Y4 Physics HT1

HT7 **Forces – Forces and their Interactions; Work Done and Energy Transfer; Elasticity**

4.5 Forces

Engineers analyse forces when designing a great variety of machines and instruments, from road bridges and fairground rides to atomic force microscopes. Anything mechanical can be analysed in this way. Recent developments in artificial limbs use the analysis of forces to make movement possible.

4.5.1 Forces and their interactions

4.5.1.1 Scalar and vector quantities

Content
Scalar quantities have magnitude only. Vector quantities have magnitude and an associated direction. A vector quantity may be represented by an arrow. The length of the arrow represents the magnitude, and the direction of the arrow the direction of the vector quantity.

4.5.1.2 Contact and non-contact forces

Content
A force is a push or pull that acts on an object due to the interaction with another object. All forces between objects are either: • contact forces – the objects are physically touching • non-contact forces – the objects are physically separated. Examples of contact forces include friction, air resistance, tension and normal contact force. Examples of non-contact forces are gravitational force, electrostatic force and magnetic force. Force is a vector quantity. Students should be able to describe the interaction between pairs of objects which produce a force on each object. The forces to be represented as vectors.

Y4 Physics HT1

4.5.1.3 Gravity

Content

Weight is the force acting on an object due to gravity. The force of gravity close to the Earth is due to the gravitational field around the Earth.

The weight of an object depends on the gravitational field strength at the point where the object is.

The weight of an object can be calculated using the equation:

weight = mass × gravitational field strength

[$W = m g$]

weight, W, in newtons, N

mass, m, in kilograms, kg

gravitational field strength, g, in newtons per kilogram, N/kg (In any calculation the value of the gravitational field strength (g) will be given.)

The weight of an object may be considered to act at a single point referred to as the object's 'centre of mass'.

The weight of an object and the mass of an object are directly proportional.

Weight is measured using a calibrated spring-balance (a newtonmeter).

Y4 Physics HT1

4.5.1.4 Resultant forces

Content
A number of forces acting on an object may be replaced by a single force that has the same effect as all the original forces acting together. This single force is called the resultant force. Students should be able to calculate the resultant of two forces that act in a straight line. (HT only) Students should be able to: • describe examples of the forces acting on an isolated object or system
• use free body diagrams to describe qualitatively examples where several forces lead to a resultant force on an object, including balanced forces when the resultant force is zero. (HT only) A single force can be resolved into two components acting at right angles to each other. The two component forces together have the same effect as the single force.
(HT only) Students should be able to use vector diagrams to illustrate resolution of forces, equilibrium situations and determine the resultant of two forces, to include both magnitude and direction (scale drawings only).

4.5.2 Work done and energy transfer

Content

When a force causes an object to move through a distance work is done on the object. So a force does work on an object when the force causes a displacement of the object.

The work done by a force on an object can be calculated using the equation:

work done = force × distance
(moved along the line of action of the force)

[$W = F s$]

work done, W, in joules, J

force, F, in newtons, N

distance, s, in metres

One joule of work is done when a force of one newton causes a displacement of one metre.

1 joule = 1 newton-metre

Students should be able to describe the energy transfer involved when work is done.

Students should be able to convert between newton-metres and joules.

Work done against the frictional forces acting on an object causes a rise in the temperature of the object.

4.5.3 Forces and elasticity

Content

Students should be able to:

- give examples of the forces involved in stretching, bending or compressing an object
- explain why, to change the shape of an object (by stretching, bending or compressing), more than one force has to be applied – this is limited to stationary objects only
- describe the difference between elastic deformation and inelastic deformation caused by stretching forces.

The extension of an elastic object, such as a spring, is directly proportional to the force applied, provided that the limit of proportionality is not exceeded.

Y4 Physics HT1

$force = spring\ constant \times extension$

$[F = k\,e]$

force, F, in newtons, N

spring constant, k, in newtons per metre, N/m

extension, e, in metres, m

This relationship also applies to the compression of an elastic object, where 'e' would be the compression of the object.

A force that stretches (or compresses) a spring does work and elastic potential energy is stored in the spring. Provided the spring is not inelastically deformed, the work done on the spring and the elastic potential energy stored are equal.

Students should be able to:

- describe the difference between a linear and non-linear relationship between force and extension
- calculate a spring constant in linear cases

- interpret data from an investigation of the relationship between force and extension

---

- calculate work done in stretching (or compressing) a spring (up to the limit of proportionality) using the equation:

  $elastic\ potential\ energy = 0.5 \times spring\ constant \times (extension)^2$

  $[E_e = \frac{1}{2}\,k\,e^2]$

Students should be able to calculate relevant values of stored energy and energy transfers.

Required practical activity 6: investigate the relationship between force and extension for a spring.

*

*

*