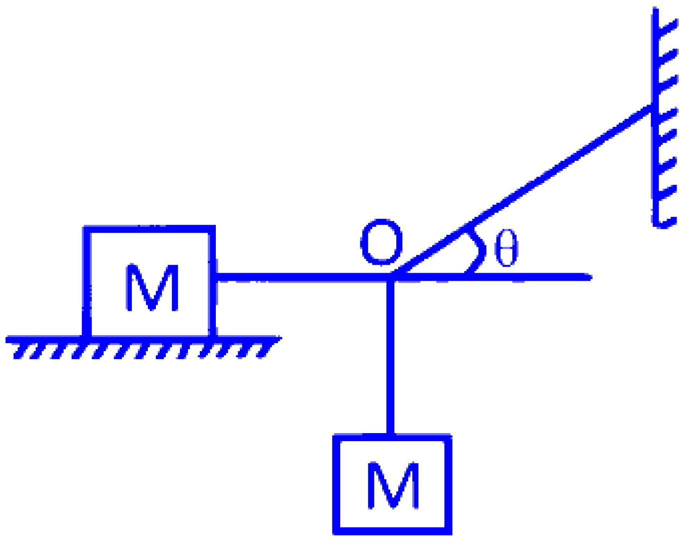
Laws of Motion

Question1

A wooden block of mass M lies on a rough floor. Another wooden block of the same mass is hanging from the point O through strings as shown in the figure. To achieve equilibrium, the co-efficient of static friction between the block on the floor with the floor itself is



KCET 2025

Options:

A. $\mu = \cot\theta$

B. $\mu = \sin\theta$

C. $\mu = \tan\theta$

D. $\mu = \cos\theta$

Answer: A

Solution:

A wooden block of mass M rests on a rough floor, while another block of the same mass is suspended from a point O by strings. To maintain equilibrium, we need to determine the coefficient of static friction between the block on the floor and the floor itself.

From the figure and given conditions, we can use the following equations for equilibrium:

The vertical component of tension:

$T \sin \theta = Mg \quad \ldots (i)$

This equation accounts for the vertical force balance, where T is the tension in the string, and θ is the angle made by the string with the vertical.

The horizontal component of tension:

$T \cos \theta = \mu Mg \quad \ldots (ii)$

Here, μ represents the coefficient of static friction.

To find μ, divide equation (ii) by equation (i):

$\frac{T \cos \theta}{T \sin \theta} = \frac{\mu Mg}{Mg}$

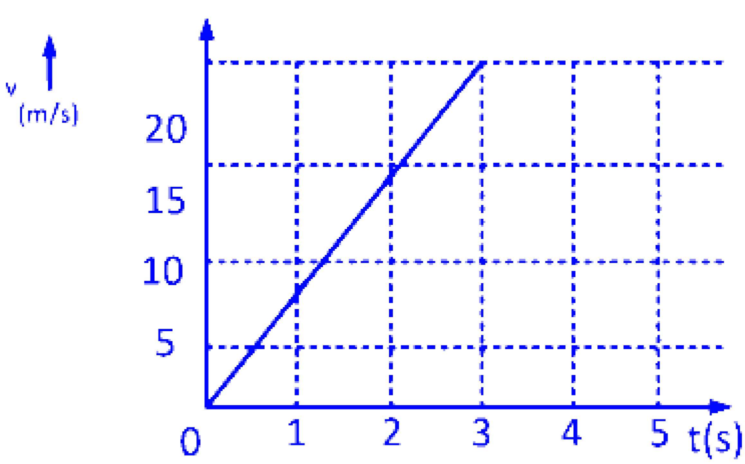
$\cot \theta = \mu$

Therefore, the coefficient of static friction is:

$\mu = \cot \theta$

Question2

A block of certain mass is placed on a rough floor. The coefficients of static and kinetic friction between the block and the floor are 0.4 and 0.25 respectively. A constant horizontal force $\mathrm{F} = 20 \mathrm{~N}$ acts on it so that the velocity of the block varies with time according to the following graph. The mass of the block is nearly (Take $\mathrm{g} \simeq 10 \mathrm{~ms}^{-2}$)



KCET 2025

Options:

A. 4.4 kg

B. 1.2 kg

C. 1.0 kg

D. 2.2 kg

Answer: D

Solution:

To determine the mass of the block, consider the following analysis using the given data:

Friction: Since the block is moving, we deal with kinetic friction in this scenario.

