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

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	=	$\frac{\ln 2}{t_{\frac{1}{2}}}$

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.

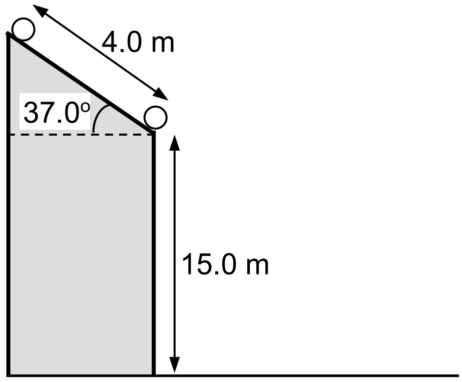

Fig. 2.1

(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.

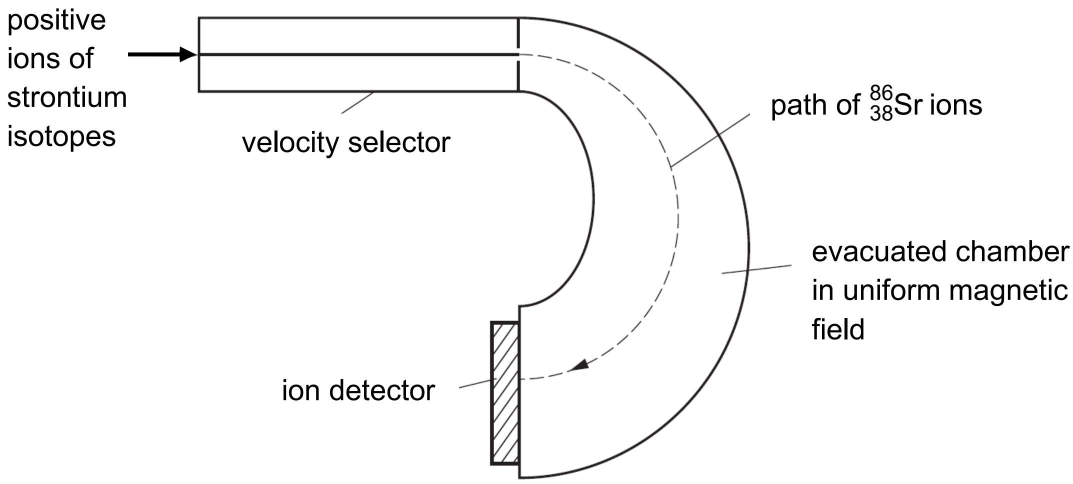


Fig. 3.1

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.

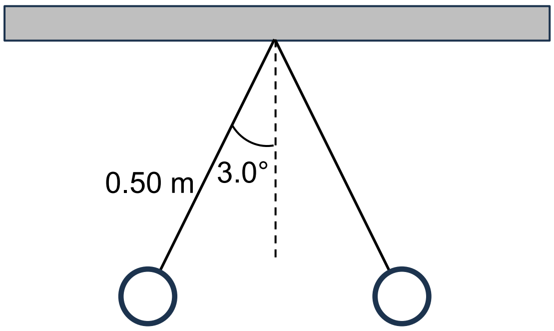


Fig. 4.1 (not to scale)

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

electric force = ………………………………… N [2]

(b) Determine the mass *m* of each sphere.

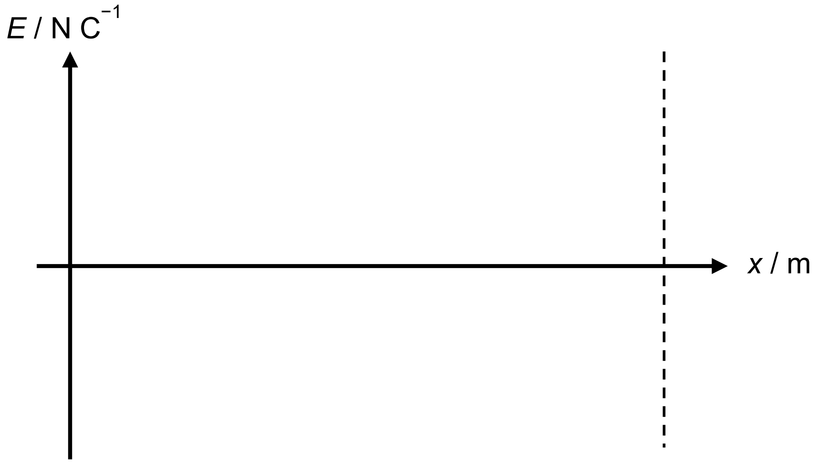
m = ………………………………… kg [2]

(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.



