**Dynamics & Space**

**Forces**

**Summary**

Forces have the ability to change the shape, speed and direction of an object.

Force is measured in newtons (N).

Forces can be measured with a newton balance (or a spring balance or force-meter).

**Mass**, *m*, is the amount of matter in an object and is measured in kilograms (kg). The mass of an object is the same, no matter where it is in the Universe.

**Weight, Mass and gravitational field strength**

$$weight=mass ×\begin{matrix}gravitational\\field strength\end{matrix} $$

$$W=mg$$

$$m=\frac{W}{g}$$

$$g=\frac{W}{m}$$

Nkg-1

N

kg

*m*

*W*

*g*

**Weight**, *W*, is the force of gravity on an object and is measured in newtons (N). The weight of an object depends on both its mass and the strength of gravity.

**Gravitational field strength**, *g*, is the weight per unit mass and is measured in newtons per kilogram (Nkg-1). The gravitational field strength is different at different places in the Universe. On Earth g has a value of 9·8 Nkg-1. The value of g decreases with distance from the planet’s surface.

**Friction** is the force that opposes motion. Friction arises when surfaces rub together. When there is friction, heat is produced.

Situations in which friction is reduced include: lubricating a bicycle wheel with oil, using rollers on a conveyor belt, wearing swimsuits made of vey smooth materials and waxing skis.

Situations in which friction is increased include: pressing brake pads onto a bake disc, using chalk to absorb moisture when rock climbing, using rubber on car tyres to increase ‘grip’.

**Air resistance**, or drag, is a form of friction. Air resistance increases with speed. Air resistance can be reduced by **streamlining**.

Forces are vector quantities and therefore have both a magnitude (size) and direction.

60 N

80 N

resultant force = 100 N @ 54° to vertical

e.g.

8 N

3 N

resultant force = 5 N right

Equal forces acting in opposite directions are known as balanced forces. When the forces on an object are balanced the object remains at rest or continues to move at a constant speed in a straight line. This is known as **Newton’s First Law of Motion**.

When the forces on an object are unbalanced the object will accelerate. The acceleration of an object depends on the mass of the object and the size of the unbalanced force:

300 m

500 m

**Force, Mass and Acceleration**

$$\begin{matrix}unbalanced\\force\end{matrix}=mass ×acceleration $$

$$F=ma$$

$$m=\frac{F}{a}$$

$$a=\frac{F}{m}$$

ms-2

N

kg

*m*

*F*

*a*

Acceleration is directly proportional to the unbalanced force on the object.

Acceleration is inversely proportional to the mass of the object.

The relationship between unbalanced force, mass and acceleration is known **as Newton’s Second Law of Motion**.

To accelerate an object upwards the lifting force must be greater than its weight, so there is an unbalanced upward force (e.g. rockets)

**Newton’s Third Law of Motion** states that ‘every action has an equal and opposite reaction’, i.e. if A exerts a force on B, B exerts and equal and opposite force on A. Pairs of action reaction forces are known as **newton pairs** (e.g. the force of a bat on a ball and the force of the ball on the bat are a newton pair).

Rockets work by the engine exerting a backward force on the exhaust gases; the gases therefore exert a forwards force on the rocket.

When an object is dropped it initially accelerates due to the force of gravity. As it travels faster air resistance increases, the unbalanced force decreases and the acceleration decreases. Eventually the weight and air resistance become balanced; at this point the object falls at a constant velocity known as its **terminal velocity**.