Acceleration Calculation:

$a = \frac{v-u}{t} = \frac{20-0}{3} = \frac{20}{3}\ \text{m/s}^2$

Here, v is the final velocity, u is the initial velocity, and t is the time.

Net Force Calculation:

The net force acting on the block can be expressed as:

$F - f_k = m \times a$

where $F = 20\,\text{N}$ is the applied force and f_k is the force due to kinetic friction.

Kinetic Friction Force:

$f_k = \text{coefficient of kinetic friction} \times \text{normal force} = 0.25 \times m \times g$

Using the Net Force Equation:

Substitute the values into the equation:

$20 - 0.25 \times m \times 10 = m \times \frac{20}{3}$

Solving for m:

$20 - 2.5m = \frac{20}{3}m$

Rearranging the terms gives:

$20 = \frac{20}{3}m + 2.5m$

Combine the terms:

$20 = \left(\frac{20+7.5}{3}\right)m$

$20 = \frac{27.5}{3}m$

Simplifying the equation:

$m = \frac{20\times3}{27.5}$

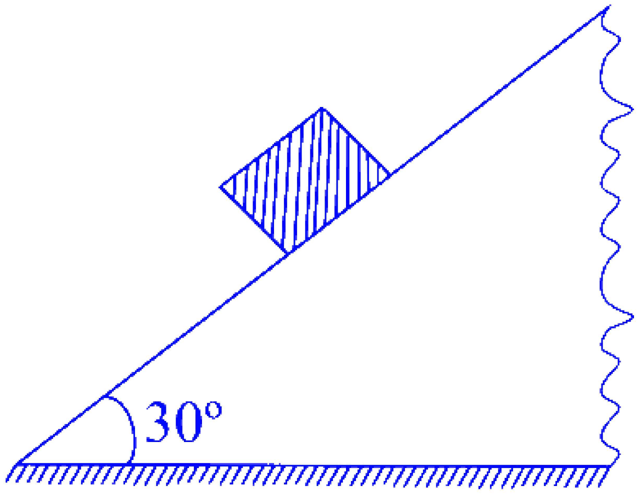
Therefore,

$m \approx 2.2\,\text{kg}$

Thus, the mass of the block is approximately 2.2 kg.

Question3

A block of certain mass is placed on a rough inclined plane. The angle between the plane and the horizontal is 30°. The coefficients of static and kinetic frictions between the block and the inclined plane are 0.6 and 0.5 respectively. Then, the magnitude of the acceleration of the block is [Take g = 10 ms^{-2}]



KCET 2024

Options:

A. 2 ms^{-2}

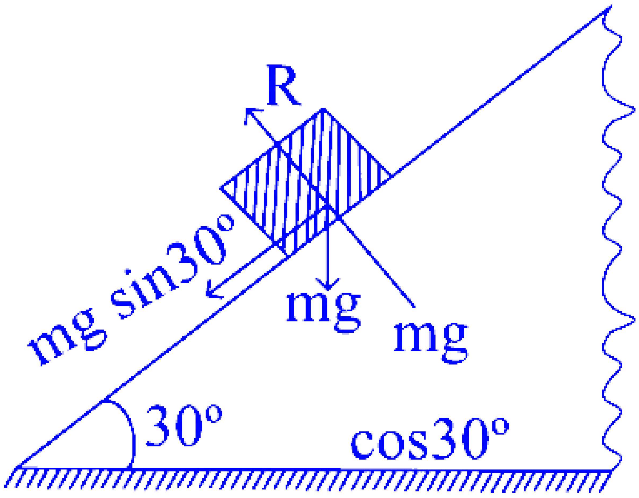
B. zero

C. 0.196 ms^{-2}

D. 0.67 ms^{-2}

Answer: B

Solution:



From the diagram, frictional force

$f_s = \mu R = \mu mg \cos 30^\circ$

$= 0.6 \times \text{mg} \times \frac{\sqrt{3}}{2}$

$= 0.3\sqrt{3}\text{mg} = 0.5196\text{mg}$

Magnitude of force pulling the block along the plane downward,

$F' = mg \sin 30^\circ = mg/2 = 0.5mg$

Since, $\quad f_s > F'$

Hence, block will not move.

