

Radiation Pressure

A spacecraft weighing 10 kg has a highly reflective flat aluminium sail of area 100 m^2 . When launched from the Earth it is set in orbit about the sun at the same distance as the Earth from the sun with the sail facing directly to the sun.

Assuming the sail is a perfect reflector estimate how many hours will elapse before it has increased its speed away from the sun by 10 m s^{-1} .

(The Earth receives sunlight equivalent to 1.5 kW m^{-2} .)

Solution:

For photons transporting energy E per square meter per second the momentum transfer is E/c per square meter per second.

However the photons are perfectly reflected, hence the transfer of momentum to the sail is $2E/c \text{ m}^{-2} \text{ s}^{-1}$.

Thus $dp/dt = f = 2 \times (1.5 \text{ kW m}^{-2}/c) \times \text{Area}$.

Therefore the force on the sail, f is $\sim 10^{-3} \text{ N}$.

Thus the acceleration a of the spacecraft is 10^{-4} m s^{-2} .

The speed increase dv over time dt is given by $dv = a dt$.

For one hour $dv = 60 \times 60 \times a = 0.36 \text{ m s}^{-1}$.

Therefore to increase the spacecraft speed by 10 m s^{-1} requires ~ 28 hours.