2025 DHS Prelim Paper 2 Suggested Solutions

1 **(a)** **(i)** mass/volume (ratio must be clear) **B1**

(ii) kg m^{-3} OR kg/m^3 **B1**

(b) v has unit of m s^{-1} **B1**
p/ρ has unit of kg m^{-1} s^{-2}/ kg m^{-3} (no e.c.f from **(a)**) **M1**
$\sqrt{p/\rho}$ has unit of m s^{-1} **B1**
LHS = RHS so γ has no unit **A0**

Marker's Comments:
Common mistakes made by equating quantities to units will not be accepted.

2 **(a)** Using $v^2 = u^2 + 2as$

$$v = \sqrt{0 + 2(5.0)(4.0)}$$
$$= 6.32 \text{ m s}^{-1}$$ **A1**

(b)

Horizontal component $= 6.32\cos 37.0^o$
$= 5.05 \text{ m s}^{-1}$ **A1**

Initial vertical component of velocity $= 6.32\sin 37.0^o = 3.80 \text{ m s}^{-1}$

Using $v_y^2 = u_y^2 + 2gs_y$

Final vertical component of velocity $= \sqrt{3.80^2 + (2 \times 9.81 \times 15.0)}$
$= 17.6 \text{ m s}^{-1}$ **A1**

(c) Ball rolling down the roof: using $v = u + at$

$$t_1 = \frac{6.32 - 0}{5.00} = 1.264 \text{ s}$$ **M1**

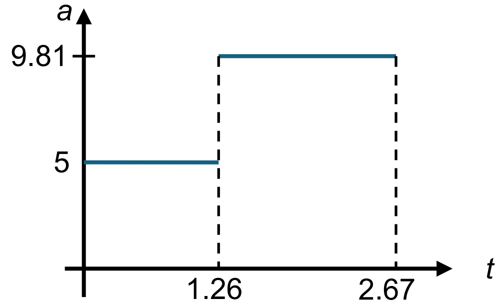
Ball falling from edge of roof to ground: using $v_y = u_y + gt$

$$t_2 = \frac{17.57 - 3.80}{9.81} = 1.404 \text{ s}$$ **M1**

Total time taken $= 1.264 + 1.404 = 2.668 = 2.67$ s **A1**

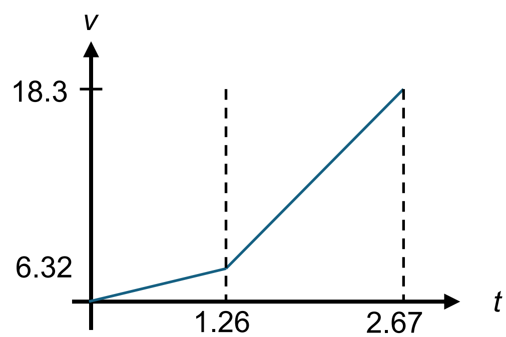
Marker's Comments:
Common mistakes made by using the wrong acceleration for calculation of the times.

(d) **(i)**



B1: Shape
B1: Correct labelled values (allow ecf)

(ii)



B1: Shape
B1: Correct labelled values (allow ecf)

Marker's Comments:
Common mistakes made is inappropriate spacing of the time, velocity and acceleration in the sketch.

3 **(a)** uniform electric and magnetic fields normal to each other AND **B1**

charged particle enters region normal to both fields

correct B direction w.r.t. E for zero deflection **B1**

For no deflection, $v = E/B$ **B1**

Marker's Comments:
Many did not state that for no deflection, $v = E/B$.

(b) $r = mv / BQ$, so B proportional to m

$B = (0.680) \times (87/86) = 0.6879$ T **C1**

$\Delta B = 7.9 \times 10^{-3}$ T **A1**

Marker's Comments:
Most were able to solve this part. Some did not calculate the change but instead gave the value of the calculated magnetic field as the answer.

4 (a)

$$F = \frac{Qq}{4\pi\varepsilon_0 r^2}$$

$$= \frac{(3.20\times10^{-7})^2}{4\pi(8.85\times10^{-12})(2\times0.50\sin3.0^0)^2}$$ **C1**

$$= 0.33616$$

$$= 0.34 \text{ N (to 2sf)}$$ **A1**

Marker's Comment:
Most students knew which formula to apply but often times made mathematical errors such as forgetting to square, or did not x 2 after resolving for the horizontal distance of the central line to the centre of one sphere.

