Name:		Index Number:		Class:	

DUNMAN HIGH SCHOOL
Preliminary Examination
Year 6

H2 PHYSICS

9749/01

Paper 1 Multiple Choice Questions

26 September 2025
1 hour

Additional Materials: Multiple Choice Answer Sheet

READ THESE INSTRUCTIONS FIRST

Write your class, index number and name at the top of this page.
Write in soft pencil.
Do not use staples, paper clips, glue or correction fluid.

There are **30** questions on this paper. Answer **all** questions. For each question there are four possible answers **A**, **B**, **C** and **D**.
Choose the **one** you consider correct and record your choice in **soft pencil** on the separate Answer Sheet.

Read the instructions on the Answer Sheet very carefully.

Each correct answer will score one mark. A mark will not be deducted for a wrong answer.
Any rough working should be done on this booklet.

The use of an approved scientific calculator is expected, where appropriate.

This document consists of **17** printed pages and **3** blank pages.

Data

speed of light in free space,	c =	3.00×10^{8} m s^{-1}
permeability of free space,	μ_o =	$4\pi \times 10^{-7}$ H m^{-1}
permittivity of free space,	ε_o =	8.85×10^{-12} F m^{-1}
	=	$(1/(36\pi)) \times 10^{-9}$ F m^{-1}
elementary charge,	e =	1.60×10^{-19} C
the Planck constant,	h =	6.63×10^{-34} J s
unified atomic mass constant,	u =	1.66×10^{-27} kg
rest mass of electron,	m_e =	9.11×10^{-31} kg
rest mass of proton,	m_p =	1.67×10^{-27} kg
molar gas constant	R =	8.31 J K^{-1} mol^{-1}
the Avogadro constant,	N_A =	6.02×10^{23} mol^{-1}
the Boltzmann constant,	k =	1.38×10^{-23} J K^{-1}
gravitational constant,	G =	6.67×10^{-11} N m^{2} kg^{-2}
acceleration of free fall,	g =	9.81 m s^{-2}

Formulae

uniformly accelerated motion, $s = ut + \frac{1}{2}at^2$

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

work done on/by a gas, $W = p\Delta V$

hydrostatic pressure, $p = \rho gh$

gravitational potential, $\phi = -Gm/r$

temperature, $T/\text{K} = T/°\text{C} + 273.15$

pressure of an ideal gas, $p = \frac{1}{3}\frac{Nm}{V}<c^2>$

mean translational kinetic energy of an ideal gas molecule, $E = \frac{3}{2}kT$

displacement of particle in s.h.m., $x = x_0 \sin \omega t$

velocity of particle in s.h.m., $v = v_0 \cos \omega t$

$= \pm\omega\sqrt{x_o^2 - x^2}$

electric current, $I = Anvq$

resistors in series, $R = R_1 + R_2 + \ldots$

resistors in parallel, $1/R = 1/R_1 + 1/R_2 + \ldots$

electric potential, $V = \frac{Q}{4\pi\varepsilon_o r}$

alternating current / voltage, $x = x_0 \sin \omega t$

magnetic flux density due to a long straight wire, $B = \frac{\mu_0 I}{2\pi d}$

magnetic flux denxity due to a flat circular coil, $B = \frac{\mu_0 NI}{2r}$

magnetic flux density due to a long solenoid, $B = \mu_0 nI$

radioactive decay, $x = x_0 \exp(-\lambda t)$

decay constant, $\lambda = \frac{\ln 2}{t_{\frac{1}{2}}}$

1 Two students A and B carry out a series of experiments to determine the density of water. The results are tabulated below. The true value for the density of water is 1000 kg m^{-3}.

density of water, ρ / kg m^{-3}	
Student A	**Student B**
1002	998
998	998
997	998
1001	997
999	997

Which of the following statements below correctly compares the two sets of experimental results?

A Results of Student A is more accurate and more precise than those of Student B.

B Results of Student A is more accurate and less precise than those of Student B.

C Results of Student A is less accurate and more precise than those of Student B.

D Results of Student A is less accurate and less precise than those of Student B.

2 An object of mass 3.0 kg is falling vertically from rest. Air resistance R, in newtons, is given by the empirical equation

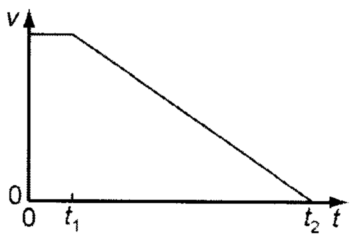
$$R = 0.60\ v$$

where v is the velocity in metres per second.

What is the maximum velocity of the object and what is the acceleration of the object when its velocity is 12 m s^{-1}?

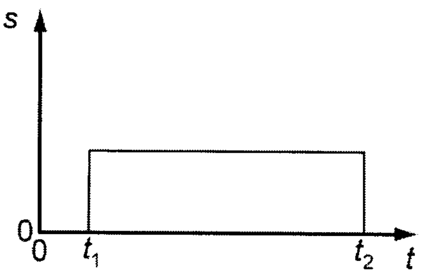
	maximum velocity / m s^{-1}	acceleration when v = 12 m s^{-1} / m s^{-2}
A	16	2.4
B	16	7.4
C	49	2.4
D	49	7.4

3 When a car driver sees a hazard ahead, she applies the brakes as soon as she can and brings the car to rest. The graph shows how the speed v of the car varies with time t after the hazard is seen.

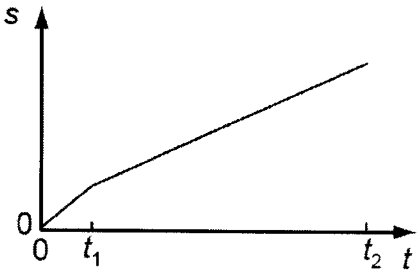


Which graph represents the variation with time t of the distance s travelled by the car after the hazard has been seen?

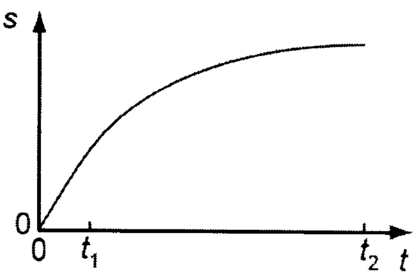
A



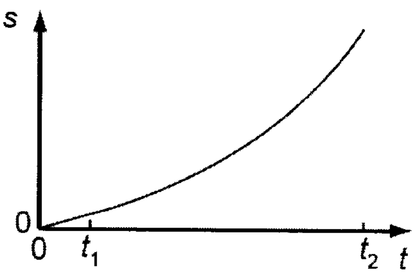
B



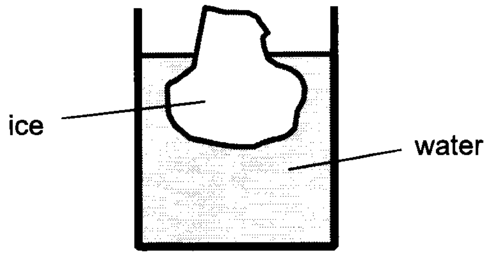
C



D



4 A lump of ice floats in water as shown.



Which statement is correct?

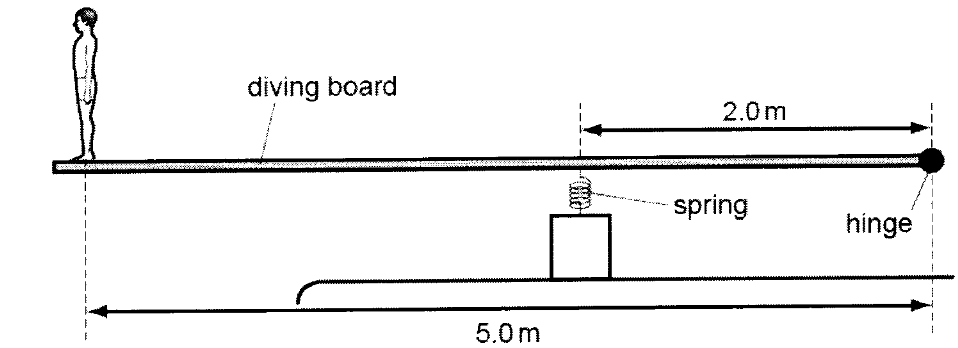
A The lump of ice floats because the area of its lower surface is larger than the area of its upper surface.

B The pressure difference between the lower and upper surface of the lump of ice gives rise to an upthrust equal to its weight.

C The ice has a greater density than the water.

D The mass of water displaced by the ice is equal to the upthrust.

5 A uniform diving board of length 5.0 m and mass 50 kg is hinged at one end and supported 2.0 m from this end by a spring of spring constant 10 kN m^{-1}. A child of mass 40 kg stands at the far end of the board.

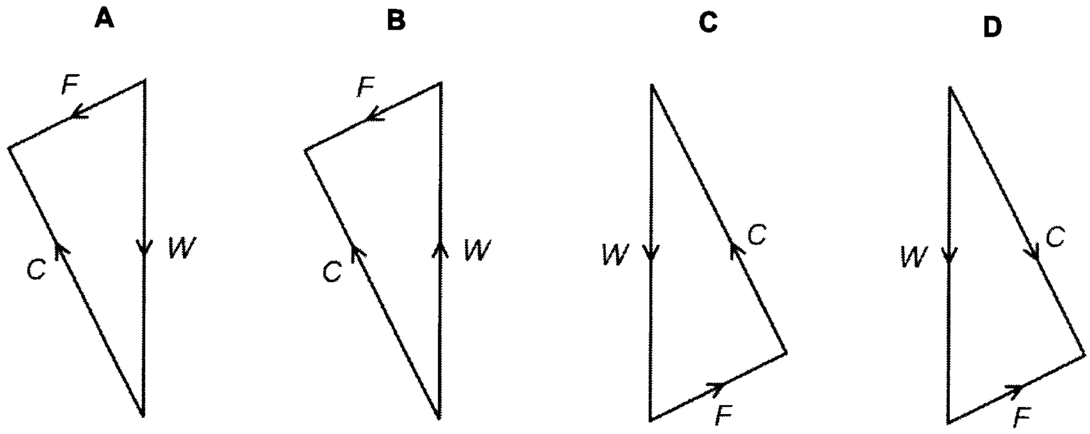


What is the extra compression of the spring caused by the child standing on the end of the board? (Assume the diving board remains horizontal with and without the child standing on it.)

