

- 5 (a)(i) A cargo spacecraft of mass  $m$  has an initial circular orbit of radius  $R_1$  about a planet of mass  $M$ . A Hohmann transfer orbit is used to transfer it to a final circular orbit of radius  $R_2$  using two engine burns.

Determine an expression for the minimum speed of the spacecraft required to enter the transfer orbit from the initial circular orbit in terms of  $m$ ,  $M$ ,  $R_1$  and  $R_2$ .

[3 marks]

(a)(ii) Show that the increase in total energy of the spacecraft for the first burn is given by

$$\frac{GMm}{2R_1} \left( \frac{R_2 - R_1}{R_2 + R_1} \right)$$

[2 marks]

(a)(iii) Determine an expression for the time of flight for the transfer from the initial to the final orbit in terms of  $m$ ,  $M$ ,  $R_1$  and  $R_2$ . [2 marks]