(b) By considering the forces on one sphere,

$$\tan\theta = \frac{F_E}{W}$$

$$m(9.81) = \frac{0.33616}{\tan3.0°}$$ **C1**

$$m = 0.65385$$

$$= 0.65 \text{ kg (to 2sf)}$$ **A1**

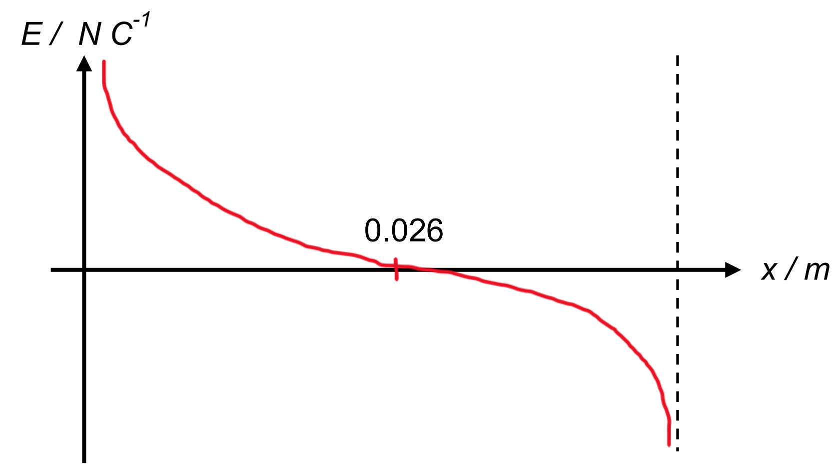
Note: Allow ecf.

Marker's Comment:
Quite a number did not attempt. Those who attempted generally managed to resolve correctly either by finding the tension first or use of the tangent function directly. A small number just simply divided the electric force by *g*.

(c) (i) The electric potential at a point is the work done per unit positive charge in bringing a small test charge from infinity to that point. **B1**

Marker's comment:
Generally the responses were missing certain key words (e.g. "work done per unit charge…") or used wrong key words. (e.g. "bring a small point charge …")

(ii)



B1: Correct Shape
B1: Intercept the horizontal axis at the midway point.

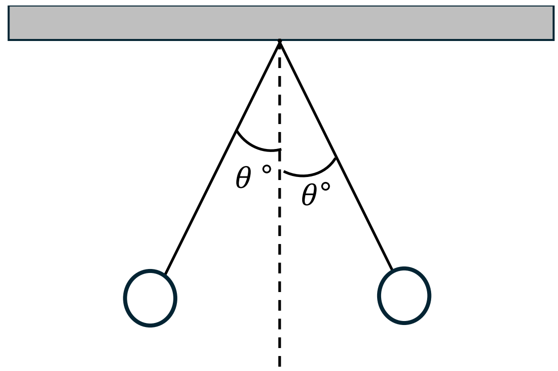
Marker's comment:
Varied responses of graphical shapes were seen. Most wrong answers gave the U-shaped graph above the horizontal axis. Many did not label the value of the *x*-intercept.

(iii) Since the electric field strength E is related to the potential as $E = -\frac{dV}{dx}$, and the graph in Fig. 4.2 is E against x. **B1**

The potential difference between two points can be found by determining the area under the graph between the two points. **B1**

Marker's comment:
Not very well done. Most responses suggested that gradient of the $E - x$ graph can be used to find the potential difference. Those who identified correctly that area of the graph is to be used often did not explain how did they arrive at that method.

(d)



B1

Each spheres will be deflected by the same, but smaller than before angle θ from the vertical. ($\theta < 3.0°$) **B1**

Note:

- Zero is given if diagram / explanation suggests unequal angle from centre vertical line.
- BOD if diagram has at least 1 angle unlabelled but there is clear symmetry about the centre vertical line

Marker's Comment:
Often times the angles in the diagram was not clearly labelled neither does their explanation often suggest that both spheres are deflected to the same extent. BOD was very often exercised as long as students drew a somewhat symmetrical diagram.

