The Space Rocket

N5

Resultant Forces (2)

Resultant forces in the horizontal direction was studied in the Forces section (1.2).
In this section we will consider resultant forces in the **vertical** direction in the context of a space rocket **launching.** In this section we will also consider the forces acting on the rocket **during flight and when landing**. This involves Newton's 1^{st}, 2^{nd} and 3^{rd} laws of motion and the weight of the rocket (W = mg).

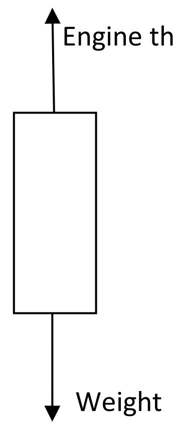
Example 1 - Launching

At launch, a rocket of mass 20 000 kg accelerates off the ground at 12 ms^{-2} (ignore air resistance)

a) **Use Newton's 3^{rd} law of motion to explain how the rocket gets off the ground.**
b) **Draw a free body diagram to show all the vertical forces acting on the rocket as it accelerates upwards.**
c) **Calculate the engine thrust of the rocket which causes the acceleration of $12ms^{-2}$.**

Solutions

a) The rocket pushes the gas out the back downwards (action) and the gas pushes the rocket upwards (reaction).
b)

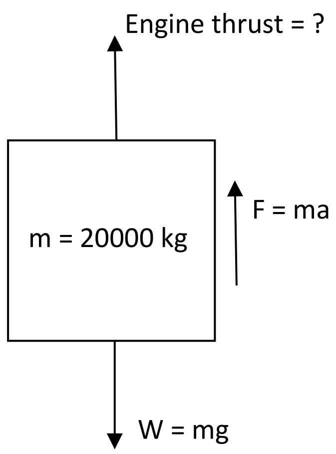


c) Calculate F and W

F = m a
F = 20 000 x 12
F = 240 000 N

W = m g
W = 20 000 x 9.8
W = 196 000 N

F = upward force (thrust) – downwards force (Weight)
240 000 = thrust – 196 000
thrust = 436 000 N



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Resultant Forces (2) (ctd)

Example 2 – During Flight

The same rocket reaches a speed of 10 000 ms^{-1} as it accelerates away from earth.

a) Can you suggest 3 reasons why the acceleration of the rocket will increase? (Hint: this time take into consideration air resistance)

b) When the rocket is in space there is negligible gravity acting on it. Use all of Newton's laws of motion to explain how the rocket moves in space.

Solution

a)
- Decrease in mass due to fuel being used up
- Decrease in air resistance as there is less air particles the further away from the surface of the Earth
- Decrease in the value of g the further away from the centre of the Earth

b) Travelling at a constant speed – all thrusters are switched off and forces or both forward and backward thrusters are on applying the same force. In both situations the forces are balanced **(1st Law)**
Accelerating – forward thrusters on and the forces are unbalanced in the forward direction **(2nd law)**
Decelerating – backward thrusters on and the forces are unbalanced in the backward direction **(2nd law)**
When the thrusters are on they propel the gases out (action) which applies a force to the rocket in the opposite direction (reaction) **(3rd law)**

Example 3 – Landing

On returning from space the rocket has to overcome two major hurdles:
- **Re-enter the Earth's atmosphere**
- **Land safely on the ground**

a) As the rocket enters the earth's atmosphere what happens to it's velocity?

b) Explain your answer to part a)

c) What is the main energy change during re-entry (think back to S1 Energy topic)?

d) When the rocket touches down on the ground, explain in terms of forces why a parachute is activated out the back of the rocket to bring it to a safe stop.

Solution

a) It decreases

b) The rocket is travelling so fast (at around 8000 ms^{-1}) as it passes into the atmosphere air so a large frictional force will act against it.

c) Kinetic to heat

d) When the parachute opens, the force due to air resistance (drag) drastically increases and causes an unbalanced force acting backwards against motion. This will result in the rocket decelerating and eventually coming to a safe stop.