Laws of Motion

CONCEPTS

C1 NEWTON'S FIRST LAW

When no net external force acts on a body, its motion does not change, that means the body is either at rest or moving with constant velocity.

SIGNIFICANCE OF THIS LAW

(i) This law defines the concept of equilibrium : $\sum \vec{F} = 0$ or $\sum F_x = 0, \sum F_y = 0$

(ii) This law is known as law of inertia. The inertial properties of a body is characterized by its mass.

(iii) Inertial frame of reference are those in which Newton's first law is valid.

C2 NEWTON'S SECOND LAW

The acceleration of a body under the action of a given set of forces is directly properties to the vector sum of the forces (the net force) and inversely proportional to the mass of the body. This relationship is Newton's second law : $\sum \vec{F} = m\vec{a}$

C3 NEWTON'S THIRD LAW

Newton's third law states that "action equals reaction"; when two bodies interact, they exert forces on each other that are equal in magnitude and opposite in direction. Each force in an action-reaction pair acts on only one of the two bodies; the action and reaction forces never act on the same body. Newtons third law is needed in equilibrium problems.

C4 APPLICATION OF NEWTON'S LAW

PROBLEM SOLVING STRATEGY

1. Identify one or more bodies to which Newton's laws will be applied.
2. Draw the free body diagram for each body. Free body diagram is the pictorial representation of all the forces acting on the body.
3. Resolve all the forces (if possible) into components in the direction of acceleration and perpendicular to it. If the body is in equilibrium then resolve the forces into components in any two mutually perpendicular direction.
4. Write the equations according to Newton's Law and solve the equations to find the required unknown

Practice Problems :

1. A particle of mass m moving with speed u along a straight line path is stopped by a constant force F. In this process the particle moves a distance

(a) $\frac{mu^2}{2F}$ (b) $\frac{mu^2}{F}$ (c) $\frac{2mu^2}{F}$ (d) $\frac{mu^2}{4F}$

2. A man is standing on a weighing machine placed in a lift. When stationary, his mass is m. Then choose the incorrect statement

(a) If the lift moves with constant velocity then machine record the weight mg.

(b) If the lift moves upward with constant acceleration *a* then machine records the weight m(g + a).

(c) If the lift moves downwards with constant acceleration *a* then machine records the weight m(g – a).

(d) If the lift moves upwards with constant retardation *a* then machine records the weight m(g + a).

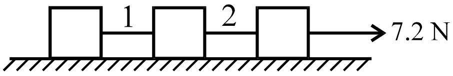
3. A uniform rope of length *l* is pulled by a constant force F applied at one of the end. The tension in the rope at a distance x from the end where the force is applied as

(a) F (b) $F\left(1+\frac{x}{l}\right)$ (c) $F\frac{x}{l}$ (d) $F\left(1-\frac{x}{l}\right)$

4. **A block of mass M is pulled along a horizontal frictionless surface by a rope of mass m by applying a force P at one end of the rope. The force exerted by the rope on the block is**

(a) $\frac{PM}{M-m}$ **(b)** $\frac{PM}{M+m}$ **(c)** $\frac{Pm}{M+m}$ **(d)** $\frac{Pm}{M-m}$

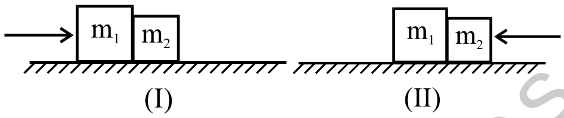
5. **Three blocks each of mass 0.6 kg are connected by two strings as shown in figure**



The horizontal surface is smooth and a force of 7.2 N is applied. The tension in the string 1 is

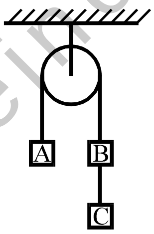
(a) **1.2 N** **(b)** **2.4 N** **(c)** **3.6 N** **(d)** **7.2 N**

6. **Two blocks A and B, having masses m_1 and m_2 respectively, are placed in contact on a smooth horizontal suface. A force F is applied horizontally on A as shown in figure (I). Let the contact force between A and B is F_1. Now the same force is applied horizontally on B as shown in figure (II). Let the contact force between them is F_2 in this case. Then F_1/F_2 equals to**



(a) **1 : 1** **(b)** $\frac{m_2}{m_1}$ **(c)** $\frac{m_1}{m_2}$ **(d)** $\frac{m_2}{m_1+m_2}$

7. **Three blocks A, B and C, each of mass m, are hanging over a fixed pulley as shown in figure. The tension in the string connecting B and C is**



(a) **zero** **(b)** **mg/3** **(c)** **2mg/3** **(d)** **mg**

8. **In the pervious problem the force exerted by the string connected to the ceiling on the pulley is**

(a) **zero** **(b)** **mg/3** **(c)** **2mg/3** **(d)** **8mg/3**

[Answers : (1) a (2) d (3) d (4) b (5) b (6) b (7) c (8) d]

C5 <u>FRICTION</u>

When a force **F** attempts to slide a body along a surface, a **frictional force** is exerted on the body by the surface. The frictional force is parallel to the surface and directed so at to oppose the sliding. It is due to bonding between the body and the surface.

If the body does not slide, the frictional force is a **static frictional force f_s**. If there is sliding, the frictional force is a **kinetic frictional force f_k**.

Properties of friction

Property 1. If the body does not move, then the static frictional force $\mathbf{f_s}$ and the component of **F** that is parallel to the surface are equal in magnitude, and $\mathbf{f_s}$ is directed opposite that components. If that parallel component increases, $\mathbf{f_s}$ also increases.

Property 2. The magnitude of $\mathbf{f_s}$ has a maximum $f_{s,max}$ that is given by

$$f_{s,max} = \mu_s N,$$

where μ_s is the **coefficient of static friction** and N is the magnitude of the normal force. If the component of

F that is parallel to the surface exceeds $f_{s,max}$, then the body slides on the surface.

Property 3. If the body begins to slide along the surface, the magnitude of the frictional force rapidly decreases to a constant value f_k given by

<u>Practice Problems :</u>

1. A block of mass 2 kg rests on a rough inclined plane making an angle of 30^0 with the horizontal. The coefficient of static friction between the block and the plane is 0.7. The frictional force on the block is

(a) 9.8 N **(b) 0.7 × 9.8 N**

(c) 9.8 × √3 N **(d) 0.7 × 9.8 × √3 N**

2. A block of weight 5N is pushed against a wall by a force of 12N. The coefficient of friction between the wall and the block is 0.6. The magnitude of the force exerted by the wall on the block is

(a) 5 N **(b) 12 N** **(c) 13 N** **(d) 15.6 N**

3. A body takes n times as much time to slide down at 45^0 rough incline as it takes to slide down a smooth 45^0 incline. The coefficient of friction is

(a) $1-\frac{1}{n^2}$ **(b)** $\frac{1}{1-n^2}$ **(c)** $\sqrt{1-\frac{1}{n^2}}$ **(d)** $\frac{1}{\sqrt{1-n^2}}$

4. A block placed on an inclined plane of slope angle θ slides down with a constant speed. The coefficient of kinetic friction is equal to

(a) sin θ **(b) cos θ** **(c) tan θ** **(d) cot θ**

[Answers : (1) a (2) c (3) a (4) c]