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SPECIALIST MATHEMATICS
Teach Yourself Series
Topic 13: Forces - Statics and Dynamics

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Forces – Statics and Dynamics

In this topic we shall study and understand the various physical parameters associated with motion of an object – mass, weight, force, momentum. Newton's laws of motion are also discussed and some applications of these laws to real life situations will be studied here.

Statics – types of forces

As it appears in Unit 4

- Inertial mass – property of an object that makes it difficult to change its state of motion
    - Is a scalar quantity
    - Usually measured in kilograms
    - Larger mass will have greater resistance to change in motion

- Momentum – measure of an object's motion
    - Momentum = mass × velocity ($p = mv$)
    - It is a vector quantity
    - It is measured in kg m/s
    - It is collinear to velocity

- Force – is a vector quantity and is measured in Newtons (N)
    - Field force – includes gravity, weight and magnetic force
    - Applied force – tension, compression, push, pull, normal reactive force
    - Resistive force – friction and air resistance

- Resultant force – sum of all forces acting on an object
    - $\underset{\sim}{R} = \underset{\sim}{F_1} + \underset{\sim}{F_2} + \underset{\sim}{F_3} = \sum \underset{\sim}{F}$
    - $\underset{\sim}{F} = \left|\underset{\sim}{F}\right| \cos(\theta)\, \underset{\sim}{i} + \left|\underset{\sim}{F}\right| \sin(\theta)\, \underset{\sim}{j}$

      (resolution of forces into horizontal and vertical components)

- Forces in equilibrium – resultant force is zero
    - $\underset{\sim}{F_1} + \underset{\sim}{F_2} + \underset{\sim}{F_3} = 0$
- Remember –
    - 1 N = 1 kg m/s^2
    - 9.8 N = 1 kg weight
    - $\underset{\sim}{g}$ = gravitational acceleration usually assumed to be 9.8 ms^{-2} in specialist maths
    - Weight, $\underset{\sim}{W} = m\underset{\sim}{g}$ (measured in newtons)

Review Questions

1. For the three forces $\underset{\sim}{F_1} = 2\underset{\sim}{i} - \underset{\sim}{j}$, $\underset{\sim}{F_2} = 3\underset{\sim}{i} + 2\underset{\sim}{j}$ and $\underset{\sim}{F_3} = -\underset{\sim}{i} + 3\underset{\sim}{j}$, find:

a. the resultant force $\underset{\sim}{R}$

b. the magnitude of the resultant force.

2.

a. A particle of mass 3 kg moving with a velocity of 3 m/s collides into a wall and rebounds with a speed of 2 m/s in the opposite direction. Find the change in momentum of the mass.

b. A 'very fast' elephant of mass 900 kg accelerates down a straight from a speed of 30 km/h to a speed of 60 km/h in 5 seconds. Find the change in momentum of the elephant.

Statics – Newton's laws of motion

As it appears in Unit 4

- First law of motion - The Law of Inertia

  An object will maintain its state of constant velocity motion or rest unless acted upon by a resultant force that is not in equilibrium.

- Uniform rectilinear motion – velocity is constant
- Constant velocity – zero acceleration and zero resultant force.
- Second law of motion - The Law of acceleration

  When the resultant force is non-zero, it will be equivalent to an object's mass times its acceleration. ($R = ma$)

- Third law of motion - The Law of action and reaction

  For every action there is an equal and opposite reaction

Review Questions

3. A Net force of 20 N acts on a mass of 3 kg, which is initially at rest. Find:

a. the magnitude of the acceleration

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Solutions to Review Questions

1.

a. $\underset{\sim}{R} = \underset{\sim}{F}_1 + \underset{\sim}{F}_2 + \underset{\sim}{F}_3$

$= 2\underset{\sim}{i} - \underset{\sim}{j} + 3\underset{\sim}{i} + 2\underset{\sim}{j} - \underset{\sim}{i} + 3\underset{\sim}{j} = 4\underset{\sim}{i} + 4\underset{\sim}{j}$

b. $\left|\underset{\sim}{R}\right| = \sqrt{4^2 + 4^2}$

$= \sqrt{32}$

$= 4\sqrt{2}$

2.

a. $\Delta \underset{\sim}{p} = m\underset{\sim}{v} - m\underset{\sim}{u} = 3 \times 2 - 3 \times (-3) = 6 + 9$

$= 15$ kg m/s

b. 30 km/h = 30 ÷ 3.6 = $\frac{50}{6}$ m/s

60 km/h = 60 ÷ 3.6 = $\frac{50}{3}$ m/s

$\Delta p = mv - mu = m(v - u)$

$= 900\left(\frac{50}{3} - \frac{50}{6}\right) = 7500$ kg m/s

3.

a. $\underset{\sim}{R} = ma\underset{\sim}{i}$

$20\underset{\sim}{i} = 3a\underset{\sim}{i}$

$a = \frac{20}{3}$ m/s^2

b. $u = 0,\ a = \frac{20}{3},\ t = 4$

$v = u + at$

$= 0 + \frac{20}{3} \times 4$

$= \frac{80}{3}$

$= 26\frac{2}{3}$ m/s

c. $s = ut + \frac{1}{2}at^2$

$= 0(4) + \frac{1}{2} \times \frac{20}{3} \times 4^2$

$= \frac{320}{6}$

$= 53\frac{1}{3}\text{m}$