A 1.0 cm **B** 6.1 cm **C** 9.8 cm **D** 16 cm

6 A sledge slides down a slope at a constant velocity. The three forces that act on the sledge are the normal contact force *C*, the weight *W* and a constant frictional force *F*.

Which diagram represents these forces acting on the sledge?



7 A piston in a gas supply pump has an area of 600 cm^2 and it moves a distance of 40 cm during one stroke. The pump moves the gas against a fixed pressure of 5000 Pa.

How much work is done by the piston during one stroke?

A 1.2×10^2 J **B** 1.2×10^4 J **C** 1.2×10^6 J **D** 1.2×10^8 J

8 An area of land is at a distance of 2.0 m below sea level. To prevent flooding, pumps are used to lift rainwater up to sea level.

What is the minimum pump output power required to lift 1.3×10^9 kg of rainwater per day?

A 15 kW **B** 30 kW **C** 150 kW **D** 300 kW

9 The minute hand of a large clock is 3.0 m long.

What is the speed at the tip of the minute hand?

A 1.7×10^{-3} m s^{-1} **B** 5.2×10^{-3} m s^{-1} **C** 0.10 m s^{-1} **D** 0.31 m s^{-1}

10 Two stars of masses M and $2M$ move in circular motion about their common centre of mass.

Which of the following statements is true?

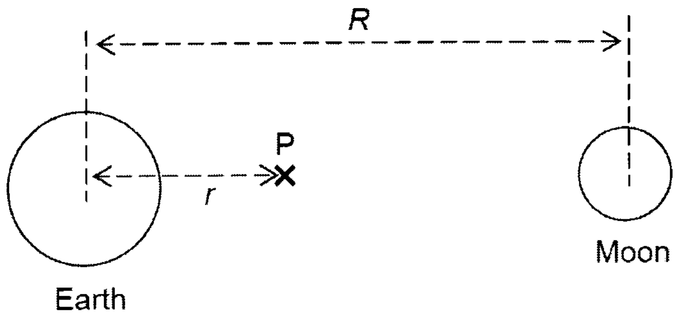
A Such a motion is not possible.

B Both stars move with the same speed.

C Both stars move with the same radius.

D Both stars move with the same angular velocity.

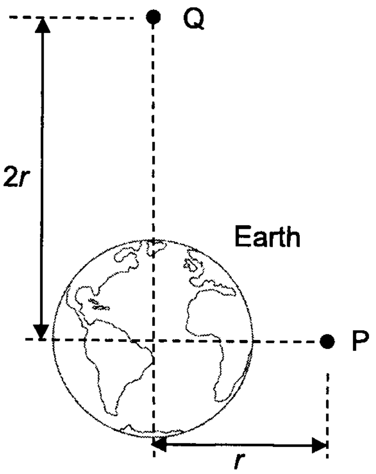
11 A spacecraft is launched from the surface of the Earth towards the Moon. In order to reach the Moon with the least effort possible, the spacecraft needs to reach a point P, beyond which it will move towards the Moon without any further input of energy. R is the distance between the Earth and the Moon, M_E is the mass of the Earth and M_M is the mass of the Moon.



What is the distance r, from the centre of the Earth to point P, in terms of R, M_E and M_M?

A $\dfrac{R}{\sqrt{\dfrac{M_E}{M_M}}}+1$ **B** $\dfrac{R}{\sqrt{\dfrac{M_M}{M_E}}+1}$ **C** $\left(\sqrt{\dfrac{M_M}{M_E}}\right)R$ **D** $\dfrac{M_M}{M_E}R$

12 P and Q are two points above Earth's surface at distances r and $2r$ respectively from the centre of the Earth.



The gravitational potential at P is –800 kJ kg^{-1}. When a 1.00 kg mass is taken from Q to P, what is the work done on the mass?

A –400 kJ **B** –200 kJ **C** 400 kJ **D** 800 kJ

13 When a graph of temperature in Kelvin against temperature in degrees Celsius is plotted, a linear graph is obtained.

What is the vertical intercept and gradient of the line?

	vertical intercept	gradient
A	–273.15	1
B	0	1 / 273.15
C	0	273.15
D	273.15	1

14 When a frictionless and well-insulated bicycle pump is used to pump up a basketball, the air in the ball becomes hotter than the surrounding air.

Which of the following statements best describes this observation?

A Thermal energy is supplied to the air during the pumping action, but the internal energy remains unchanged.

B Work is done on the air and since little thermal energy escapes, the internal energy increases.

C The internal energy of the air increases because thermal energy is supplied and work is done on the air.

D After compression, the internal energy decreases as thermal energy is lost to the surroundings.

15 Which of the following statements is true for an object undergoing very lightly damped oscillations?

A The period of oscillation increases over time.

B The total energy of the object decreases exponentially with time.

C The amplitude of the oscillation is proportional to the frequency.

D The damping force is always pointing towards the equilibrium point.

16 A speaker of a public address system operates at 2000 W and radiates sound uniformly in all directions.

If a typical adult ear has a surface area of 2.1×10^{-3} m^2 and assuming that the sound from the speaker strikes the surface of the ear perpendicularly, how much power is intercepted by the ear of an adult standing 78 m away from the speaker?

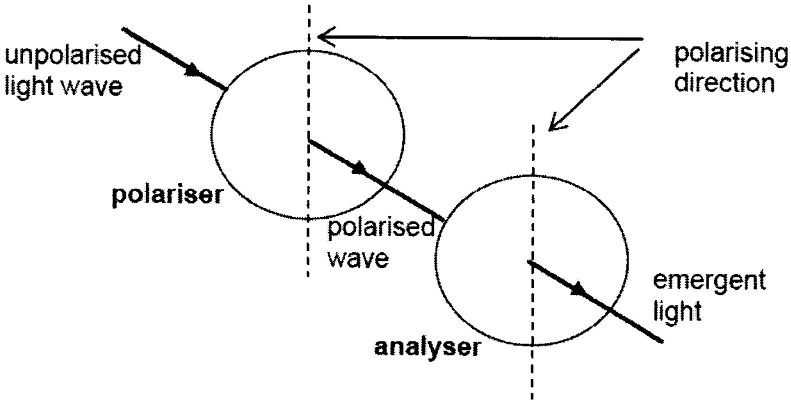
A 5.49×10^{-5} W

B 2.20×10^{-4} W

C 4.28×10^{-3} W

D 2.61×10^{-2} W

17 An unpolarised light wave is passed through two polaroids. Their polarising axes are aligned as shown.



The analyser could be rotated such that its polarising axis could be at different angles with respect to the polariser. Which of the following order of angles gives the correct order of increasing intensity of the emergent light?

A 0°, 90°, 135°

B 0°, 135°, 90°

C 90°, 0°, 135°

D 90°, 135°, 0°

18 A guitar string of length L stretched between two ends is plucked. It is known that the speed of transverse waves on the string is v and the speed of sound waves is c.

Which of the following expressions, in which n has integer values 1, 2, 3, ... etc., will give the frequencies of all stationary waves which can be formed on the wire?

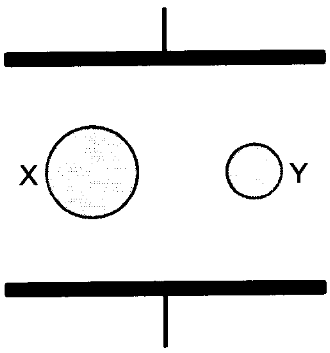
A $\frac{nv}{L}$ **B** $\frac{nv}{2L}$ **C** $\frac{2nc}{L}$ **D** $\frac{nc}{L}$

19 Monochromatic light is incident normally on a diffraction grating and first order diffraction is observed at an angle of 28.6°.

Which of the following statements is true?

A The second order image is observed at an angle of 57.2° and there are only 6 intensity maxima formed.
B The second order image is observed at an angle of 57.2° and there are only 7 intensity maxima formed.
C The second order image is observed at an angle of 73.2° and there are only 4 intensity maxima formed.
D The second order image is observed at an angle of 73.2° and there are only 5 intensity maxima formed.

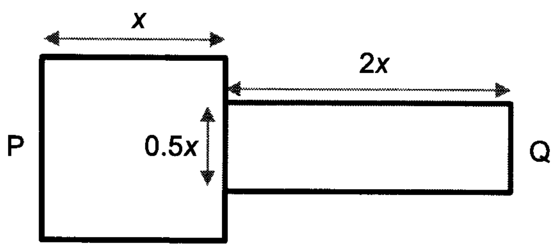
20 The diagram shows two unequally charged spheres X and Y of masses $2m$ and m respectively. They are kept stationary by the application of a potential difference between two parallel plates.



If the plates are moved closer together, what is the subsequent motion of the two charges?

A Both X and Y will move upward with the same acceleration.
B Both X and Y will move upward but X will have a larger acceleration than Y.
C Both X and Y will move downward with the same acceleration.
D Both X and Y will move downward but X will have a larger acceleration than Y.

21 A thin square sheet of metal of uniform thickness and of side x has a resistance of 4.0 Ω measured between opposite edges. It is connected to another sheet of the same metal of the same thickness but of length $2x$ and width $0.5x$.

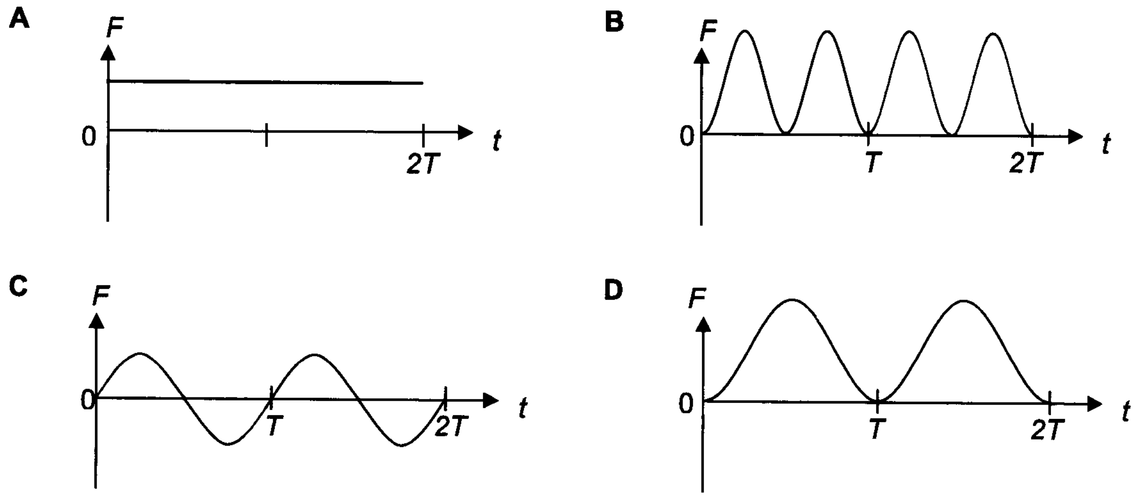


What is the resistance between edges P and Q?

