10.1: Introduction

If you are asked to state Newton's Second Law of Motion, I hope you will not reply: "Force equals mass times acceleration" - because that is not Newton's Second Law of Motion. Newton's Second Law of Motion is:

The alteration of motion is ever proportional to the motive force impressed; and is made in the direction of the right line in which that force is impressed.

In short: Force equals Rate of Change of Momentum, or, in symbols, $F = \dot{p}$. On differentiating the right hand side, we obtain $F = m\dot{v} + \dot{m}v$. In other words, if the mass is constant then indeed force equals mass times acceleration - but *only* if the mass is constant. In a rocket, a very appreciable fraction of the mass of the rocket is fuel, which is burned and ejected at a very high rate, so that the mass of the rocket is rapidly diminishing during the motion. It is one of the great problems of rocket design that such a high proportion of the initial mass must be fuel. For this reason, other possible methods of driving spacecraft are being investigated by many groups. For example, in the ion propulsion system of the Deep Space One spacecraft, electrically accelerated ions are ejected at high speed from the spacecraft. The force produced and the acceleration are minute, but, because it can be kept up for a very long time, very high speeds can eventually be reached. "Solar sail" systems similarly rely on the very tiny force that can be exerted by the solar wind, but this tiny force can be exerted during most of the lifetime of a spacecraft's flight, and hence again high speeds can be reached.

This chapter, however, concerns just conventional rocket motion. In the next section I consider the motion of a rocket in space subject only to the one force from the high-speed ejection of burned fuel in the absence of any other forces. At a later date, if I can find the time and energy, I may add further sections on rocket motion against gravity, which might be uniform or might fall off with distance from Earth, and we might include air resistance or not. But to begin with, we deal solely with a rocket isolated in space and subject to no additional forces.