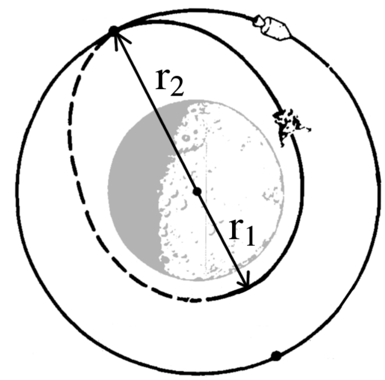
**Answer all question on the back of this page (or on a separate sheet). Please be as neat as you can. Show all work, including units. Circle your final answer clearly.**

## Landing on the Moon




To land on the Moon, the Lunar Module (LM) has to go from lunar orbit the the lunar surface. To do this the LM changes its orbit to a non-circular one where the furthest point ($\mathbf{r}_2$) is at lunar orbit, and the closest point ($\mathbf{r}_1$) is near the lunar surface.

The velocity (in km/s) of the LM at the closest point of the orbit is:

$$\text{V [km/s]} = 70 \times \sqrt{\frac{2}{r_1} - \frac{2}{r_1 + r_2}}$$

**1** (10 pts) Calculate the velocity of the LM at its closest point of the orbit for $\mathbf{r}_1$ = 1,731 km and $\mathbf{r}_2$ = 1,841 km.

Of course the final velocity of the LM on the Moon has to be 0 km/s. This means that the LM has to make a burn of $\Delta$V = your answer to question #1 to land on the Moon.

The rocket equation can be rewritten to find how much of our rocket has to be fuel if we are given a value for $\Delta V$ and $u$.

$$\text{Fuel Fraction} = 1 - \exp(-\Delta V/u)$$

**2** (10 pts) Calculate what fraction of the LM that has to be fuel in order for it to make its final burn to land on the Moon (assume u = 3 km/s).

**3** (5 pts) If the total mass of the LM is 15,065 kg. Calculate the mass of the fuel needed to make LM's final burn to land on the Moon.