$\therefore \quad a = 0$

Question4

A body of mass 10 kg is kept on a horizontal surface. The coefficient of kinetic friction between the body and the surface is 0.5. A

horizontal force of 60 N is applied on the body. The resulting acceleration of the body is about

KCET 2023

Options:

A. 1 ms^{-2}

B. 5 ms^{-2}

C. 6 ms^{-2}

D. zero

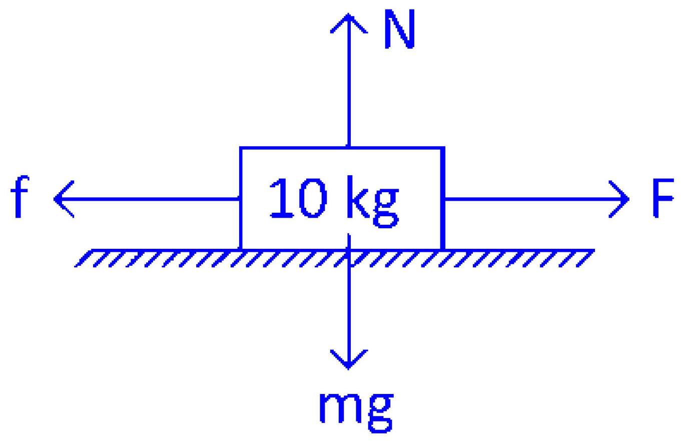
Answer: A

Solution:

Given, mass of the body, $m = 10$ kg

Coefficient of kinetic friction, $\mu_k = 0.5$

Force applied in horizontal direction, $F = 60$ N

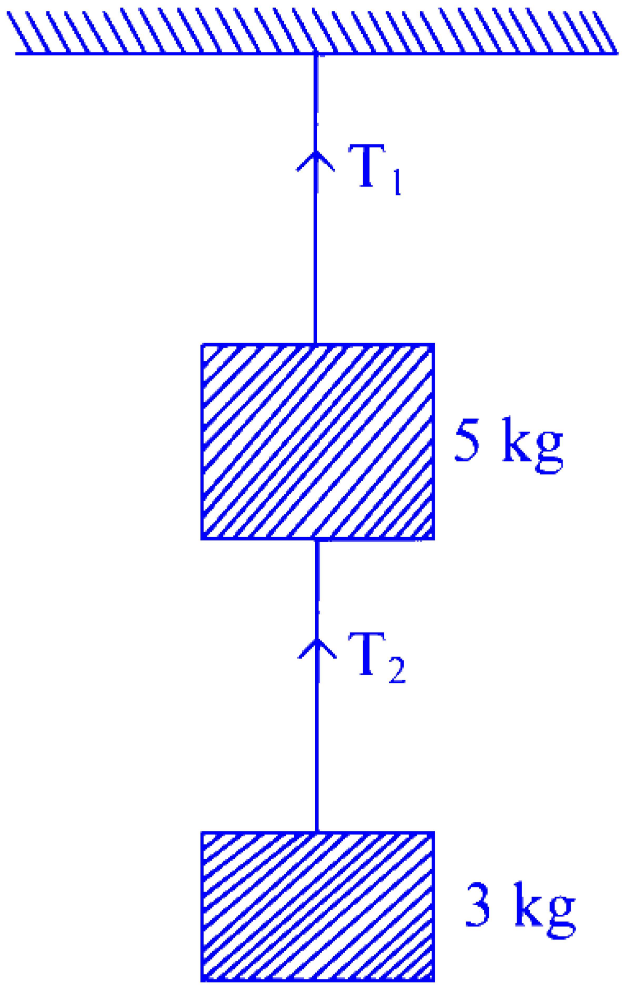


Let f be the frictional force on the body.

$$\text{Thus,} \quad ma = F - \mu mg$$
$$= 60 - 10 \times (10)(0.5) = 60 - 50$$
$$\Rightarrow 10 \times a = 10 \Rightarrow a = 1 \text{ m/s}^2$$

Question5

Two masses of $5 \mathrm{~kg}$ and $3 \mathrm{~kg}$ are suspended with the help of massless inextensible strings as shown in figure below.



