Exercises on Mechanics

Motion

- Linear Motion (equations of motion)
- Vectors and scalars

Forces

Newton's laws of motion
- Force and momentum
- Friction

Conservation of momentum

Circular motion
- Centripetal acceleration and force
- Angular velocity

Gravity
- Newton's Law
- Weight
- Variation of g
- Satellites

Density and pressure
- Boyle's law
- Archimedes' Principle

Moments
- Levers
- Couples

Conditions for equilibrium

Simple harmonic motion
- Hooke's law
- Pendulum

Energy
Work
Energy
- Conservation of energy
- Kinetic energy
- Potential energy
- Mass-energy

Power
- Percentage efficiency

Definitions

Work

Energy

Power

Newton's laws of motion

Newton's law of gravitation

Friction

Momentum

Conservation of momentum

Density

Pressure

Boyle's law

Archimedes' principle

Law of flotation

Angular velocity

Centripetal acceleration

Laws of equilibrium

Laws of moments

Hooke's Law

Formulae

Linear Motion	$v = u + at$
	$s = ut + \frac{1}{2}at^2$
	$v^2 = u^2 + 2as$
Momentum	$p = mv$
Force	$F = ma$
Conservation of momentum	$p_{before} = p_{after}$
Angle in radians	$\theta = \frac{s}{r}$
Angular velocity	$\omega = \frac{\theta}{t}$
Angular / linear velocity	$v = r\omega$
Centripetal acceleration	$a = r\omega^2 = \frac{v^2}{r}$
Centripetal force	$F = mr\omega^2 = \frac{mv^2}{r}$
Newton's law of gravitation	$F = \frac{Gm_1m_2}{d^2}$
Weight	$W = mg$
Acceleration due to gravity	$g = \frac{GM}{R^2}$
Period of a satellite	$T^2 = \frac{4\pi^2R^3}{GM}$

Density	$\rho = \frac{m}{V}$
Pressure	$P = \frac{F}{A}$
Pressure in a liquid	$P = \rho gh$
Boyle's Law	$pV = cons\tan t$
Moments	$M = F.s$
Couple	$T = F.d\ (d = 2s)$
Hooke's Law	$F = -k.s$
Simple Harmonic Motion	$a = -\omega^2 s$
Period of a pendulum	$T = 2\pi\sqrt{\frac{l}{g}}$
Work	$W = Fs$
Potential Energy	$E_p = mgh$
Kinetic Energy	$E_k = \frac{1}{2}mv^2$
Mass-energy equivalence	$E = mc^2$
Power	$P = \frac{W}{t}$
Percentage efficiency	$= \frac{output}{input}.100$

Vectors and Scalars

Scalar Quantity — A quantity that has _____ only and has _____ in space

Examples

Scalar Quantity	Unit
_____	_____
_____	_____
_____	_____
_____	_____
_____	_____
_____	_____
_____	_____
_____	_____
_____	_____
_____	_____

Adding scalars is easy: 1 kg plus 2 kg always equals 3 kg.

Example 1:

It took a student 30 minutes to walk to the bus stop to the get the bus to school and then a further hour to finally get to school. Calculate the student's total time to get to school.

Vector Quantity — A quantity that has _____ magnitude and _____ in space.

Examples

Vector Quantity	Unit
_____	_____
_____	_____
_____	_____
_____	_____
_____	_____
_____	_____

Representing a vector quantity

Vectors are represented by an arrow on a diagram. The length of the arrow represents _____ and the _____ of the arrow shows its _____.

Example 2

A force 10 N acting in a South-Easterly direction. A velocity of 2 m/s to the right is represented in the diagram below.

Adding vectors is not as straightforward as scalar quantities. Combining a 1 N force with a 2 N force can equal 1 N or 3 N, or anything in between. The direction of the two forces must be taken into account when combining them.

The **resultant** force is the single force that has the same effect as a number of separate forces.

If the forces act in the same straight line the resultant is found by simple addition or subtraction.