5 (a) Acceleration is directly proportional to the displacement. **B1**

Acceleration is always in the opposite direction to its displacement **B1**

(b) (i) 0.034 m **B1**

(ii)

$$\omega = \frac{v_0}{x_0}$$

$$= \frac{0.60}{0.034}$$ **C1**

$$= 17.647$$

$$= 18 \text{ rad s}^{-1}$$ **A1**

Marker's Comment:
Parts (a) and (b) were generally well done.

(c) **(i)** Upwards is taken to be positive from the graph,

$$F_{net} = N - W = -m\omega^2 x$$ **B1**

When the object loses contact, $N = 0$

(Concept must be correct, incorrect concept penalise this 1 mark)

$$mg = m\omega^2 x$$

$$x = \frac{g}{\omega^2}$$

$$= \frac{9.81}{17.647^2}$$ **C1**

$$= 0.0315$$

$$= 0.032 \text{ m}$$ **A1**

Marker's comment:

Many responses revealed misconceptions amongst students. These include:

- F_{net} = 0 (contradiction as this would mean acceleration = 0)
- $N = W = m\omega^2 x$ (this would imply that W = 0 since N = 0)
- $mg = -m\omega^2 x$ (implies W is opposite direction to F_{net})

If students somehow managed to obtain the correct mathematical working despite the obvious conceptual error, marking was very lenient to award partial credit for these responses. Students should also refrain from forcefully removing "–" signs from their workings as this would violate equivalence in their workings.

(ii) C marked at (0.032, 0.2) **B1**

Note: e.c.f. only if marked in 1st quadrant.

Marker's comment:

Students found this challenging. Most students did not mark point C on the curve but rather on its x-value on the horizontal axis. Students who managed to get the right answer to c(i) often failed to consider the context of the oscillation (starting point and subsequent motion) and marked it in the 4th quadrant instead.

6 **(a)** **(i)** cannot predict when a particular nucleus will decay
or
cannot predict which nucleus will decay next **B1**

(ii) (decay is) not affected by external (environmental) factors **B1**

(b) fluctuations in (measured) count rate **B1**

(c) The average time taken for the initial number of nuclei (or activity) of that particular radioactive nuclide to reduce to half of its initial value. **B1**

> **Marker's Comment:**
> The word 'average' is crucial because individual nuclear decay is unpredictable. Half-life describes the statistical behaviour of many nuclei, not a precise countdown for each nucleus. Distinguish: 'nuclide' = a specific isotope type (e.g. C-14); 'nucleus' = individual atomic core.

(d) **(i)** activity (of X at time *t*) **B1**

(ii) **B3**

- Y is a stable isotope
- total number of nuclei is constant
- half-life (of X) is 13.6 s
- decay constant (of X) is 0.051 s^{-1} $\left[\ln 2/t_{\frac{1}{2}} = \ln 2/13.6\text{ s} = 0.051\text{ s}^{-1}\right]$
- amount (of X) at t = 0 is 0.066 mol
  $\left[n_0 = N_0/N_A = 4.00\times10^{22}/6.02\times10^{23} = 0.066\text{ mole}\right]$
- activity (of X) at t = 0 is 2.0 × 10^{21} Bq
  $\left[A_0 = \lambda N_0 = (0.051)(4.00\times10^{22}) = 2.0\times10^{21}\text{ Bq}\right]$

Any three points, 1 mark each

> **Marker's Comment:**
> Incorrect to say Y's half-life is longer than X's. Y is stable (doesn't decay), so the concept of half-life doesn't apply to Y.

(e) mass of 1 nucleus = (7.3 × 10^{-4}) / (4.0 × 10^{22}) **C1**

nucleon number = mass of nucleus / (1.66 × 10^{-27}) **C1**

= (7.3 × 10^{-4}) / (4.0 × 10^{22} × 1.66 × 10^{-27})

= 11 **and** given as an integer **A1**

OR

number of moles = (4.0 × 10^{22}) ÷ (6.02 × 10^{23}) = 0.0664 mol

molar mass = (7.3 × 10^{-4} kg) ÷ (0.0664 mol) = 0.011 kg mol^{-1} = 11 g mol^{-1}

For a nuclide, the molar mass (in g mol^{-1}) is numerically equal to the nucleon number *A*. Therefore: *A* = 11 **and** given as an integer

7 **(a)** **(i)** The photoelectric effect is the emission of (photo)electrons from a cold metal surface when electromagnetic radiation of sufficiently high frequency is incident upon it. **B1**

Marker's Comment:
State the photoelectric effect as an observed phenomenon first, then use photon theory to explain why threshold frequency exists in part **(ii)** - don't mix definition with explanation.

