

**Question**

A rocket emits mass (fuel) at a rate  $\alpha$  with a speed  $u$  relative to the rocket.

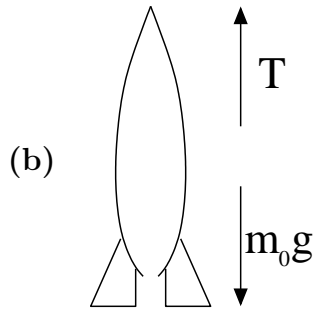
- (a) Show that the thrust exerted on the rocket by its engines is  $u\alpha$ .
- (b) If the rocket has initial mass on the launch pad of  $m_0$  what is the minimum exhaust velocity that will allow it to lift off *immediately*?

**Answer**

- (a) Thrust is the rate of change of momentum of the rocket.

$$T = m \frac{dv}{dt} = -u \frac{dm}{dt} \quad (\text{as } mdv = u dm)$$

$$\Rightarrow T = u\alpha \quad \text{as } \frac{dm}{dt} = -\alpha$$



For immediate start the acceleration of the rocket must be  $\geq 0$

Therefore  $T - m_0 g \geq 0$

$$\Rightarrow u \geq \frac{m_0 g}{\alpha}$$