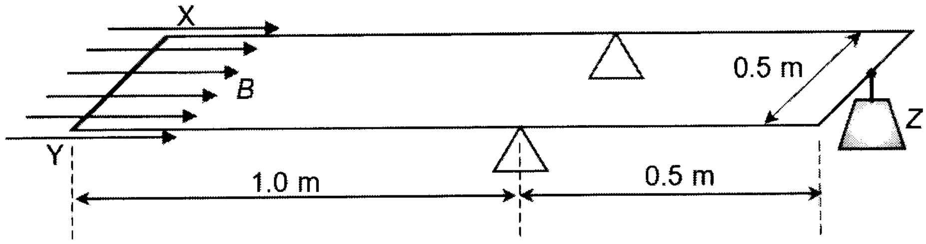
A 8 Ω **B** 12 Ω **C** 16 Ω **D** 20 Ω

22 Two parallel conductors carry equal sinusoidal alternating currents which are in phase. The periods of the alternating currents are T.

Which of the following graphs shows how F, the mutual force of attraction varies with time t?



23 A 1.5 m by 0.5 m light and rigid rectangular conducting frame is pivoted along its longer sides with a weight *Z* hung on one shorter side as shown. A uniform horizontal magnetic field *B* of flux density 0.050 T is applied at right-angles to the section XY of the frame.

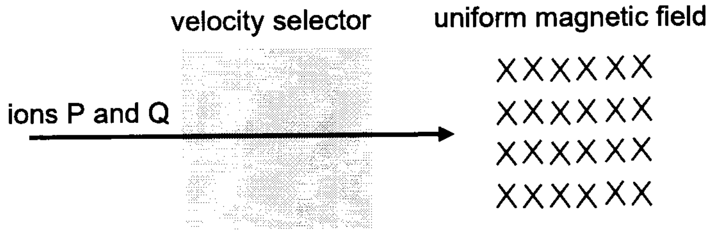


When a current passes through the section XY of the frame, which combination of the magnitude and direction of current flowing in section XY, and the weight *Z* makes the frame horizontal?

	magnitude of current in section XY	direction of current in section XY	*Z* / N
A	1.96 A	from X to Y	0.049
B	1.96 A	from Y to X	0.098
C	3.92 A	from X to Y	0.196
D	3.92 A	from Y to X	0.098

24 Two ions P and Q pass through a velocity selector un-deviated. Ion P has 2 times the charge and 1.5 times the mass of ion Q.

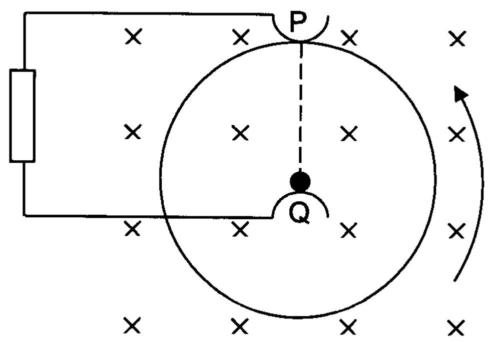
They then enter a region of uniform magnetic field where P travels in a circular arc of radius 3.7 cm.



What is the radius of the circular arc travelled by ion Q?

A 1.2 cm **B** 2.8 cm **C** 4.9 cm **D** 11 cm

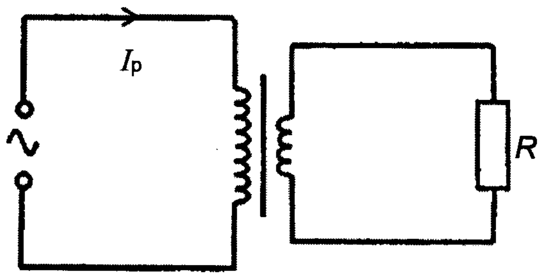
25 The diagram shows a metal disc rotating anticlockwise in a uniform magnetic field.



Which of the following describes the direction of current along radius PQ and the potential of P with respect to Q?

	direction of current along radius PQ	potential of P with respect to Q
A	P to Q	lower
B	Q to P	lower
C	Q to P	higher
D	P to Q	higher

26 An ideal transformer is used to step down the a.c. voltage supply to a resistive load *R*. If the number of turns in the primary coil is doubled, what is the new current in the primary coil?



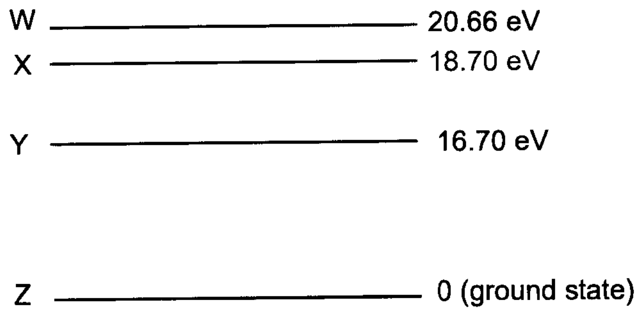
A Twice the original current in the primary coil.

B Same as the original current in the primary coil.

C Half the original current in the primary coil.

D One quarter of the original current in the primary coil.

27 Some of the electron energy levels for neon in a helium-neon laser are shown.



Which energy change for electrons results in laser light of wavelength 633 nm?

A W → X   **B** W → Y   **C** W → Z   **D** X → Y

28 A proton has a kinetic energy of 1.00 MeV.

If its momentum is measured with an uncertainty of 1.00%, what is the minimum uncertainty in its position?

A 5.64×10^{-14} m

B 9.08×10^{-14} m

C 2.87×10^{-12} m

D 9.77×10^{-10} m

29 In order to detect a leak in a water-pipe buried 0.4 m below a soccer field, which of the following radioactive isotope should be added to the water?

	emitter	half-life
A	β	a few hours
B	α	a few hours
C	β	several years
D	α	several years

30 Two deuterium nuclei fuse together to form a Helium-3 nucleus, with the release of a neutron. The reaction is represented by

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

The binding energies per nucleon are:

for $^{2}_{1}H$ 1.09 MeV,
for $^{3}_{2}He$ 2.54 MeV.

How much energy is released in this reaction?

A 0.36 MeV **B** 1.45 MeV **C** 3.26 MeV **D** 5.44 MeV

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Name:		Centre/Index Number:		Class:	

DUNMAN HIGH SCHOOL
Preliminary Examination
Year 6

H2 PHYSICS

9749/02

Paper 2 Structured Questions

17 September 2025

2 hours

Candidates answer on the Question Paper

READ THESE INSTRUCTIONS FIRST

Write your class, index number and name at the top of this page
Write in dark blue or black pen.
You may use an HB pencil for any diagrams or graphs.
Do not use staples, paper clips, glue or correction fluid.

Answer **all** questions in the spaces provided on the question paper.

The use of an approved scientific calculator is expected, where appropriate.

You may lose marks if you do not show your working or if you do not use appropriate units.

The number of marks is given in brackets [ ] at the end of each question or part question.

For Examiner's Use	
1	5
2	10
3	5
4	11
5	9
6	11
7	9
8	20
s.f.	-1
Total	80

This document consists of **21** printed pages and **3** blank pages.

Data

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the Planck constant,	h =	6.63×10^{-34} J s
unified atomic mass constant,	u =	1.66×10^{-27} kg
rest mass of electron,	m_e =	9.11×10^{-31} kg
rest mass of proton,	m_p =	1.67×10^{-27} kg
molar gas constant,	R =	8.31 J K^{-1} mol^{-1}
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acceleration of free fall,	g =	9.81 m s^{-2}

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	v^2	=	$u^2 + 2as$
work done on/by a gas,	W	=	$p\Delta V$
hydrostatic pressure,	p	=	ρgh
gravitational potential,	ϕ	=	$-Gm/r$
temperature,	T/K	=	T/°C + 273.15
pressure of an ideal gas,	p	=	$\frac{1}{3}\frac{Nm}{V}\langle c^2 \rangle$
mean translational kinetic energy of an ideal gas molecule,	E	=	$\frac{3}{2}kT$
displacement of particle in s.h.m.,	x	=	$x_0 \sin \omega t$
velocity of particle in s.h.m.,	v	=	$v_0 \cos \omega t$
		=	$\pm\omega\sqrt{x_o^2 - x^2}$
electric current,	I	=	$Anvq$
resistors in series,	R	=	$R_1 + R_2 + \ldots$
resistors in parallel,	$1/R$	=	$1/R_1 + 1/R_2 + \ldots$
electric potential,	V	=	$\frac{Q}{4\pi\varepsilon_o r}$
alternating current / voltage,	x	=	$x_0 \sin \omega t$
magnetic flux density due to a long straight wire,	B	=	$\frac{\mu_0 I}{2\pi d}$
magnetic flux density due to a flat circular coil,	B	=	$\frac{\mu_0 NI}{2r}$
magnetic flux density due to a long solenoid,	B	=	$\mu_0 nI$
radioactive decay,	x	=	$x_0 \exp(-\lambda t)$
decay constant,	λ	=	$\frac{\ln 2}{t_{\frac{1}{2}}}$

1 **(a)** **(i)** Define *density*.

....

.... [1]

(ii) State the base units in which density is measured

.... [1]

(b) The speed v of sound in a gas is given by the expression

$$v = \sqrt{\frac{\gamma p}{\rho}}$$

where p is the pressure of the gas of density ρ. γ is a constant.

Given that p has the base units of kg m^{-1} s^{-2}, show that the constant γ has no unit.

[3]

[Total: 5 marks]

2 A ball, initially at rest, slides down the roof of a house at a constant acceleration of 5.0 m s^{-2}. It moves through a distance of 4.0 m before dropping off the edge of the roof to the muddy ground and coming to a complete stop upon impact,15.0 m below. The roof slopes downward at an angle of 37.0° as shown in Fig. 2.1.

