

A level Physics B

H557/01 Fundamentals of physics

Question Set 22

1 (a)

This question is about propulsion systems for spacecraft.

A solar sail uses the momentum of photons in solar radiation for propulsion.

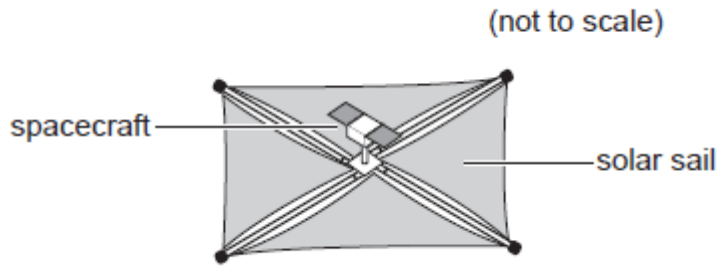


Fig.1.1

Relativity shows that a photon of energy E has momentum $p = \frac{E}{c}$.

(i) Show that $\frac{E}{c}$ has the units of momentum.

[1]

(ii) The total photon power of the radiation received from the Sun on a 1.0 m^2 area of solar sail is P .

Show that the thrust force T from photon reflection is given by $T = \frac{2P}{c}$.

Assume that the Sun's rays are normal to the sail and all the radiation is reflected.

[3]

(iii) The total photon power density is 1400 W m^{-2} .
The 1.0 tonne spacecraft has a 10^6 m^2 solar sail.

Calculate the acceleration of the spacecraft.

acceleration = ms^{-2} [2]

- (b) An ion drive uses the momentum of ions for propulsion. It ionises a gas and uses an accelerating field to accelerate the positive ions to a high velocity.

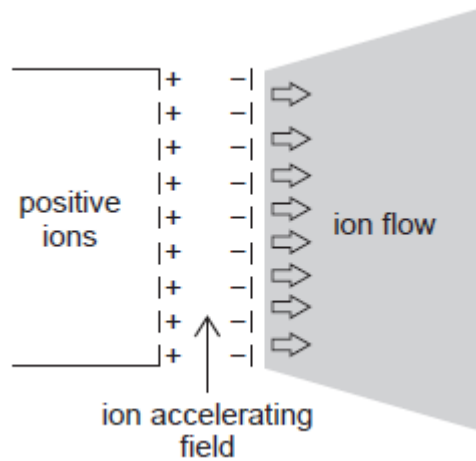


Fig. 1.2

- (i) A positive ion of charge Q and mass m is accelerated through a p.d. V . Show that the momentum per unit mass $\frac{p}{m}$ it gains is given by the expression

$$\frac{p}{m} = \sqrt{2V\left(\frac{Q}{m}\right)}.$$

[2]

- (ii) Discuss an advantage of using ions of hydrogen ${}^1\text{H}^+$ as propellant instead of xenon ${}^{130}\text{Xe}^+$.

[2]

- (iii) An ion drive with accelerating p.d. $V = 2000 \text{ V}$ must produce a thrust of 0.24 N . Show that the mass flow rate $\frac{\Delta m}{\Delta t}$ is less than $4 \times 10^{-7} \text{ kg s}^{-1}$.

$$\frac{Q}{m} \text{ for } {}^1\text{H}^+ \text{ ions} = 9.6 \times 10^7 \text{ C kg}^{-1}.$$

[2]

Total Marks for Question Set: 12

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