2024 Ph H2 Q4
Section: Our Dynamic Universe
Topic: Gravitation, Energy, Momentum

Question Summary

This question relates to the DART mission's collision with the asteroid Dimorphos. It involves:

- Comparing the mass of Earth and Didymos (orders of magnitude),
- Calculating gravitational force between Earth and Didymos,
- Calculating kinetic energy transferred from DART to Dimorphos,
- Sketching the force-time graph during the impact.

Worked Solution

(a) (i) Comparing masses in orders of magnitude:

- Mass of Earth = $6.0 \times 10^{24}\ \text{kg}$
- Mass of Didymos = $5.3 \times 10^{11}\ \text{kg}$
- Difference in order of magnitude = $24 - 11 = 13$

✅ **Answer: 13 orders of magnitude**

(a) (ii) Gravitational force between Earth and Didymos:

Use Newton's Law of Universal Gravitation:

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

Where:

- $G = 6.67 \times 10^{-11}\ \text{N m}^2\text{kg}^{-2}$
- $m_1 = 6.0 \times 10^{24}\ \text{kg}$ (Earth)
- $m_2 = 5.3 \times 10^{11}\ \text{kg}$ (Didymos)
- $r = 1.1 \times 10^{10}\ \text{m}$

$$F = \frac{(6.67 \times 10^{-11})(6.0 \times 10^{24})(5.3 \times 10^{11})}{(1.1 \times 10^{10})^2}$$

$$F = \frac{2.124 \times 10^{26}}{1.21 \times 10^{20}} = 1.76 \times 10^{6}\ \text{N}$$

✅ **Answer:** $1.76 \times 10^{6}\ \text{N}$

(b) (i) Kinetic energy of DART before impact:

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

- $m = 570\ \text{kg}$,
- $v = 6.6\ \text{km/s} = 6600\ \text{m/s}$

$$E_k = \frac{1}{2} \times 570 \times 6600^2 = 1.24 \times 10^{10}\ \text{J}$$

✅ **Answer:** $1.24 \times 10^{10}\ \text{J}$

(b) (ii) Force-time graph for collision:

Sketch a curve starting at zero, rising smoothly to a peak (representing maximum force), then symmetrically falling back to zero. This represents the short-duration impact.

✏️ *(Graph is qualitative and does not require values on axes)*

Revision Tips

- ⚖️ Know how to compare values in **orders of magnitude**.
- 🌍 Use **Newton's Law of Universal Gravitation** confidently with standard form.
- 🚀 Kinetic energy depends **quadratically on speed** — double the speed, quadruple the energy!
- 📈 Impact forces often form a **symmetric pulse** in force-time graphs.