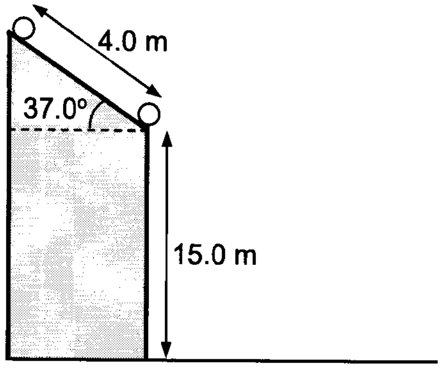


Fig. 2.1

(a) Show that the speed of the ball when it reaches the edge of the roof is 6.32 m s^{-1}.

[1]

(b) Calculate the horizontal and vertical components of the velocity of the ball just before it lands on the ground.

horizontal component of velocity = ... m s^{-1}

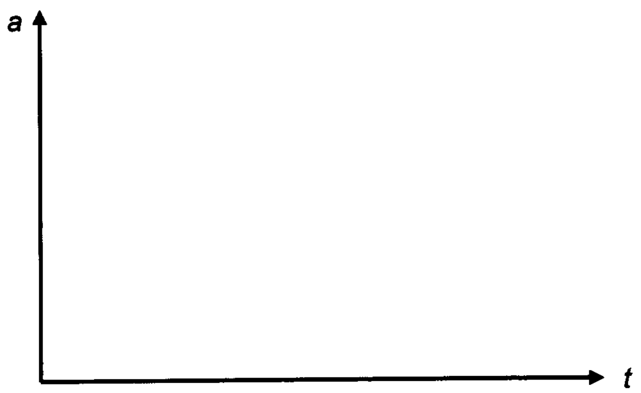
vertical component of velocity = ... m s^{-1} [2]

(c) Determine the total time that the ball is in motion.

total time = ... s [3]

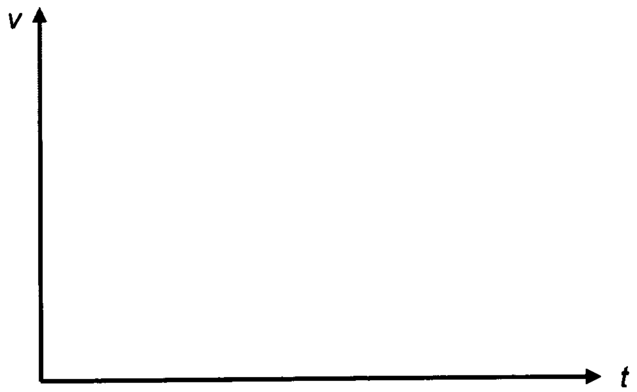
(d) Sketch labelled graphs to show the variation with time of the

(i) magnitude of acceleration a of the ball,



[2]

(ii) speed v of the ball.



[2]

[Total: 10]

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3 **(a)** Explain how an electric field and a magnetic field may be used for the velocity selection of charged particles. You may draw a diagram if you wish.

....

....

....

....

....

.... [3]

(b) The isotopes strontium-87 ($^{87}_{38}Sr$) and strontium-86 ($^{86}_{38}Sr$) are found in samples of Moon rock. Particles of a sample of Moon rock are vaporised, releasing strontium isotopes that are sent into the velocity selector of a mass spectrometer as shown in Fig. 3.1. The positive ions of strontium isotopes then pass through a uniform magnetic field which makes them follow separate circular paths.

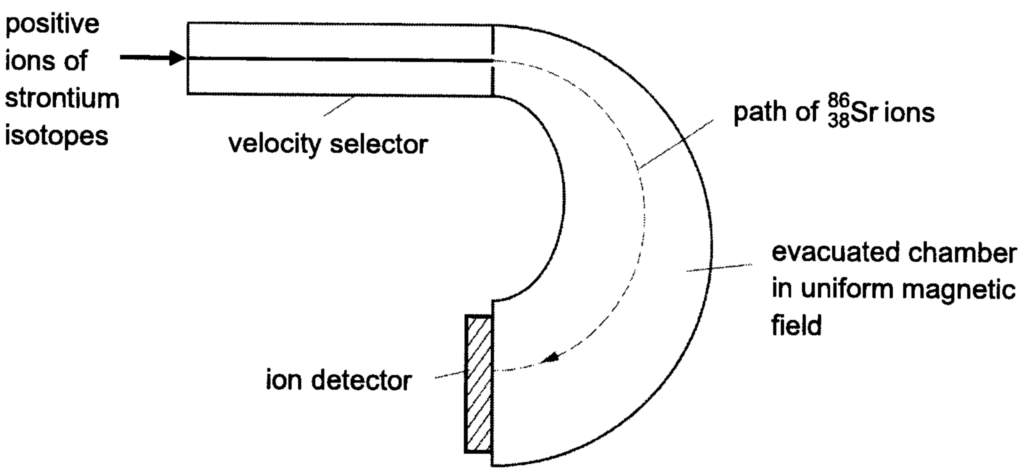


Fig. 3.1

The velocity selector allows strontium ions of speed 7.6×10^5 m s^{-1} to enter the evacuated chamber in uniform magnetic field of magnetic flux density 680 mT.

Determine the change in the magnetic flux density needed to make the strontium-87 ($^{87}_{38}Sr$) ions follow the same path taken initially by the strontium-86 ions.

change in magnetic flux density = ... T [2]

[Total: 5]

4 Two equally charged conducting spheres with small radii, each of mass m and charge $+3.20 \times 10^{-7}$ C are hung from the ceiling with insulated strings of negligible mass and length 0.50 m as shown in Fig. 4.1.

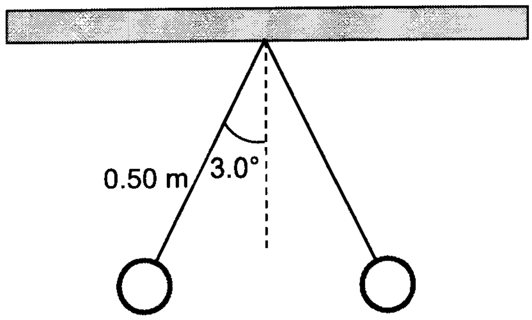


Fig. 4.1 (not to scale)

(a) Determine the magnitude of the electric force acting on each sphere.

electric force = ... N [2]

(b) Determine the mass m of each sphere.

m = ... kg [2]

(c) **(i)** Define electric potential at a point.

....

.... [1]

(ii) On Fig. 4.2 below, sketch the variation of the net electric field strength with distance x between the two spheres.

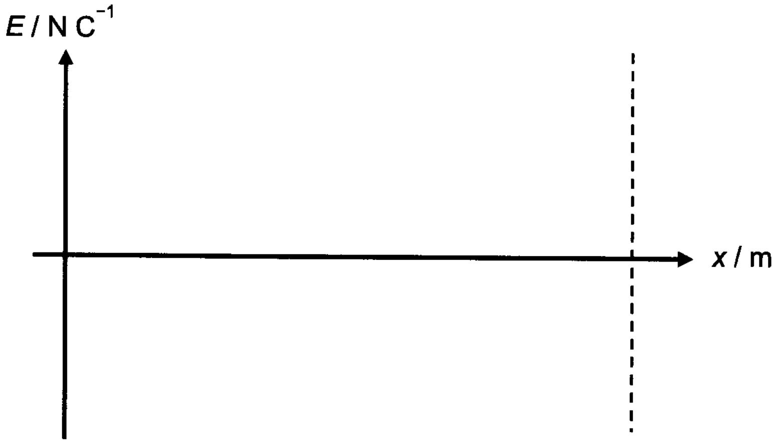


Fig. 4.2

[2]

(iii) Explain how the potential difference between two points along the line joining the centre of the spheres may be determined using your graph in Fig. 4.2.

....

....

.... [2]

(d) Describe, with the help of a diagram, the effect on the positions of the spheres when the charge on one sphere is reduced while the charge on the other sphere remains the same, with all other factors remaining the same.

....

.... [2]

[Total: 11]

5 A flat horizontal plate is made to oscillate in simple harmonic motion in a vertical direction as shown in Fig. 5.1. The plate starts its oscillation at its equilibrium position and moves downwards initially.

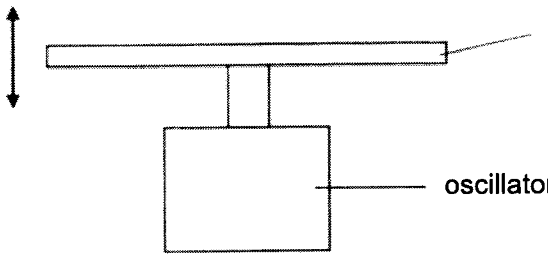


Fig. 5.1

The variation of velocity v with displacement x for this oscillation is shown in Fig. 5.2. Point S marks the start of the oscillation.

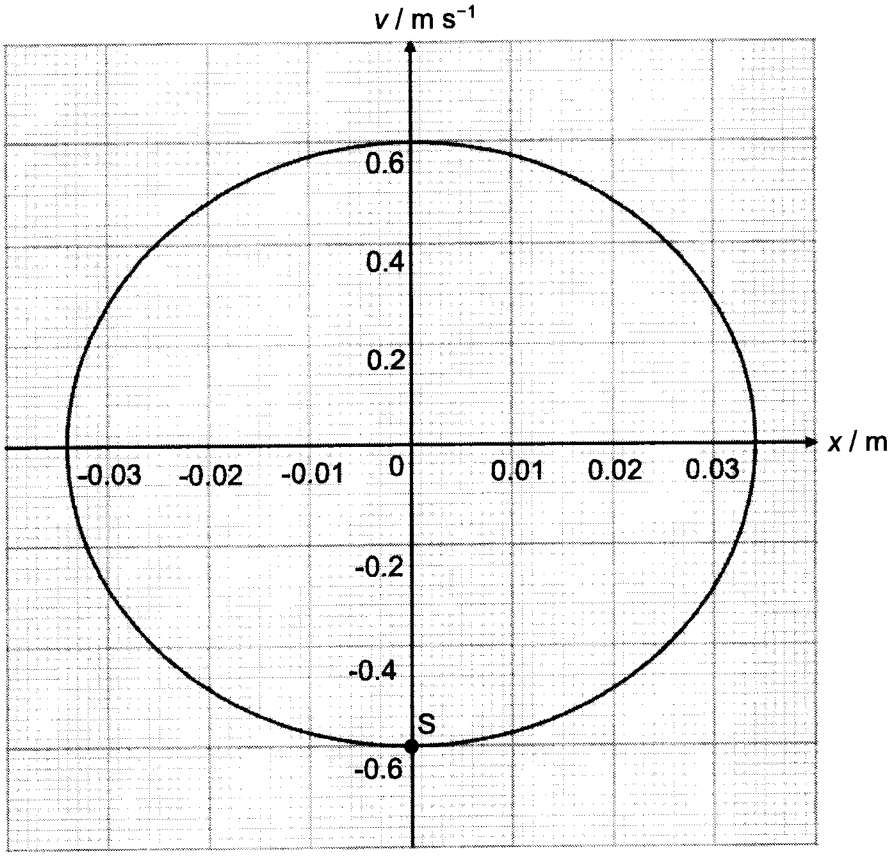


Fig. 5.2

(a) Define *simple harmonic motion.*

....

