NEET QUESTIONS

LAWS OF MOTION

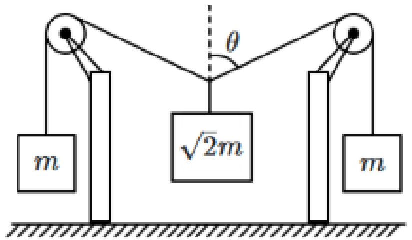
Q1: Fundamentally, the normal force between two surfaces in contact is:

1. Electromagnetic
2. Gravitational
3. Weak nuclear force
4. Strong nuclear force

1. **What the normal force is:**
   In mechanics the "normal reaction" is the macroscopic contact force that prevents interpenetration of two bodies at their interface.
2. **Zoom to the microscopic origin:**
   At the contact, outer-shell electrons of atoms in the two surfaces approach angstrom (10^{-10} m) separations. The dominant interactions at this scale are **electromagnetic**:
   - **Coulomb repulsion** between overlapping electron clouds.
   - **Pauli exclusion–driven** increase in electronic energy when wavefunctions overlap, which manifests as an effective short-range repulsion; this effect is still rooted in electromagnetism because it concerns electrons in electromagnetic atomic orbitals.
3. **Why not gravitational:**
   Gravity between individual atoms is ~10^{39} times weaker than the electromagnetic interaction, so it cannot account for the sizable contact forces observed.
4. **Why not weak or strong nuclear forces:**
   - **Strong force** acts among quarks/nucleons with range $\sim 10^{-15}$ m (femtometers), far shorter than interatomic spacings; it does not mediate forces between neutral solids.
   - **Weak force** governs processes like beta decay, not mechanical contact.

Therefore, the normal force is emergent from interatomic electromagnetic interactions.

Q2: The pulleys and strings shown in the figure are smooth and of negligible mass. For the system to remain in equilibrium, the angle θ should be:



1. 0°
2. 30°
3. 45°
4. 60°

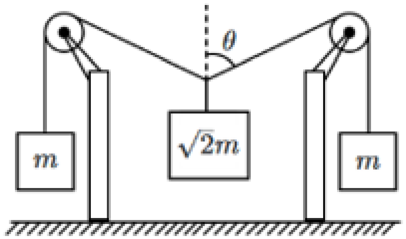
Step 1: Identify forces

- On the **left and right sides**, masses m hang → each provides tension

$$T = mg$$

- On the **middle block** of mass $\sqrt{2}m$:
  - Downward force: $W = \sqrt{2}mg$
  - Upward support from two identical tensions T, each making an angle θ with the vertical.

Step 2: Vertical equilibrium condition



The **vertical components** of the two tensions balance the weight:

$$2T\cos\theta = \sqrt{2}mg$$

Substitute $T = mg$:

$$2(mg)\cos\theta = \sqrt{2}mg$$

Cancel mg (nonzero):

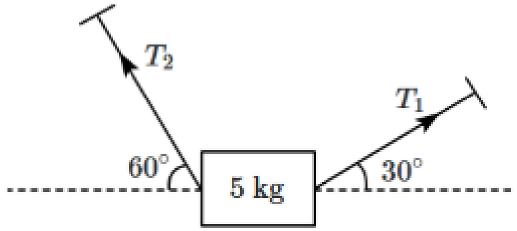
$$2\cos\theta = \sqrt{2}$$

$$\cos\theta = \frac{1}{\sqrt{2}}$$

Step 3: Solve for θ

$$\theta = 45^\circ$$

Q3: A body of mass 5 kg is suspended by the strings making angles 60° and 30° with the horizontal.