(ii) Electromagnetic radiation can exist as discrete quanta of energy known as photons with energy $E = hf$ where h is the Planck constant and f is the frequency of the electromagnetic radiation. **B1**

When photons are incident on the metal, electrons in the metal can absorb and gain the photon's energy to overcome the energy needed to bring it to the surface and the work function in order to escape from the metal surface. **B1**

There is a minimum energy of photon needed to minimally overcome the work function of the metal, which corresponds to the surface-most electrons being ejected. Since the energy of the photon is directly proportional to the frequency of electromagnetic radiation, there is a minimum threshold frequency for the photoelectric effect to occur. **B1**

(b) **(i)** $E = hf$ **C1**

work function $= 6.63 \times 10^{-34} \times 8.8 \times 10^{14}$
$= 5.8 \times 10^{-19}$ J **A1**

(ii) $hf = \Phi + \frac{1}{2}mv_{max}^2$ **C1**

$6.63 \times 10^{-34} \times 11 \times 10^{14} = 5.8 \times 10^{-19} + \frac{1}{2} \times 9.11 \times 10^{-31} \times v_{max}^2$ **C1**

$v_{max} = 5.7 \times 10^5 \text{ m s}^{-1}$ **A1**

Marker's Comment:
The common errors: using e instead of m_e in kinetic energy formula and calculating stopping potential instead of maximum speed.

8 **(a)**

$$d_{avg} = \frac{53+67}{2} = 60 \text{ m}$$

$$\Delta d = \frac{67-53}{2} = 7 \text{ m}$$ **C1**

Percentage uncertainty $= \frac{7}{60} \times 100\% = 12\%$ (to 2sf) **A1**

> **Marker's comment**
> Common error was not dividing the range by 2.

(b)(i) The gravitational force exerted on Dimorphos by Didymos provides the centripetal force **M1**

$$\frac{GMm}{r^2} = mr\omega^2$$

$$\frac{GMm}{r^2} = mr\left(\frac{2\pi}{T}\right)^2$$ **M1**

Rearranging and making T^2 the subject, $T^2 = \frac{4\pi^2 r^3}{GM}$ **A0**

(b)(ii) The orbital radius decreased **B1**

The orbital period of Dimorphos decreased from 11.9 hours to 11.4 hours after DART's impact. Since T^2 is proportional to r^3, when the orbital period decreases, the radius of its orbit will also decrease **B1**

> **Marker's Comment:**
> Part (b) was generally well done. Common error in (b)(ii) was stating that T was proportional to r.

(c)(i) For the two patterns to be just distinguishable (or resolved), the central maximum of one must lie on the first minimum of the other. **B1**

> **Marker's Comment:**
> Not well done. Many students referred to Rayleigh's Criterion in terms of the minimum angle for resolution.

(c)(ii)

$$b \sin\theta = \lambda$$

$$\sin\theta = \frac{\lambda}{b}$$

For the two asteroids to be just distinguishable, their angular separation from the perspective the telescope lens, $\theta_A = \frac{s}{r}$, equal to θ. Since θ and θ_A is small,

$$r = s\left(\frac{b}{\lambda}\right)$$

$$= 1189\left(\frac{208 \times 10^{-3}}{700 \times 10^{-9}}\right)$$ **C1**

$$= 3.53 \times 10^{8} \text{ m}$$ **A1**

<u>Note:</u> λ can be any value between 400 nm to 700 nm. (visible light range)
Accepted values of r range from 3.53×10^8 m to 6.18×10^8 m.

> **<u>Marker's Comment:</u>**
> Very poorly done, only a small handful managed to get this right. Vast majority who attempted centred their working around the field of view value of 0.29°, which showed that students were not clear in their understanding of the differences between what is meant by field of vision vs Rayleigh's Criterion.

(d)(i) The ROSA solar array <u>delivers 120 W of power per kilogram of the solar array</u>. **B1**

BOD: delivers <u>120</u> W of power per kilogram of the <u>engine / generator.</u>

.