.... [2]

(b) Deduce, from Fig. 5.2,

(i) the amplitude of the oscillation,

amplitude = ... m [1]

(ii) the angular frequency ω of the oscillation.

ω = ... rad s^{-1} [2]

(c) A mass of 0.100 kg is placed on the plate before the plate starts to oscillate.

(i) Determine the displacement of the plate when the mass just loses contact with the plate.

displacement = ... m [3]

(ii) Mark on Fig. 5.2, the point **C** when the mass just loses contact. [1]

[Total: 9]

6 **(a)** Radioactive decay is both random and spontaneous.

State what is meant by

(i) random.

....

.... [1]

(ii) spontaneous.

....

.... [1]

(b) State one piece of evidence for the random nature of decay.

....

.... [1]

(c) Define half-life of a radioactive isotope.

....

.... [1]

(d) Radioactive isotope X decays to isotope Y. A sample contains only nuclei of X at time $t = 0$. Fig. 6.1 shows the variation with t of the numbers of nuclei of X and of Y as the sample decays.

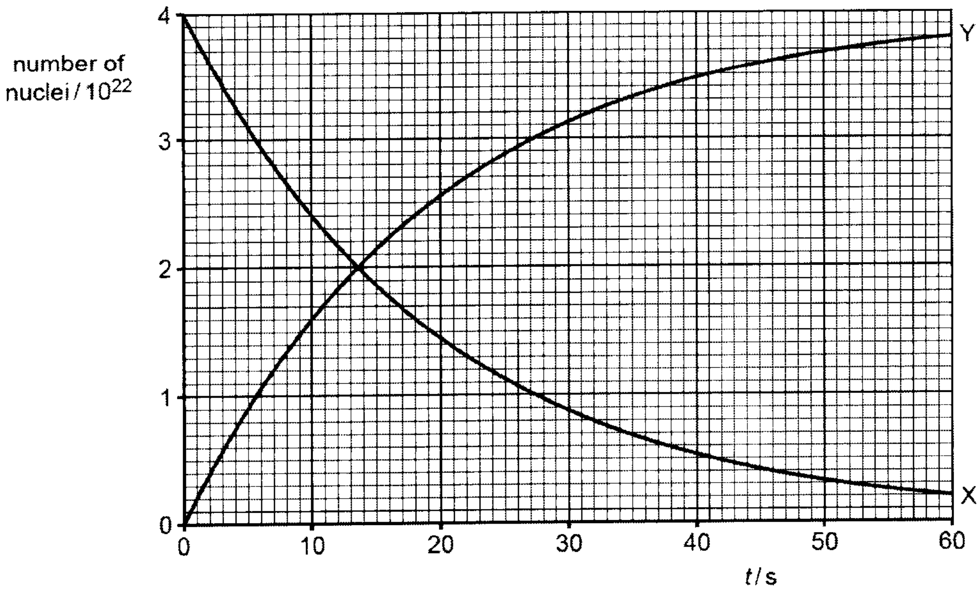


Fig. 6.1

(i) State the name of the quantity represented by the magnitude of the gradient of line X in Fig. 6.1.

.... [1]

(ii) State three conclusions about X or Y that may be drawn from Fig. 6.1. The conclusions may be qualitative or quantitative. Use the space below for any working that you need.

1. ....

....

2. ....

....

3. ....

.... [3]

(e) The mass of radioactive isotope X in the sample in **(d)** is 7.3×10^{-4} kg at time $t = 0$.

Determine the nucleon number of isotope X.

nucleon number = ... [3]

[Total: 11]

7 **(a)** **(i)** State what is meant by the *photoelectric effect*.

....

.... [1]

(ii) Use the theory of particulate nature of electromagnetic radiation to explain why there is a threshold frequency for the photoelectric effect.

....

....

....

....

....

....

.... [3]

(b) A polished sheet of magnesium in a vacuum is illuminated by ultraviolet radiation.

For emission of electrons to occur, the frequency of the ultraviolet radiation must be at least 8.8×10^{14} Hz.

(i) Calculate the work function energy of magnesium.

work function energy = ... J [2]

(ii) For ultraviolet radiation with a frequency of 11×10^{14} Hz, calculate the maximum speed of the emitted electrons.

maximum speed = ... $m\ s^{-1}$ [3]

[Total: 9]

8 Read the passage below and answer the questions that follow.

DART – Planetary Defence against Catastrophic Asteroid Impacts

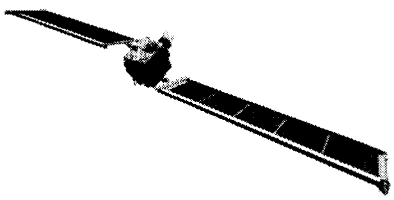
Asteroid 2024 YR4 is a large near-Earth asteroid that when it was first discovered, it appeared to have a very small chance to impact Earth on Dec. 22, 2032. Owing to the trajectory and size of 2024 YR4 (estimated to have a diameter of 53 to 67 m), its discovery initially sparked concerns of heavy, localised destruction potentially capable of levelling a city. Its impact could potentially release energy worth about 7.7 megatonnes of TNT. This is equivalent to about 500 times the energy released by "Little Boy"; the atomic bomb dropped on Hiroshima. As observations of 2024 YR4 continued through early 2025, NASA concluded that the asteroid poses no significant impact risk to Earth in 2032 and is no longer considered a threat. However, in the event that the asteroid's impact is highly probable, an asteroid deflection mission, similar to the Double Asteroid Redirection Test (DART) craft, might have been sent to 2024 YR4 to avert its impact.

DART is a NASA-funded technology demonstration of a kinetic impactor technology that could be used to mitigate the threat of a hazardous asteroid. The kinetic impactor is currently the simplest and most technologically mature method available to defend against asteroids. In this technique, a spacecraft is launched that simply slams itself into the asteroid at several km per second speed, thereby putting the asteroid in a slightly different orbit around its companion body. The DART project, which was launched in 2021, successfully demonstrated that a spacecraft can navigate itself to a successful impact on the target and alter the target's orbit. In the project, DART was sent on a roughly 11-million-kilometre journey towards its target: a near-Earth binary asteroid system where a smaller asteroid named "Dimorphos" orbits in a nearly circular orbit with a period of 11.9 hours around a larger asteroid called "Didymos". The two asteroids are separated by a distance of 1189 m. In 2022, NASA confirmed that DART's impact successfully altered Dimorphos's orbital period to 11.4 hours, thereby confirming that its orbit has been altered.

The main structure of the DART spacecraft is a box from which other structures are housed and can extend from. The DART payload consists of a single instrument, the Didymos Reconnaissance and Asteroid Camera for Optical Navigation (DRACO) which is a high-resolution imager to support navigation and targeting. DRACO is a narrow-angle telescope with a 208-millimeter aperture and field of view of 0.29 degrees. The spacecraft components and DART's low thrust engine are powered by two Roll-Out Solar Arrays (ROSA), each with a power-to-mass ratio of 120 W kg^{-1}.

Data for DART is shown in Table 8.1.

Table 8.1



dimensions of main body (box)	1.3 m × 1.2 m × 1.3 m (length × width × height)
dimensions of main body (with other structures fully extended)	1.9 m × 1.8 m × 2.6 m (length × width × height)
dimensions of each solar array (ROSA)	8.5 m × 2.4 m (length × width)
mass of each solar array (ROSA)	16.95 kg
mass at launch	610 kg
mass at impact	580 kg
speed of DART at impact	6580 km s^{-1}

For space travel and navigation, the DART spacecraft used and demonstrated the NASA Evolutionary Xenon Thruster Commercial (NEXT-C) electric propulsion system, which allowed for tremendous flexibility in trajectory design. The most popular choice of fuel used by ion thrusters is the noble gas Xenon ($^{131}_{54}Xe$). However, other noble gases such as Argon ($^{40}_{18}Ar$) or Krypton ($^{84}_{36}Kr$) may also be used. In the NEXT-C ion thruster, Xenon is first ionised through electron bombardment where high energy electrons collide with Xenon atoms, stripping away an electron and turning the neutral Xenon atoms into Xenon ions. The Xenon ions are then accelerated to speeds of up to 40 km s^{-1} with respect to the thruster through a potential difference between two electrodes, creating ion jets. The ions are then expelled from the engine, creating thrust. The NEXT-C offers improved performance compared to other ion propulsion systems and is capable of producing up to 235 mN of thrust.

(a) Determine the percentage uncertainty in the diameter of Asteroid 2024 YR4.

percentage uncertainty = ... % [2]

(b) **(i)** By considering the orbital motion of Dimorphos around Didymos, show that the period T of Dimorphos's orbit is related by the following expression

$$T^2 = \frac{4\pi^2 r^3}{GM}$$

where G is the gravitational constant, r is the distance between the two asteroids and M is the mass of Didymos.

[2]

(ii) Hence, state and explain the change in the orbital radius of Dimorphos after DART's impact.

....

....

....

.... [2]

(c) **(i)** Define Rayleigh's Criterion.

....

.... [1]

(ii) Using Rayleigh's Criterion, determine the distance of DART from the Didymos-Dimorphos binary asteroid system for the two bodies to be just resolvable by DRACO before impact.

distance = ... m [2]

(d) (i) Suggest what is meant by a 'power-to-mass ratio of 120 W kg^{-1}.

