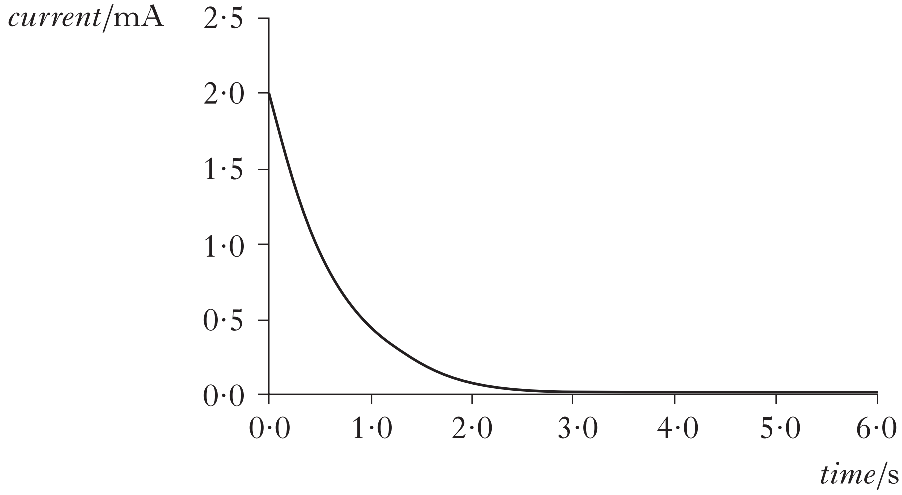


Calculate the resistance of R. **2**

32. (continued)

(*c*) The 220 μF capacitor is now replaced with one of different value. This new capacitor is fully charged by moving the switch to **A**. It is then discharged by moving the switch to **B**.

The graph of current against time as this capacitor discharges is shown.



(i) Explain why the value of the initial discharging current remains the same as in part (*b*). **1**

(ii) How does the capacitance of this capacitor compare with the capacitance of the original 220 μF capacitor?

You must justify your answer. **2**

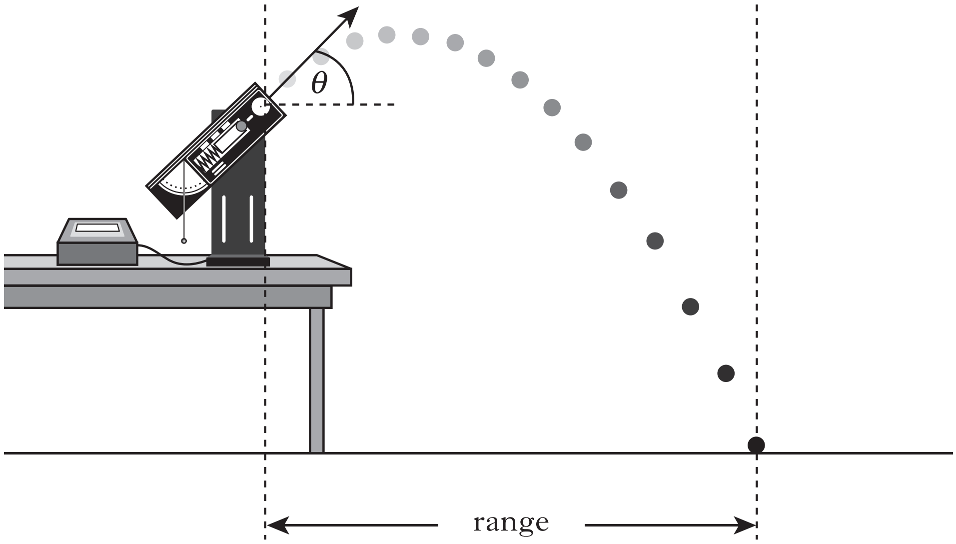
(7)

[Turn over

Marks

33. A group of students carries out an experiment to find how the horizontal range of a ball depends on the angle of launch, θ.

They use a projectile launcher as shown.



The results are shown in the table.

Angle of launch, θ (°)	*Range* (m)
20	1·55
30	1·64
40	1·63
50	1·43
60	1·18
70	0·95

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

(*b*) Use your graph to estimate the angle of launch that produces the maximum range of the ball. **1**

(*c*) Using the same apparatus, the students now wish to determine more precisely the angle of launch that produces the maximum range.

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

(*d*) Describe further experimental work that could be carried out to investigate another factor that may affect the horizontal range of a projectile. **2**

(7)

[*END OF QUESTION PAPER*]

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$d = \bar{v}t$

$s = \bar{v}t$

$v = u + at$

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

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

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

$W = mg$

$F = ma$

$E_w = Fd$

$E_p = mgh$

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

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

$p = mv$

$Ft = mv - mu$

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

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

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

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

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

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

$v = H_0 d$

$E_w = QV$

$E = mc^2$

$E = hf$

$E_k = hf - hf_0$

$E_2 - E_1 = hf$

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

$v = f\lambda$

$d\sin\theta = m\lambda$

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

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

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

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

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

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

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

$Q = It$

$V = IR$

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

$R_T = R_1 + R_2 + \ldots$

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

$E = V + Ir$

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

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

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

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

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

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

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