Example 1

Determine the resultant of forces of 20 N and 30 N:

(a) Acting in the same direction.
(b) Acting in opposite directions

If the resultant forces cannot be found by simple addition or subtraction then the triangle law or the parallelogram law is used.

Triangle law is used when the two vectors drawn are head to tail. The **resultant** vector is the vector from the tail of the first to the head of the second.

Parallelogram law is used when the two vectors drawn are tail to tail. In this case complete the parallelogram and the **resultant** vector is the diagonal of the parallelogram from where the two tails meet.

Example 2

Determine the resultant force of 20 N and 30 N when they are acting at right angles to each other.

Example 3

Find the resultant of a force of 3 units due north and a force of 4units due east.

Example 4

Two people A and B, pull on ropes at an angle of 90^{o} to each other with forces 15 N and 20 N respectively. At what angle, relative to A, and with what force, must a donkey, C, pull the angle of the rope to balance the pull of the other two?

Example 5

A horse is pulling a railway truck at constant velocity with a force of 500 N at an angle of 30^o to the truck. If the trucks velocity is constant, what force is moving the truck? Suggest a reason why the truck is not accelerating, despite the force acting on it.

Example 6

A parachutist is falling with a vertical velocity of 15 m/s when he is blown by a wind that has a horizontal velocity of 8m/s. Calculate the resultant velocity of the parachutist. At a certain instant during the descent the parachutist is directly over a point X on the grounds. The parachutist lands 10 seconds later at a point Y. What is the distance XY?

Resolution of Vectors

A **resultant vector can be resolved into its component vectors.** In leaving cert physics you will only deal with the perpendicular components of a vector.

When resolving a vector into two perpendicular components:

- From the tail of the vector, draw in the two required perpendicular directions.
- Complete the parallelogram
- Fill in the information given in the question onto your diagram.
- Calculate the magnitude of the components using trig ratio's

Example 7

A stone of weight 50 N rests on a sloped roof. The roof is inclined 20^o to the horizontal. Resolve the weight of the stone into components parallel and perpendicular to the roof.

Questions

1. Two forces, of 3 N and 4 N, act at right angles to each other. What is the magnitude and direction of their resultant?

2. A man walks at 5 m/s perpendicularly across a boat whish is moving at 12 m/s. What is the man's resultant velocity?

3. A train is travelling over a straight section of track at 30 km/hr.
   a) A passenger walks up and then down the corridor at a speed of 5km/hr. What are her velocities in each case relative to the track?
   b) She then turns and walks perpendicularly into a compartment; what is her resultant velocity as she does this?

4. A builder of mass 65 kg is working on a roof inclined at an angle of 30° to the horizontal. Find the force:
   a) Tending to make him slip off the roof
   b) Pressing him directly on to it.

5. A barge is being towed by two horses, one on each canal bank, and each pulling with a force of 1800 N. The two paths are 12 m apart and the ropes are each 24 m in length. Calculate the force pulling the barge along the canal.

6. A water skier is being pulled horizontally with a force of 150 N. His weight is 700 N. What is the resultant force of these two forces and in which direction does it act? What force balances this resultant and in what direction does it act?

7. A skier of mass 50 kg is travelling at constant velocity down a slope of angle 10°.
   a) What is the resultant force acting on her?
   b) What force prevents her from accelerating?
   c) What is her weight?
   d) In what direction does her weight act?
   e) What component of her weight is pulling her down the slope?
   f) What is the reaction between her and the slope?

8. To directly cross a river 500 m wide, a motor boat capable of travelling at 4.5 m/s is headed upstream at 45° to the river bank. Calculate the amount of time in crossing the river.

9. Two tugboats are pulling a large steamer, each wit a force of 7000 N. The angle between the cables on which the tugboats are pulling is 30°. What is the resultant pull on the streamer?

10. A 15 kg mass is supported by a light cord attached to a hook in the ceiling. Another cord is attached to the mass and pulled horizontally until the supporting cord makes an angle of 30° with the vertical. Find the tension in both strings.