....

.... [1]

(ii) Determine the power output delivered to DART by ROSA.

power output = ... W [2]

(e) (i) Suggest and explain a reason why Xenon is preferable as a fuel source compared to Argon or Krypton in ion thrusters.

....

.... [2]

(ii) Fig. 8.1 shows the two parallel electrodes in the NEXT-C ion thruster.
On Fig. 8.1, sketch 6 lines to represent the electric field between the plates.

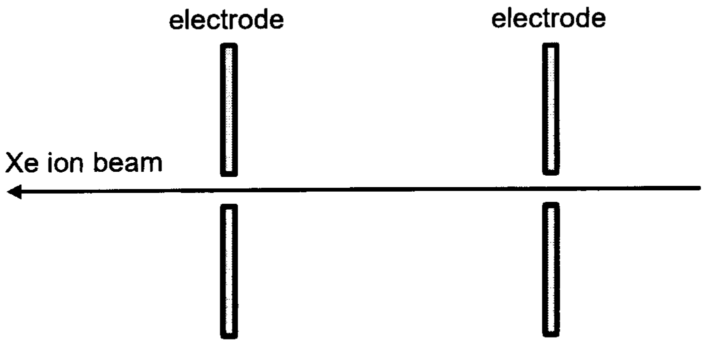


Fig. 8.1 [1]

(iii) Determine the potential difference between the two plates when Xenon ions are accelerated to its maximum exhaust speed.

potential difference = ... V [2]

(iv) Determine the number of Xenon ions being expelled per second by the NEXT-C ion thruster in order to achieve its maximum thrust.

number of Xenon ions expelled per second = ... s^{-1} [3]

[Total: 20]

End of Paper

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Name:		Centre/Index Number:		Class:	

DUNMAN HIGH SCHOOL
Preliminary Examination
Year 6

H2 PHYSICS

9749/03

Paper 3 Longer Structured Questions

26 September 2025

2 hours

Candidates answer on the Question Paper

READ THESE INSTRUCTIONS FIRST

Write your class, index number and name at the top of this page
Write in dark blue or black pen.
You may use an HB pencil for any diagrams or graphs.
Do not use staples, paper clips, glue or correction fluid.

Section A

Answer **all** questions.

Section B

Answer any **one** question.

The use of an approved scientific calculator is expected, where appropriate.
You may lose marks if you do not show your working or if you do not use appropriate units.

The number of marks is given in brackets [ ] at the end of each question or part question.

For Examiner's Use	
Section A	
1	6
2	8
3	6
4	8
5	12
6	11
7	9
Section B (circle attempted)	
8 / 9	20
s.f.	-1
Total	80

This document consists of **26** printed pages and **2** blank pages

Data

speed of light in free space,	c =	3.00×10^{8} m s^{-1}
permeability of free space,	μ_o =	$4\pi \times 10^{-7}$ H m^{-1}
permittivity of free space,	ε_o =	8.85×10^{-12} F m^{-1}
elementary charge,	e =	1.60×10^{-19} C
the Planck constant,	h =	6.63×10^{-34} J s
unified atomic mass constant,	u =	1.66×10^{-27} kg
rest mass of electron,	m_e =	9.11×10^{-31} kg
rest mass of proton,	m_p =	1.67×10^{-27} kg
molar gas constant,	R =	8.31 J K^{-1} mol^{-1}
the Avogadro constant,	N_A =	6.02×10^{23} mol^{-1}
the Boltzmann constant,	k =	1.38×10^{-23} J K^{-1}
gravitational constant,	G =	6.67×10^{-11} N m^{2} kg^{-2}
acceleration of free fall,	g =	9.81 m s^{-2}

Formulae

uniformly accelerated motion,	s	=	$ut + \frac{1}{2}at^2$
	v^2	=	$u^2 + 2as$
work done on/by a gas,	W	=	$p\Delta V$
hydrostatic pressure,	p	=	ρgh
gravitational potential,	ϕ	=	$-Gm/r$
temperature,	T/K	=	T/°C + 273.15
pressure of an ideal gas,	p	=	$\frac{1}{3}\frac{Nm}{V}\langle c^2 \rangle$
mean translational kinetic energy of an ideal gas molecule,	E	=	$\frac{3}{2}kT$
displacement of particle in s.h.m.,	x	=	$x_0 \sin \omega t$
velocity of particle in s.h.m.,	v	=	$v_0 \cos \omega t$
		=	$\pm\omega\sqrt{x_o^2 - x^2}$
electric current,	I	=	$Anvq$
resistors in series,	R	=	$R_1 + R_2 + \ldots$
resistors in parallel,	$1/R$	=	$1/R_1 + 1/R_2 + \ldots$
electric potential,	V	=	$\frac{Q}{4\pi\varepsilon_o r}$
alternating current / voltage,	x	=	$x_0 \sin \omega t$
magnetic flux density due to a long straight wire,	B	=	$\frac{\mu_0 I}{2\pi d}$
magnetic flux density due to a flat circular coil,	B	=	$\frac{\mu_0 NI}{2r}$
magnetic flux density due to a long solenoid,	B	=	$\mu_0 nI$
radioactive decay,	x	=	$x_0 \exp(-\lambda t)$
decay constant,	λ	=	$\frac{\ln 2}{t_{\frac{1}{2}}}$

Section A

Answer **all** the questions in this section in the spaces provided.

1 **(a)** Define gravitational field strength at a point.

....

.... [1]

(b) From Newton's Law of gravitation and the definition of gravitational field strength, show that the gravitational field strength due to a point mass is given by

$$g = \frac{GM}{r^2}$$

where G is the gravitational constant, M is the mass of the point mass, and r is the distance from the point mass.

[2]

(c) By reference to the lines of gravitational force near to the surface of the Earth, explain why the gravitational field strength g close to the Earth's surface is approximately constant.

....

....

....

....

....

.... [3]

[Total: 6]

2 **(a)** State Newton's second law of motion.

....

.... [1]

(b) A ball of mass 65 g hits a wall with a velocity of 5.2 m s^{-1} perpendicular to the wall. The ball rebounds perpendicularly from the wall with a speed of 3.7 m s^{-1}. The contact time of the ball with the wall is 7.5 ms.

Calculate, for the ball hitting the wall,

(i) the change in momentum,

change in momentum = ... N s [2]

(ii) the magnitude of the average force.

average force = ... N [1]

(c) **(i)** For the collision in **(b)** between the ball and the wall, state how the following apply:

1. Newton's third law,

....

.... [2]

2. the law of conservation of momentum.

....

.... [1]

(ii) State, with a reason, whether the collision is elastic or inelastic.

....

.... [1]

[Total: 8]

3 (a) State what is meant by the *moment of a force*.

....

.... [1]

(b) A traffic light hangs from a uniform metal pole AB, freely pivoted at point A, as shown in Fig. 3.1. The pole is 7.5 m long and has a mass of 8.0 kg. The mass of the traffic light is 12.0 kg.

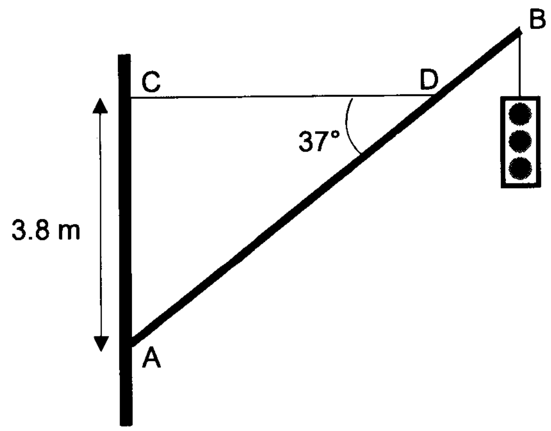

Fig. 3.1

(i) Determine the tension in the horizontal cable CD. Assume the mass of cable CD is negligible.

tension = ... N [2]

(ii) Determine the force exerted on the metal pole at pivot A.

force = ... N

direction: .... [3]

[Total: 6]

4 (a) In a space, such as a swimming pool enclosure, water at 30 °C and water vapour, also at 30 °C coexist.

(i) State what is meant by *internal energy* of a system.

....

.... [1]

(ii) With reference to your answer in **(a)(i)**, compare the internal energy per unit mass of water and water vapour at the same temperature.

....

....

....

.... [2]

(b) A helium balloon containing 15000 m^3 of helium at a temperature of 288 K was launched from sea level until it reaches an altitude of 32.0 km. Data concerning atmospheric conditions are given in table 4.1.

Table 4.1

	sea level altitude = 0	equilibrium altitude = 32.0 km
pressure of helium	101 kPa	0.890 kPa
temperature	288 K	228 K
density of air	1.23 kg m^{-3}	0.0134 kg m^{-3}

Assuming that the helium gas behaves as an ideal gas, calculate

(i) the volume of helium at an altitude of 32.0 km,

volume of helium = ... m^3 [2]

(ii) the average translational kinetic energy of one helium atom in the balloon when it is at an altitude of 32.0 km,

average kinetic energy = ... J [1]

(iii) the change in internal energy of the balloon.

change in internal energy = ... J [2]

[Total: 8]

5 **(a)** Low-pressure vapour in a lamp emits monochromatic light that is not coherent.

(i) State what is meant by *coherent* light.

....

.... [1]

(ii) Explain, by reference to the mechanism by which the vapour produces light, why the emitted light is not coherent.

....

....

....

....

....

.... [3]

(b) Coherent light of wavelength 590 nm is incident normally on a double slit, as shown in Fig. 5.1.

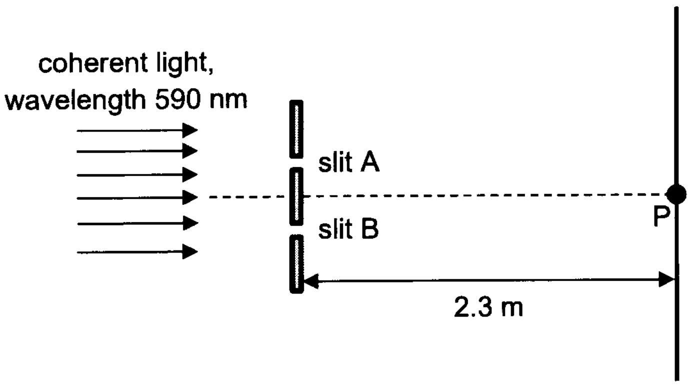

Fig. 5.1

The separation of the slits A and B in the double slit arrangement is 1.2 mm.