When whole system is going upwards with acceleration $2 \mathrm{~m} / \mathrm{s}^2$, the value of T_1 is (use, $g=9.8 \mathrm{~m} / \mathrm{s}^2$)

KCET 2022

Options:

A. 35.4 N

B. 23.6 N

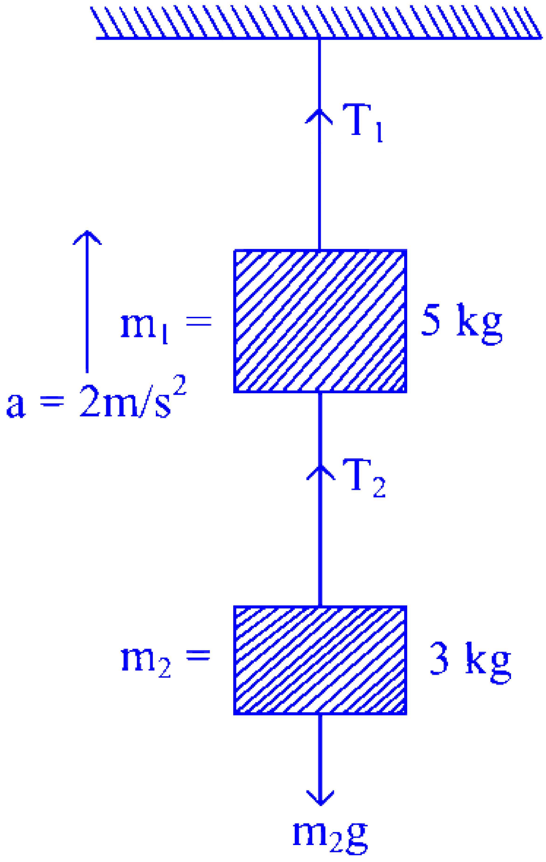
C. 59 N

D. 94.4 N

Answer: D

Solution:

The given situation is shown below



Equation of motion for body m_2,

$$T_2 - m_2 g = m_2 a$$
$$T_2 - 3g = 3 \times 2$$
$$T_2 = 3g + 6 = 3 \times 9.8 + 6 = 35.4 \text{ N}$$

Equation of motion of mass of 5 kg,

$$T_1 - T_2 - m_1 g = m_1 a$$
$$\Rightarrow \quad T_1 - 35.4 - 5 \times 9.8 = 5 \times 2$$
$$\Rightarrow \quad T_1 - 84.4 = 10$$
$$\Rightarrow \quad T_1 = 10 + 84.4 = 94.4 \text{ N}$$

Question6

An object with mass 5 kg is acted upon by a force, $\mathbf{F} = (-3\hat{\mathbf{i}} - 4\hat{\mathbf{j}})\text{N}$. If its initial velocity at $t = 0$ is $\mathbf{v} = (3\hat{\mathbf{i}} + 12\hat{\mathbf{j}})\text{m/s}$, the time at which it will just have a velocity along y-axis is -

KCET 2019

Options:

A. 5 s

B. 10 s

C. 2 s

D. 15 s

Answer: A

Solution:

To determine the time at which the object has a velocity only along the y-axis, we need to find when the x-component of the velocity becomes zero. The force acting on the object will change its velocity over time according to Newton's second law.

Given:

Mass of the object, $m = 5 \, \text{kg}$

Force, $\mathbf{F} = (-3\hat{\mathbf{i}} - 4\hat{\mathbf{j}}) \, \text{N}$

Initial velocity, $\mathbf{v}_0 = (3\hat{\mathbf{i}} + 12\hat{\mathbf{j}}) \, \text{m/s}$

The acceleration $\mathbf{a}$ can be found using $\mathbf{F} = m\mathbf{a}$:

$\mathbf{a} = \frac{\mathbf{F}}{m} = \frac{-3\hat{\mathbf{i}} - 4\hat{\mathbf{j}}}{5} = \left(-0.6\hat{\mathbf{i}} - 0.8\hat{\mathbf{j}}\right) \, \text{m/s}^2$

The velocity at time t is given by:

$\mathbf{v}(t) = \mathbf{v}_0 + \mathbf{a}t = (3\hat{\mathbf{i}} + 12\hat{\mathbf{j}}) + (-0.6\hat{\mathbf{i}} - 0.8\hat{\mathbf{j}})t$

Simplifying gives:

$\mathbf{v}(t) = (3 - 0.6t)\hat{\mathbf{i}} + (12 - 0.8t)\hat{\mathbf{j}}$

For the velocity to be only along the y-axis, the x-component of the velocity must be zero:

$3 - 0.6t = 0$

Solving for t:

$0.6t = 3t = \frac{3}{0.6} = 5\,\mathrm{s}$

Thus, the time at which the object will have a velocity only along the y-axis is **5 seconds**. The correct answer is **Option A: 5 s**.