[2]

Fig. 4.2

(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.

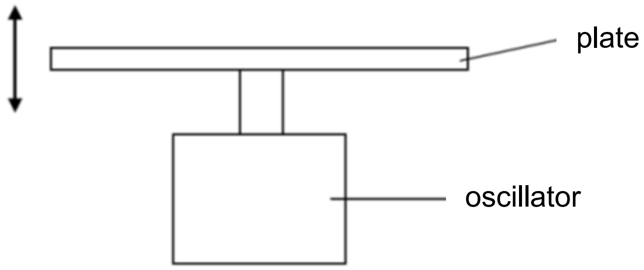


Fig. 5.1

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.

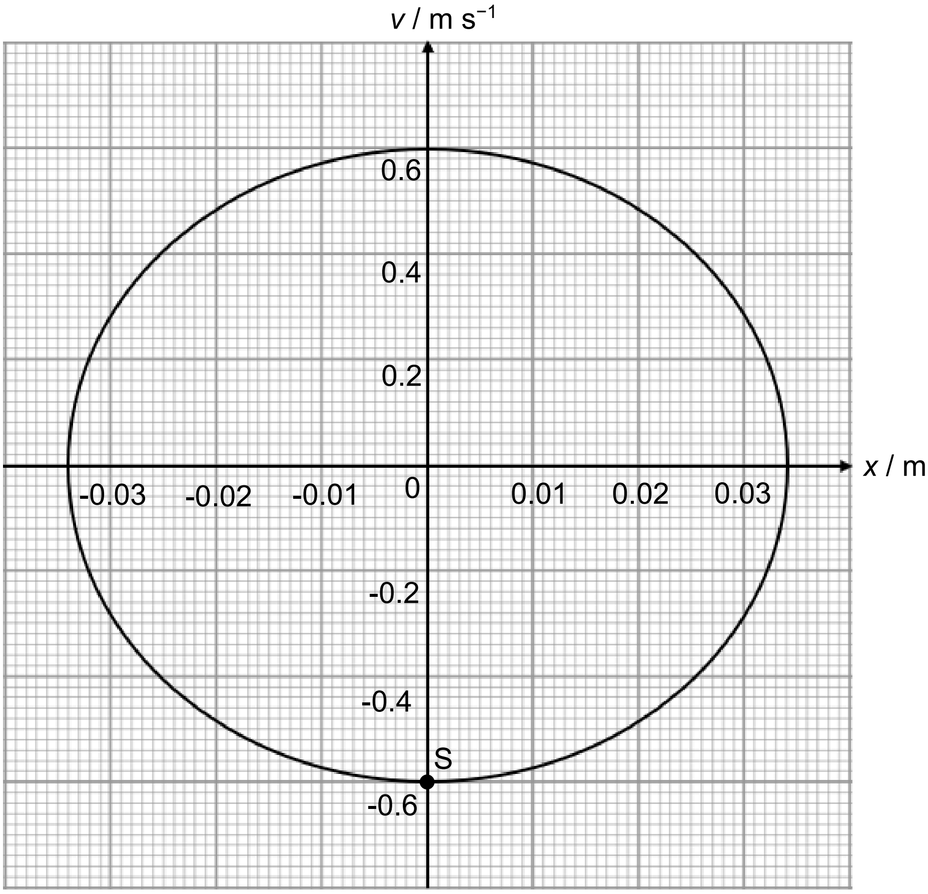


Fig. 5.2

(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.