Then:

(A)	$T_1 = 25$ N
(B)	$T_2 = 25$ N
(C)	$T_1 = 25\sqrt{3}$ N
(D)	$T_2 = 25\sqrt{3}$ N

Choose the correct option from the given ones:

1.	(A), (B), and (C) only
2.	(A) and (B) only
3.	(A) and (D) only
4.	(A), (B), (C), (D)

Given. A body of mass $5\ \mathrm{kg}$ is held in equilibrium by two strings which make angles 60° and 30° with the horizontal (left string: 60°, right string: 30°). Tensions are T_2 (left) and T_1 (right). Assume $g = 10\ \mathrm{m/s^2}$ (this choice is required to match the numerical options).

Thus the weight is

$$W = mg = 5 \times 10 = 50\ \mathrm{N}.$$

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1. Free-body force components

Resolve each tension into horizontal and vertical components (angles measured from horizontal):

- Right string T_1: horizontal component $T_1 \cos 30^\circ$ (to the right), vertical component $T_1 \sin 30^\circ$ (upwards).
- Left string T_2: horizontal component $T_2 \cos 60^\circ$ (to the left), vertical component $T_2 \sin 60^\circ$ (upwards).

Equilibrium requires net horizontal and vertical forces to vanish.

2. Horizontal equilibrium

$$T_1 \cos 30^\circ = T_2 \cos 60^\circ.$$

Using $\cos 30^\circ = \frac{\sqrt{3}}{2}$ and $\cos 60^\circ = \frac{1}{2}$,

$$T_1 \frac{\sqrt{3}}{2} = T_2 \frac{1}{2} \quad \Rightarrow \quad T_2 = \sqrt{3}\, T_1. \qquad (1)$$

3. Vertical equilibrium

$$T_1 \sin 30^\circ + T_2 \sin 60^\circ = W.$$

Using $\sin 30^\circ = \frac{1}{2}$, $\sin 60^\circ = \frac{\sqrt{3}}{2}$ and substituting (1),

$$\frac{T_1}{2} + \frac{(\sqrt{3}\, T_1)\sqrt{3}}{2} = 50 \quad \Rightarrow \quad \frac{T_1}{2} + \frac{3T_1}{2} = 50$$

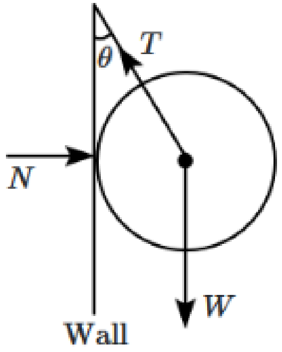
$$\Rightarrow 2T_1 = 50 \quad \Rightarrow \quad T_1 = 25 \text{ N}.$$

Then from (1):

$$T_2 = \sqrt{3} \cdot 25 = 25\sqrt{3} \text{ N}.$$

- (A) $T_1 = 25$ N — true.
- (B) $T_2 = 25$ N — false ($T_2 = 25\sqrt{3}$).
- (C) $T_1 = 25\sqrt{3}$ N — false ($T_1 = 25$).
- (D) $T_2 = 25\sqrt{3}$ N — true.

Q4: A metal sphere is suspended from a wall by a string. The forces acting on the sphere are shown in the figure. Which of the following statements is NOT correct?



1.	$\vec{N}+\vec{T}+\vec{W}=0$	2.	$T^2=N^2+W^2$
3.	$T=N+W$	4.	$N=W\tan\theta$

Step 1: Force balance equations

For equilibrium,

$$\vec{N} + \vec{T} + \vec{W} = 0.$$

This is always true (Newton's first law in vector form).

Now resolve components:

- **Along horizontal (x):**

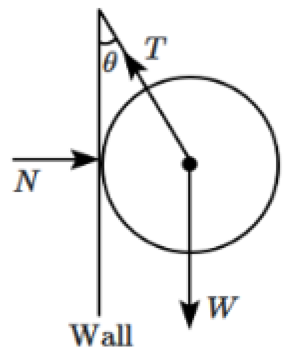
$$T \sin\theta = N.$$

- **Along vertical (y):**

$$T \cos\theta = W.$$

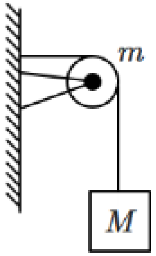
Step 2: Relations

1. From equilibrium:
   $\vec{N} + \vec{T} + \vec{W} = 0.$ ✅ Correct.
2. Square both equations and add:
   $(T \sin\theta)^2 + (T \cos\theta)^2 = N^2 + W^2.$
   $\Rightarrow T^2 = N^2 + W^2.$ ✅ Correct.
3. The option "$T = N + W$" implies **scalar addition**. But in reality, T is the vector sum of N and W:
   $\vec{T} = -(\vec{N} + \vec{W}).$
   Its magnitude is not simply $N + W$ (except in trivial case $\theta = 45^\circ$ with special values). So ❌ this is **NOT correct.**
4. From dividing the two equations:
   $\dfrac{N}{W} = \dfrac{T \sin\theta}{T \cos\theta} = \tan\theta.$
   So $N = W \tan\theta.$ ✅ Correct.



1.	$\overrightarrow{N} + \overrightarrow{T} + \overrightarrow{W} = 0$	2.	$T^2 = N^2 + W^2$
3.	$T = N + W$	4.	$N = W \tan\theta$

Q6: A string of negligible mass going over a clamped pulley of mass m supports a block of mass M as shown in the figure. The force on the pulley by the clamp is given by:



1. $\sqrt{2}Mg$
2. $\sqrt{2}mg$
3. $g\sqrt{(M+m)^2+m^2}$
4. $g\sqrt{(M+m)^2+M^2}$

Step 1. Forces acting on the pulley

The pulley is fixed (clamped), so the clamp provides a reaction force to balance:

1. The pulley's own weight: mg downward.
2. Two tensions from the string:
   - One vertical downward (supporting block M), magnitude T.
   - One horizontal (anchored end of string), also magnitude T.

Thus the pulley is acted on by three external forces:

- mg vertically downward.
- T vertically downward.
- T horizontally toward the wall.

Step 2. Value of tension in string

The block of mass M is in equilibrium (system is stationary).

For block: $T = Mg$.

Step 3. Net force on pulley

Now the pulley experiences:

- Horizontal force = $T = Mg$.
- Vertical force = $mg + T = mg + Mg$.

So the resultant force (which clamp must balance) is:

$$F = \sqrt{(Mg)^2 + (mg + Mg)^2}.$$

Step 4. Simplify

$$F = g\sqrt{M^2 + (M + m)^2}.$$

Step 5. Match with options

Option (4):

$$g\sqrt{(M + m)^2 + M^2}$$

is exactly what we obtained.

Q7: Choose the incorrect alternative:

1.	Newton's first law is the law of inertia.
2.	Newton's first law states that if the net force on a system is zero, the acceleration of any particle of the system is not zero.
3.	Action and reaction act simultaneously.
4.	The area under the force-time graph is equal to the change in momentum.

1. *Newton's first law is the law of inertia.*

✅ Correct. This is indeed the statement of Newton's first law.

2. *Newton's first law states that if the net force on a system is zero, the acceleration of any particle of the system is not zero.*

❌ Incorrect. Newton's first law actually states that if net external force is zero, a body continues in its state of rest or uniform motion (i.e., acceleration is zero). The given statement is the **opposite** of the law.

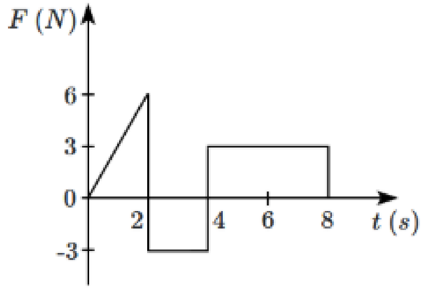
3. *Action and reaction act simultaneously.*

✅ Correct. Newton's third law states this precisely.