Question7

A block rests on a rough inclined plane making an angle of 30° with the horizontal, The coefficient of static friction between the block and the plane is 0.8 . If the frictional force on the block is 10 N , the mass of the block is (Take $g = 10\ \mathrm{ms}^{-2}$)

KCET 2018

Options:

A. 1 kg

B. 2 kg

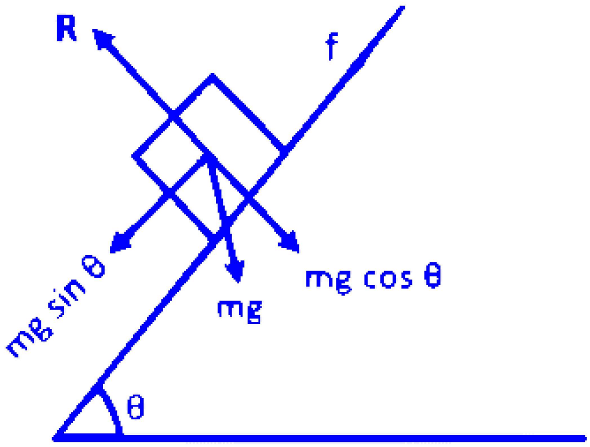
C. 3 kg

D. 4 kg

Answer: B

Solution:

When a block is at rest on a rough inclined plane, several forces act on it: gravity, normal force, and friction.



Normal Force and Friction: The normal force R is given by the component of the gravitational force perpendicular to the incline, which can be expressed as $R = mg\cos\theta$.

Frictional Force: Given that the block is at rest, the frictional force f_r is balancing out the component of gravity acting down the slope. This frictional force is 10 N as provided.

Equilibrium Condition: Since the block is stationary, the frictional force equals the gravitational force component parallel to the incline:

$f_r = mg\sin\theta$

Given:

$f_r = 10\,\mathrm{N}, \quad \theta = 30^\circ, \quad \text{and } g = 10\,\mathrm{m/s}^2$

Calculating Mass:

$10 = m \times 10 \times \sin 30^\circ$

$\sin 30^\circ = 0.5$

$10 = m \times 10 \times 0.5$

$m = \frac{10}{5} = 2\,\mathrm{kg}$

Thus, the mass of the block is 2 kg.

Question8

A man weighing 60 kg is in a lift moving down with an acceleration of $1.8\ \mathrm{ms}^{-2}$. The force exerted by the floor on him is

KCET 2018

Options:

A. 588 N

B. 480 N

C. zero

D. 696 N

Answer: B

Solution:

To find the force exerted by the floor (the normal force N) on the man:

Define directions:

Let downward be positive (since the acceleration is downward).

Write the net force equation:

The forces acting on the man are:

Weight (downward), $W = mg$

Normal force (upward), N

Since the acceleration a is downward, the net force in the downward direction is

Net force $= ma$.

Set up the equation:

$$\underbrace{mg}_{\text{downward}} - \underbrace{N}_{\text{upward}} = ma.$$

Solve for N:

$$mg - N = ma \quad \Rightarrow \quad N = mg - ma = m(g - a).$$

Plug in values:

$$m = 60\,\text{kg}, \quad g \approx 9.8\,\text{m/s}^2, \quad a = 1.8\,\text{m/s}^2.$$

$$N = 60 \times (9.8 - 1.8) = 60 \times 8.0 = 480\,\text{N}.$$

Therefore, the force exerted by the floor on the man is $480\,\text{N}$.

Answer: 480 N (Option B).

Question9

A body of the mass 50 kg is suspended using a spring balance inside a lift at rest. If the lift starts falling freely, the reading of the spring balance is

KCET 2017

Options:

A. < 50 kg

B. $= 50$ kg

C.

> 50 kg

D. =0$

Answer: D

Solution:

Given:

Mass of the body, $m = 50\,\text{kg}$

When the lift is moving downward, the scale reading is calculated as:

Scale reading $= \frac{m(g-a)}{g}$

If the lift starts falling freely, then the acceleration a equals gravitational acceleration g. So, we have:

$a = g$

Substituting $a = g$ into the scale reading formula, we get:

Scale reading $= \frac{m(g-g)}{g} = 0$

Thus, when the lift is in free fall, the spring balance will read 0.