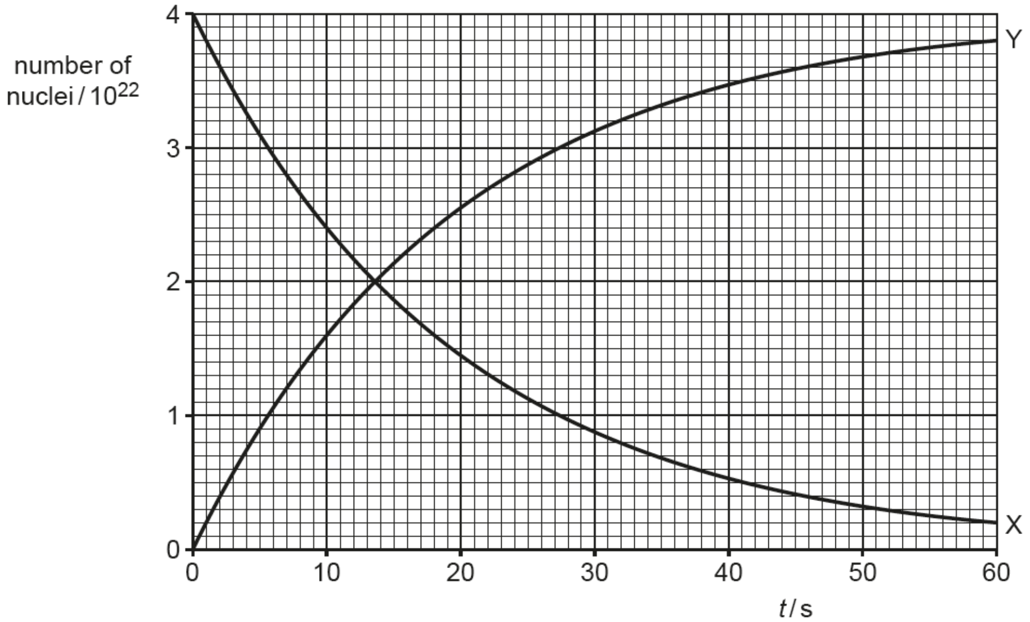


Fig. 6.1

(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

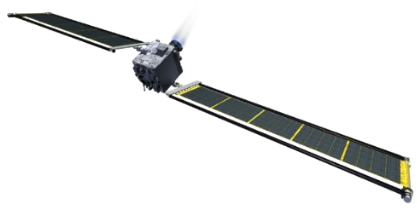
Asteroid 2024 YR4 is a large near-Earth asteroid that when it was first discovered, it appeared to have a very small chance to impact Earth on Dec. 22, 2032. Owing to the trajectory and size of 2024 YR4 (estimated to have a diameter of 53 to 67 m), its discovery initially sparked concerns of heavy, localised 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

<table>
<tr><td rowspan="7"></td><td>dimensions of main body (box)</td><td>1.3 m × 1.2 m × 1.3 m
(length × width × height)</td></tr>
<tr><td>dimensions of main body (with other structures fully extended)</td><td>1.9 m × 1.8 m × 2.6 m
(length × width × height)</td></tr>
<tr><td>dimensions of each solar array (ROSA)</td><td>8.5 m × 2.4 m
(length × width)</td></tr>
<tr><td>mass of each solar array (ROSA)</td><td>16.95 kg</td></tr>
<tr><td>mass at launch</td><td>610 kg</td></tr>
<tr><td>mass at impact</td><td>580 kg</td></tr>
<tr><td>speed of DART at impact</td><td>6580 km s^{-1}</td></tr>
</table>

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.

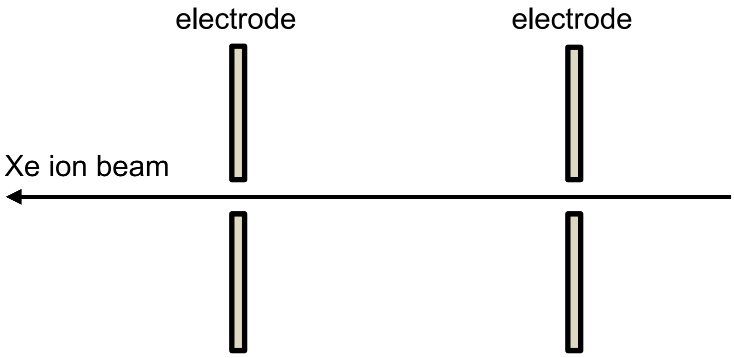


Fig. 8.1 [1]

(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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