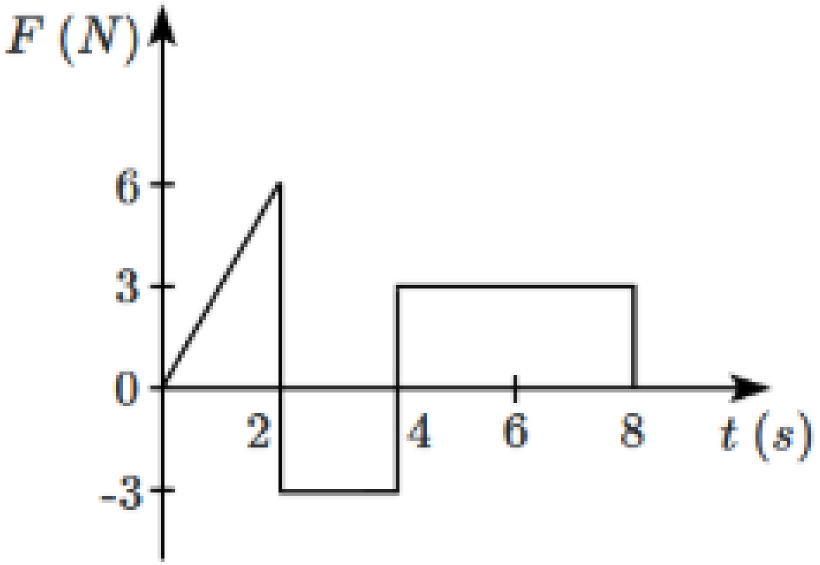
4. *The area under the force–time graph is equal to the change in momentum.*

✅ Correct. Since impulse = $\int F\,dt = \Delta p$.

Q8: The force F acting on a particle of mass m is indicated by the force-time graph shown below. The change in momentum of the particle over the time interval from 0 to 8 s is:



1. 24 N-s
2. 20 N-s
3. 12 N-s
4. 6 N-s



Change in momentum = impulse = area under the F–t graph (from $t = 0$ to 8 s).

Compute areas interval by interval (carefully, sign included):

1. $0 \leq t \leq 2$: triangular region rising from $F = 0$ to $F = 6$ N.
   Area $= \frac{1}{2} \times \text{base} \times \text{height} = \frac{1}{2} \times 2 \times 6 = 6$ N s.
2. $2 \leq t \leq 4$: rectangular region at $F = -3$ N.
   Area $= \text{base} \times \text{height} = 2 \times (-3) = -6$ N s.
3. $4 \leq t \leq 8$: rectangular region at $F = +3$ N.
   Area $= 4 \times 3 = 12$ N s.

Sum the contributions:

$$\Delta p = 6 + (-6) + 12 = 12 \text{ N s}.$$

Q9: On the application of an impulsive force, a sphere of mass **500 grams** starts moving with an acceleration of **10 m/s²**. The force acts on it for **0.5 s.** The gain in the momentum of the sphere will be:

1. 2.5 kg·m/s
2. 5 kg·m/s
3. 0.05 kg·m/s
4. 25 kg·m/s

Given data:

- Mass of sphere:

$$m = 500 \text{ g} = 0.5 \text{ kg}$$

- Acceleration:

$$a = 10 \text{ m/s}^2$$

- Time of action:

$$t = 0.5 \text{ s}$$

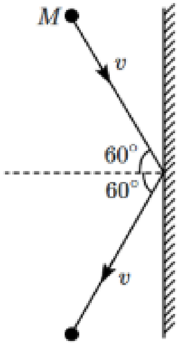
Step 1: Velocity gained

$$v = a \cdot t = 10 \times 0.5 = 5 \text{ m/s}$$

Step 2: Gain in momentum

$$\Delta p = mv = 0.5 \times 5 = 2.5 \text{ kg}\backslash\text{cdotpm/s}$$

Q10: A rigid ball of mass M strikes a rigid wall at 60° and gets reflected without loss of speed, as shown in the figure. The value of the impulse imparted by the wall on the ball will be:



1.	Mv	2.	$2Mv$
3.	$\frac{Mv}{2}$	4.	$\frac{Mv}{3}$

Answer: $J = Mv$

Why:

- Resolve the velocity into components **normal** ($\hat{n}$, perpendicular to wall) and **tangential** ($\hat{t}$, along the wall).
- Given "reflected without loss of speed" and a smooth rigid wall:
  - Tangential component stays the **same**.
  - Normal component **reverses** direction with the same magnitude.
- Before impact: $v_n = v\cos 60^\circ, \quad v_t = v\sin 60^\circ$.
- After impact: $v_n' = -v_n, \quad v_t' = v_t$.

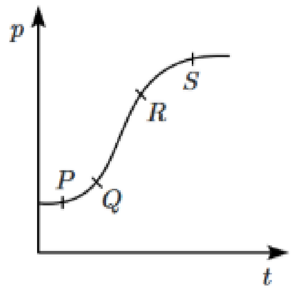
Impulse on the ball = change in momentum:

$$\vec{J} = \Delta\vec{p} = M(\vec{v}' - \vec{v}) = M\left[(v_n' - v_n)\hat{n} + (v_t' - v_t)\hat{t}\right] = M\left[(-v_n - v_n)\hat{n} + 0 \cdot \hat{t}\right] = -2Mv_n\hat{n}.$$

Magnitude:

$$|\vec{J}| = 2Mv_n = 2Mv\cos 60^\circ = 2Mv \cdot \tfrac{1}{2} = Mv.$$

Q11: The variation of momentum with the time of one of the bodies in a two-body collision is shown in fig. The instantaneous force is the maximum corresponding to the point:



1. P
2. Q
3. R
4. S

1. Instantaneous force on the body is $F = \frac{dp}{dt}$ (rate of change of momentum).
2. On a p vs t plot, $\frac{dp}{dt}$ is the slope of the tangent at a point.
3. The force is therefore largest where the tangent slope is steepest.
4. From the graph the steepest slope occurs at point R, so the instantaneous force is maximum there.

Q12:

A particle moves in the XY-plane under the action of a force F such that the components of its linear momentum p at any time t are

$$p_x = 2\cos t, \quad p_y = 2\sin t.$$

The angle between F and p at time t will be:

1. 90°
2. 0°
3. 180°
4. 30°

1. Momentum vector:

$$\mathbf{p}(t) = \big(2\cos t,\ 2\sin t\big).$$

2. Force is rate of change of momentum:

$$\mathbf{F}(t) = \frac{d\mathbf{p}}{dt} = \big(-2\sin t,\ 2\cos t\big).$$

3. Compute dot product $\mathbf{p}\cdot\mathbf{F}$:

$$\mathbf{p}\cdot\mathbf{F} = (2\cos t)(-2\sin t) + (2\sin t)(2\cos t) = -4\cos t\sin t + 4\sin t\cos t = 0.$$

4. Since the dot product is zero, $\mathbf{p}$ and $\mathbf{F}$ are perpendicular. Therefore the angle between them is 90°.

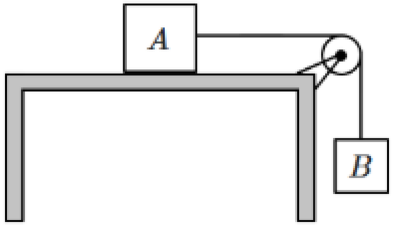
Answer: (1) 90°.

Q13:

A block A of mass $7\,\mathrm{kg}$ is placed on a frictionless table. A thread tied to it passes over a frictionless pulley and carries a body B of mass $3\,\mathrm{kg}$ at the other end. The acceleration of the system will be: (given $g = 10\,\mathrm{m/s^2}$)

Options:

1. $100\,\mathrm{m/s^2}$
2. $3\,\mathrm{m/s^2}$
3. $10\,\mathrm{m/s^2}$
4. $30\,\mathrm{m/s^2}$



Label masses: $m_A = 7\ \mathrm{kg}$ (on table), $m_B = 3\ \mathrm{kg}$ (hanging). Let acceleration magnitude be a. Take positive direction: A to the right, B downward. Tension in the string is T.