Interference fringes are observed on a screen placed parallel to the plane of the double slit and 2.3 m from it.

Assume that, for the fringes near point P on the screen, the light reaching the screen from slit A alone has intensity I and that from slit B alone has intensity $\frac{1}{3}I$.

(i) Apart from coherence, state two other conditions required for two-source interference fringes to be observed.

1. ....

....

2. ....

.... [2]

(ii) Determine the separation of the bright fringes.

separation = ... m [2]

(iii) Point P on the screen is equidistant from the two slits A and B.

Determine the intensity, in terms of I, of a dark fringe near P.

intensity = ... I [4]

[Total: 12]

6 **(a)** A small coil C has 64 turns and cross-sectional area 0.71 cm^2. The coil is placed inside a solenoid as shown in Fig. 6.1.

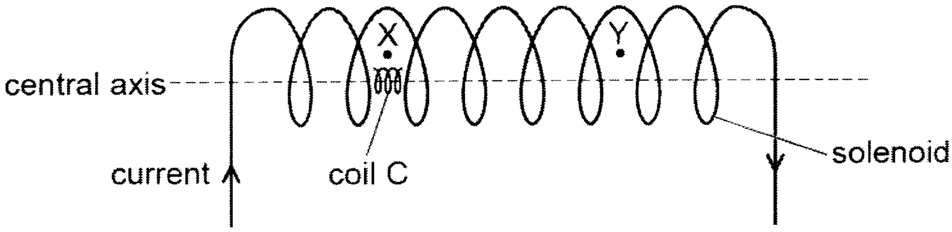

Fig. 6.1

The centre of coil C is on the central axis of the solenoid.

(i) There is a constant current in the solenoid.

Coil C is moved through the solenoid from position X to position Y.

On Fig. 6.2, sketch a line to show the variation of the magnetic flux linkage in coil C with position as it moves from X to Y.

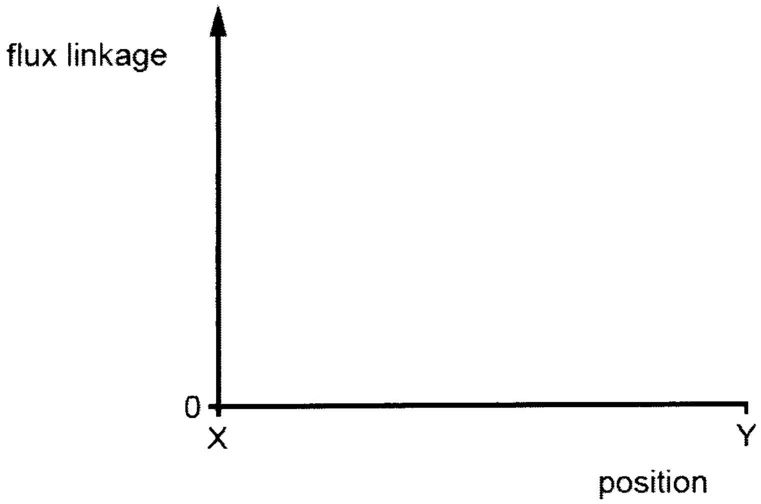

Fig. 6.2 [1]

(ii) Explain the shape of your line in **(a)(i)**.

....

....

....

....

.... [2]

(iii) Coil C is now held stationary at X. The current in the solenoid varies so that the magnetic flux density B at X varies from time 0 to time 4*t* as shown in Fig. 6.3.

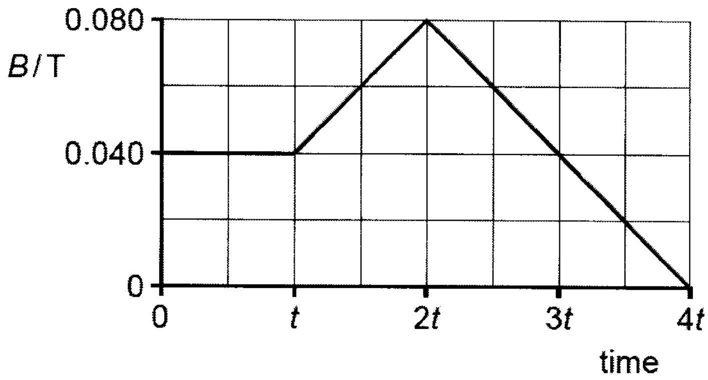

Fig. 6.3

Calculate the maximum magnetic flux linkage in coil C.

maximum flux linkage = ... Wb [2]

(iv) On Fig. 6.4, sketch a line to show the induced electromotive force (e.m.f.) *E* in coil C from time 0 to time 4*t*.

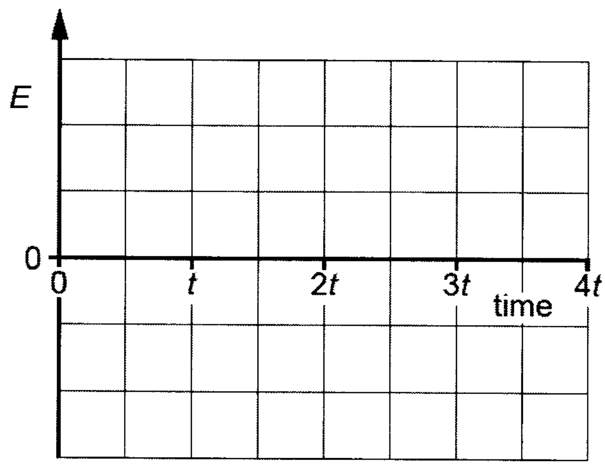

Fig. 6.4 [3]

(b) A metal spring rests on a smooth table. The turns of the spring are equally spaced. The ends of the spring are connected to a d.c. power supply, as shown in Fig. 6.5.

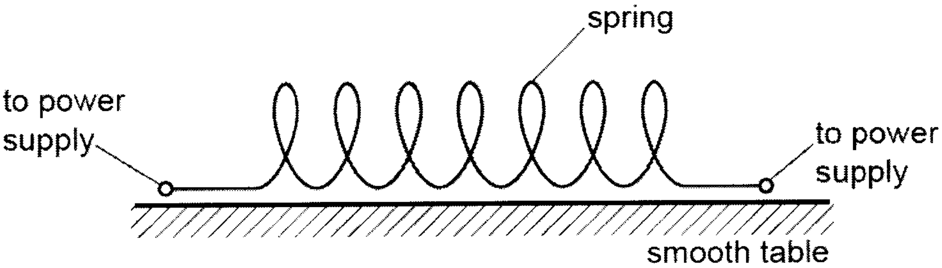

Fig. 6.5

The spring is connected to the d.c. power supply using flexible leads. The spring is not under tension.

With reference to magnetic fields, describe and explain the change in the distance between the turns of the spring when the power supply is first switched on.

....

....

....

....

....

....

....

.... [3]

[Total: 11]

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7 **(a)** State what is meant by the *frequency of an alternating current*.

....

....

.... [1]

(b) An alternating current I in a resistor of resistance 680 Ω varies with time t according to

$$I = 3.5\sin(40\pi t)$$

where I is in A and t is in s.

(i) Show that the period of the alternating current is 50 ms.

[1]

(ii) On Fig. 7.1, sketch the variation of I with t between t = 0 and t = 100 ms.

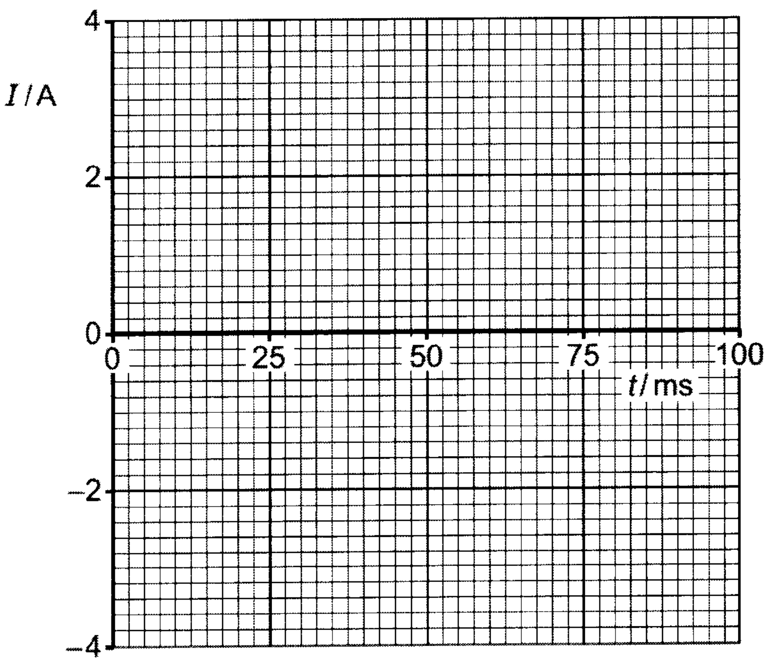


Fig. 7.1

[3]

(iii) Determine the root-mean-square (r.m.s.) current in the resistor.

r.m.s current = ... A [1]

(c) Use data from **(b)**, including your answer in **(b)(iii)**, show by calculation that the mean power in the 680 Ω resistor is half of the peak power.

[3]

[Total: 9]

Section B

Answer **one** question from this section in the spaces provided.

8 **(a)** The Earth may be assumed to be a uniform sphere of radius of 6370 km and mass of 5.98×10^{24} kg. An object of mass 1.00 kg is placed on the Equator.

Calculate

(i) the centripetal acceleration of the object,

centripetal acceleration = ... m s^{-2} [2]

(ii) the gravitational force exerted on the object by the Earth.

gravitational force = ... N [2]

(b) The object in **(a)** is suspended from a spring balance fixed to the ceiling of a laboratory, as shown in Fig. 8.1. There are two forces acting on the object, namely the gravitational force F_G by the Earth and the support force F_s by the spring.