Do not accept: delivers 120 W of power per kilogram of the <u>spacecraft / DART / fuel burnt</u>

> **<u>Marker's comment:</u>**
> Students who got this right generally answered to the context of the question. Many did not read that ROSA is a solar panel which means that the fuel burnt does not affect the power to mass ratio.

(d)(ii) Total mass of ROSA array $= 2 \times 16.95$

$= 33.9$ kg **C1**

$P = 33.9 \times 120$

$= 4068$ **A1**

$= 4070$ W (to 3sf)

> **Marker's Comment:**
> Common error was not realising that students are supposed to use the mass of ROSA, instead the mass used was either the mass of fuel burnt or mass of DART

(e)(i) Xenon has a relatively high atomic mass compared to Argon or Krypton. **B1**

Hence when the Xenon ions are being expelled at higher momentum for the same ion speed, the thrust force generated is greater **B1**

OR

Xenon has lower ionization energy than Argon or Krypton. **B1**

Hence, it requires less energy to create Xenon ions to be used in the ion thruster **B1**

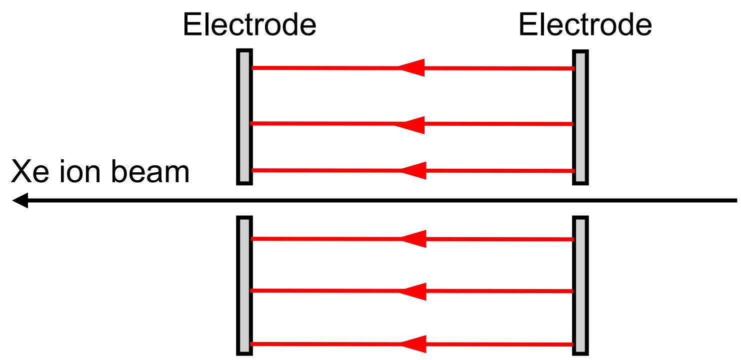
OR

Xenon has the highest number of electrons / largest atomic radii due to its high nucleon number. **B1**

Hence, less energy is needed to remove valence electron to form Xenon ions since there are electrons that are further away from the nucleus / less tightly bound to the Xenon nucleus. **B1**

> **Marker's Comment:**
> Most were able to identify that Xenon has either highest mass number or proton number, but their subsequent explanations often showed misconceptions.
>
> The most common misconception was that a high mass would therefore mean that Xenon would release the most energy via nuclear fission. Another fairly common misconception was that students were unable to distinguish ionisation energy vs binding energy and students often times suggested that the binding energy of Xenon is lower and hence it needs less energy to form Xenon ions.

(e)(ii)



B1

- 6 horizontal parallel lines, equally spaced apart pointing leftwards

<u>Note:</u> 0 m for free-hand drawings

<u>Marker's Comments:</u> Most drawings had an issue with the equal spacing. Many had a much larger space between the middle 2 field lines compared to the others.

(e)(iii) By Conservation of Energy,

$$\text{Gain in KE} = \text{Loss in } U_E$$

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

Since the Xe ion has 131 nucleons and has a charge of +1.60 × 10^{-19} C due to having 1 electron removed,

$$\frac{1}{2}(131 \times 1.66 \times 10^{-27})(40000)^2 = \left(1.60 \times 10^{-19}\right)V$$ **C1**

$$V = 1087.3 \text{ V}$$

$$= 1100 \text{ V (to 2sf)}$$ **A1**

<u>Marker's Comment:</u> Many did not attempt. Common errors were to assume that the charge of Xenon ion is +54*e* or did not convert 40 km s^{-1} to m s^{-1}.

(e)(iv) At the maximum exhaust speed of ejection,

$$F = \frac{dp}{dt} = \frac{dm}{dt}v$$

$$\frac{dm}{dt} = \frac{F_{\max}}{v_{\max}} = \frac{235 \times 10^{-3}}{40000} = 5.875 \times 10^{-6}$$ **C1**

no. of Xe ions expelled per second $= \dfrac{dm}{dt} \div m_{Xe}$

$$= \frac{5.875 \times 10^{-6}}{131 \times 1.66 \times 10^{-27}}$$ **C1**

$$= 2.70 \times 10^{19}$$ **A1**

Marker's Comment:
Most did not attempt. A handful used the mass of proton instead of the value of *u*.