For block A (horizontal, no friction):

$$T = m_A a. \tag{1}$$

For block B (vertical):

$$m_B g - T = m_B a. \tag{2}$$

Add (1) and (2) to eliminate T:

$$m_B g = (m_A + m_B)\,a \quad \Rightarrow \quad a = \frac{m_B g}{m_A + m_B}.$$

Plug numbers ($g = 10\ \mathrm{m/s^2}$):

$$a = \frac{3 \times 10}{7 + 3} = \frac{30}{10} = 3\ \mathrm{m/s^2}.$$

Direction: B goes down, A moves right.

Answer: $3\ \mathrm{m/s^2}$ **(option 2).**

Q15: A simple pendulum hangs from the roof of a train moving on horizontal rails. If the string is inclined **towards the front** of the train, then the train is:

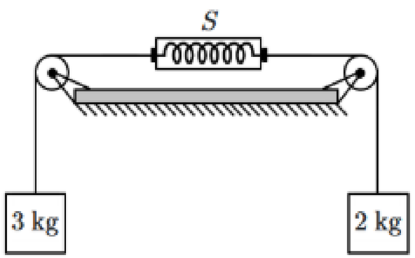
Options:

1. moving with constant velocity
2. in accelerated motion
3. in **retarded motion**
4. at rest

Step-by-step reasoning

1. Work in the train's (non-inertial) frame. If the train has acceleration $\vec{a}$ (forward defined as +), a pseudo-force $\vec{F}_{\text{pseudo}} = -m\vec{a}$ acts on the bob (i.e. opposite to the train's acceleration).
2. If the train is accelerating **forward** ($+a$), the pseudo-force points **backward**, so the bob is pulled back and the string tilts **toward the rear**.
3. The question states the string tilts **toward the front**. That can only happen if the pseudo-force points **forward** — which means the train's actual acceleration is **backward** (i.e. the train is slowing down).
4. Thus the train is in **retarded motion** (decelerating).
   (You can also use the equilibrium relation $\tan\theta = \frac{a_{\text{pseudo}}}{g} = \frac{a_{\text{train opposite}}}{g}$ to relate the tilt angle to the magnitude of deceleration.)

Q16: The strings and pulleys shown in the figure are massless. The reading shown by the light spring balance S is:



1.	2.4 kg	2.	5 kg
3.	2.5 kg	4.	3 kg

1. Because the string is continuous and the pulleys are frictionless and massless, the tension is the **same** everywhere in the string. Let that tension be T. The spring balance reads this tension; in weight units its reading (in kg) is T/g.
2. Let the heavier mass $m_1 = 3$ kg move downward and the lighter $m_2 = 2$ kg move upward with acceleration a. (Sign convention: downward for m_1 positive.)

   For m_1:

   $$m_1 g - T = m_1 a. \tag{1}$$

   For m_2:

   $$T - m_2 g = m_2 a. \tag{2}$$

3. Add (1) and (2) to eliminate T:

   $$m_1 g - m_2 g = (m_1 + m_2)\, a \quad \Rightarrow \quad a = \frac{(m_1 - m_2)g}{m_1 + m_2}.$$

4. Substitute this a into (1) to find T:

   $$T = m_1 g - m_1 a = m_1 g - m_1 \frac{(m_1 - m_2)g}{m_1 + m_2} = \frac{2m_1 m_2}{m_1 + m_2}\, g.$$