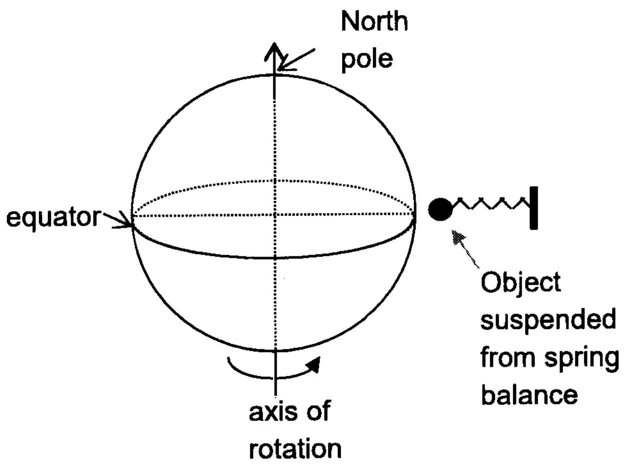


Fig. 8.1

(i) Draw a labelled force diagram to show the forces on the object.

[2]

(ii) Using your answers to **(a)(i)** and **(a)(ii)**, calculate the magnitude of $\boldsymbol{F_s}$.

$\boldsymbol{F_s}$ = ... N [2]

(iii) A student, situated at the Equator, releases a ball from rest in a vacuum and measures its acceleration towards the Earth's surface. He then states that this acceleration is 'the acceleration due to gravity'.

Comment on his statement.

....

....

....

.... [2]

(c) An elastic rope is attached to a man on one end and to a bridge on the other end. The man has a mass of 80.0 kg while the rope has a natural length of 25.0 m and an elastic constant of 120 N m^{-1}. The man steps off the bridge and falls vertically downwards from rest. Assume that air resistance acting on the man is negligible.

(i) Explain why the person has maximum speed when the tension in the elastic rope is equal to his weight.

....

....

....

....

....

.... [2]

(ii) Determine the maximum speed of the man after he steps off the bridge.

maximum speed = ... m s^{-1} [3]

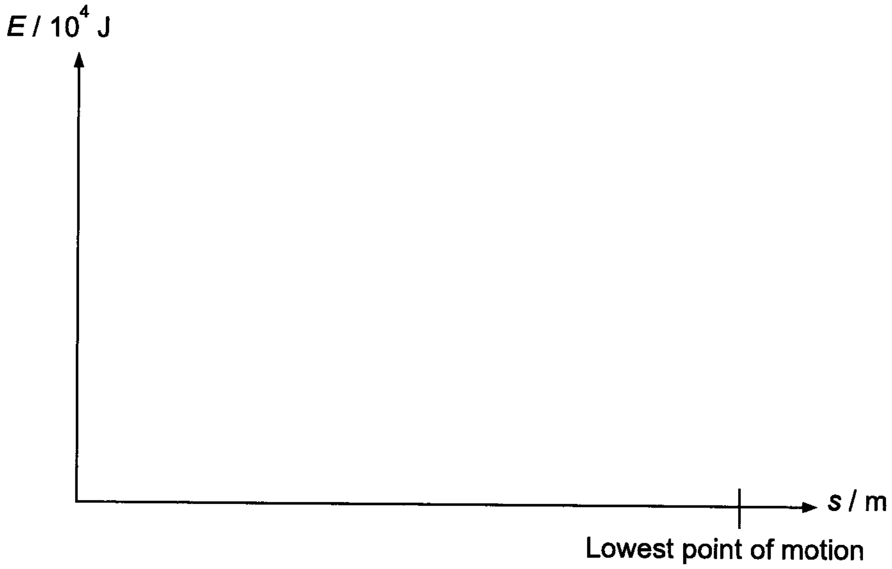
(iii) Calculate the extension of the elastic rope when the man is at the lowest point of his motion.

extension = ... m [2]

(iv) Sketch on Fig. 8.2 three well-labelled graphs for the variation with downward displacement *s* of

1. the gravitational potential energy of the man, (Label as **G**)
2. the elastic potential energy stored in the rope and (Label as **E**)
3. the kinetic energy of the man. (Label as **K**)

Assume that gravitational potential energy of the man is zero at the lowest point of the man's motion. Take $s = 0$ m as the start point of motion.



[3]

Fig. 8.2

[Total: 20]

9 A battery of electromotive force (e.m.f.) E and internal resistance r is connected in series to a variable resistor R which has resistance between 0 Ω and 10 Ω, as shown in Fig. 9.1. The ammeter and the voltmeter are both ideal.

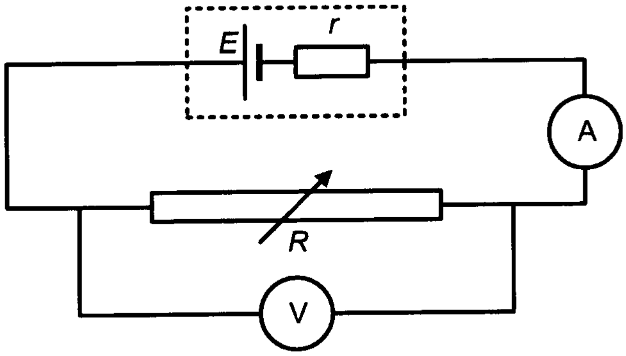


Fig. 9.1

Fig. 9.2 shows the variation of potential difference (p.d.) V across the variable resistor with the current I flowing through it.

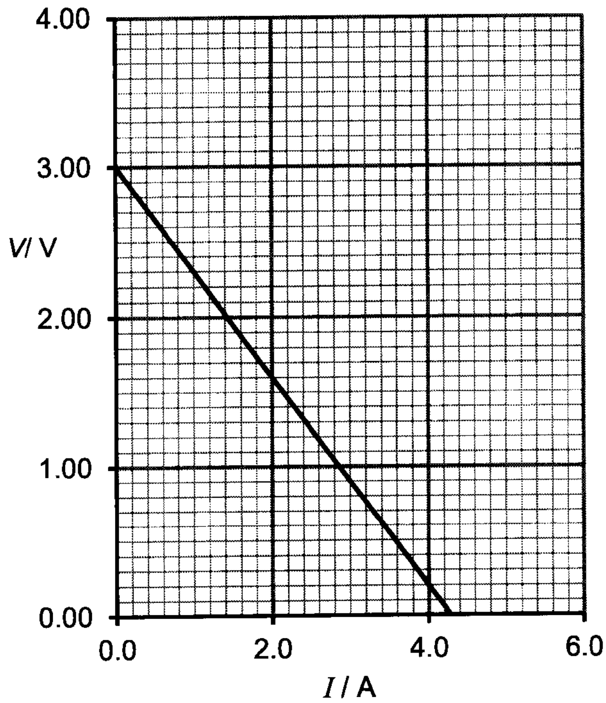


Fig. 9.2

(a) State how the graph in Fig. 9.2 can be obtained using the electrical circuit in Fig. 9.1.

....

.... [1]

(b) Comment on the following statements:

(i) "In Fig. 9.2, since the p.d. *V* across the variable resistor is not proportional to the current *I* flowing through it, the variable resistor does not obey Ohm's law."

....

....

.... [1]

(ii) "The battery supplies electrons to the circuit to produce current."

....

....

.... [1]

(c) Using Fig. 9.2,

(i) deduce the e.m.f. *E* of the battery,

E = ... V [1]

(ii) determine the internal resistance *r* of the battery.

r = ... Ω [2]

(d) **(i)** Using your answers to **(c)**, deduce the p.d. *V* across the variable resistor when the power delivered to it is maximum.

V = ... V [1]

(ii) Calculate the maximum power delivered to the variable resistor.

maximum power delivered = ... W [2]

(iii) On Fig. 9.3, sketch the variation of power *P* delivered to the variable resistor when the p.d. *V* across it is varied.

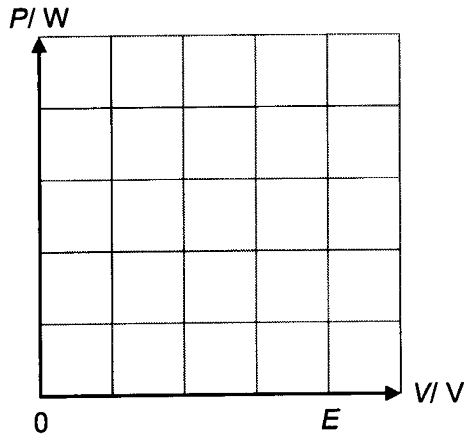


Fig. 9.3

[2]

(e) **(i)** Determine or deduce the efficiency of the circuit when the power delivered is maximum.

efficiency = ... % [1]

(ii) Determine or deduce the value of R to achieve maximum efficiency.

R = ... Ω [1]

(iii) A student designs a sound system that is analogous to the electrical circuit in Fig. 9.1. The e.m.f. source and the variable resistor represent the amplifier and the loudspeaker, respectively.

Explain whether a high-efficiency or high-power transfer is more desirable in this sound system.

....

....

....

....

....

....

.... [2]

(f) To calculate the e.m.f. E' of an unknown cell, a 2.00 V driver cell of negligible internal resistance is connected to a 4.00 Ω resistor and a metre-wire PQ of resistance 6.00 Ω, as shown in Fig. 9.4.

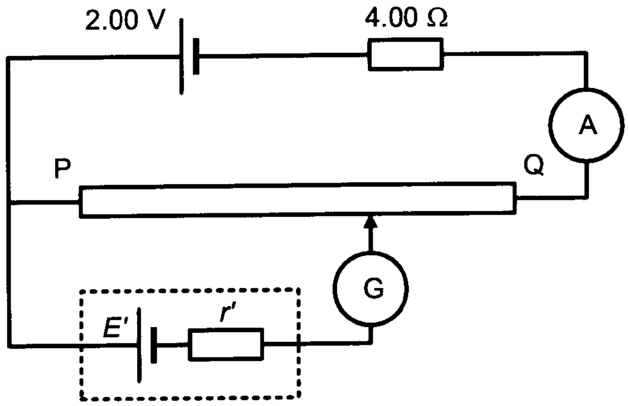


Fig. 9.4

(i) If the balance point is 0.600 m from P, determine the e.m.f. E' of the unknown cell.

E' = ... V [2]

(ii) By drawing an additional electrical component on Fig. 9.4, show how the circuit can be modified to determine the internal resistance r' of the unknown cell. [1]

(iii) If the 2.00 V driver cell is rated at 2000 mAh (milli-ampere hour), calculate the maximum duration that it can be used to power a device which draws 0.080 A of current.

maximum duration = ... h [2]

[Total: 20]

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