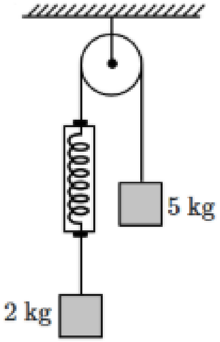
   (Alternatively you can substitute into (2) — same result.)
5. Put numbers $m_1 = 3,\ m_2 = 2,\ g = 10$:

   $$T = \frac{2 \times 3 \times 2}{3 + 2}\, g = \frac{12}{5}\, g.$$

   Thus the spring balance reading in *kgf* is

   $$\frac{T}{g} = \frac{12}{5} = 2.4\ \text{kg}.$$

Q17: In the given figure, the spring balance is massless, so the reading of the spring balance will be:



1.	2 kg	2.	3.5 kg
3.	2.9 kg	4.	3.1 kg

We have an Atwood's machine setup:

- One side has a $5\,\mathrm{kg}$ mass.
- Other side has a **spring balance** (massless) connected to a $2\,\mathrm{kg}$ mass.
- Pulley is frictionless and string massless.

  We need the reading of the spring balance (in kg units).

Step 1: System acceleration

Let's take downward direction as positive for the $5\,\mathrm{kg}$.

The two masses are $m_1 = 5\,\mathrm{kg}$ and $m_2 = 2\,\mathrm{kg}$.

Net force difference = $(m_1 - m_2)g = (5-2)g = 3g$.

Total mass = $m_1 + m_2 = 7$.

So acceleration:

$$a = \frac{(m_1 - m_2)g}{m_1 + m_2} = \frac{3g}{7}.$$

Step 2: Tension in the string

For the lighter mass (m_2), upward force is tension T, downward force is m_2g, acceleration is upward (since the heavier side goes down).

Equation:

$$T - m_2g = m_2a.$$

So:

$$T = m_2g + m_2a.$$

Substitute values ($m_2 = 2$, $g = 10$, $a = \frac{30}{7}$):

$$T = 2 \times 10 + 2 \times \frac{30}{7} = 20 + \frac{60}{7} = \frac{140 + 60}{7} = \frac{200}{7}.$$

$$T \approx 28.6\,\text{N}.$$

Step 3: Spring balance reading

The spring balance is in series with the $2\,\text{kg}$ mass.

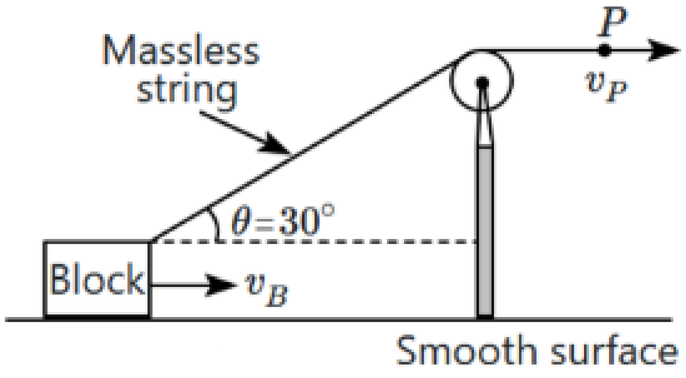
It measures the **tension** in the string.

So reading (in kgf units):

$$\frac{T}{g} \approx \frac{28.6}{10} \approx 2.86\,\text{kg}.$$

Closest option: **2.9 kg.** ✅

Q18: What is the velocity of the block when the angle between the string and the horizontal is 30° as shown in the diagram?



1. $v_B = v_P$
2. $v_B = \frac{v_P}{\sqrt{3}}$
3. $v_B = 2v_P$
4. $v_B = \frac{2v_P}{\sqrt{3}}$

1. Let the straight segment from the block to the pulley have length l_1. The horizontal segment from the pulley to point P has length l_2. Total string length $L = l_1 + l_2$ is constant, so

$$\dot{l}_1 + \dot{l}_2 = 0.$$

2. Let the horizontal distance between the block and the vertical through the pulley be s. The block moves horizontally so $\dot{s} = v_B$. The geometry of the triangle gives

$$l_1 = \sqrt{h^2 + s^2} \quad \text{and} \quad \cos\theta = \frac{s}{l_1},$$

where h is the fixed vertical height of the pulley above the block and θ is the angle the string makes with the horizontal.

3. Differentiate l_1:

$$\dot{l}_1 = \frac{s}{\sqrt{h^2 + s^2}}\,\dot{s} = \frac{s}{l_1}\,v_B = \cos\theta\,v_B.$$

4. The horizontal segment length changes at the speed of point P, so $\dot{l}_2 = v_P$.
5. Using $\dot{l}_1 + \dot{l}_2 = 0$ (length constant),

$$\cos\theta \, v_B + v_P = 0.$$

Taking magnitudes (directions set by the picture) gives

$$v_P = \cos\theta \, v_B \quad \Rightarrow \quad v_B = \frac{v_P}{\cos\theta}.$$

6. For $\theta = 30^\circ$, $\cos 30^\circ = \frac{\sqrt{3}}{2}$, so

$$v_B = \frac{v_P}{\sqrt{3}/2} = \frac{2}{\sqrt{3}} v_P.$$

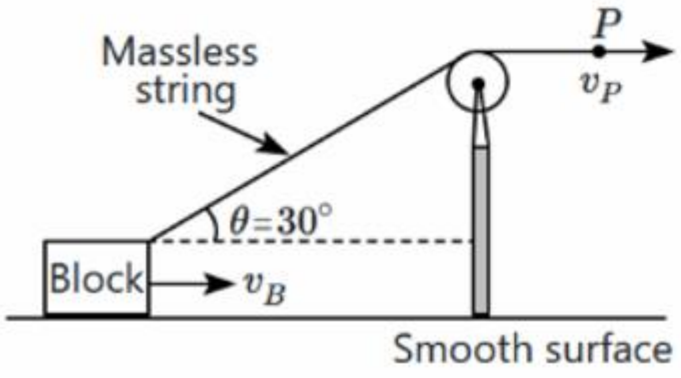
So the correct choice is
$v_B = \dfrac{2v_P}{\sqrt{3}}$. (option 4)

The string does not stretch so the component of velocity of the block **along the string** toward the pulley must equal the rate at which the other end of the string (point P) withdraws string from the pulley.

- Component of block velocity along the string = $v_B \cos\theta$ (toward the pulley).
- Rate at which horizontal segment lengthens = v_P.

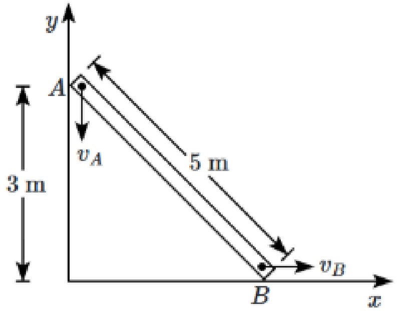
Thus

$$v_B \cos\theta = v_P \quad \Rightarrow \quad v_B = \frac{v_P}{\cos\theta} = \frac{2v_P}{\sqrt{3}}.$$



- **ALTERNATE SOLUTION**

Q19: The figure shows a rod of length 5 m. Its ends, A and B, are restrained to moving in horizontal and vertical guides. When the end A is 3 m above O, it moves at 4 m/s. The velocity of end B at that instant is:



1. 2 m/s
2. 3 m/s
3. 4 m/s
4. 0.20 m/s

Let A be at $(0, y)$ (moving only vertically) and B at $(x, 0)$ (moving only horizontally). The rod length is constant:

$$x^2 + y^2 = 5^2 = 25.$$

Differentiate w.r.t. time t:

$$2x\frac{dx}{dt} + 2y\frac{dy}{dt} = 0 \quad \Rightarrow \quad xv_B + yv_A = 0,$$

where $v_B = \dfrac{dx}{dt}$ (positive to the right) and $v_A = \dfrac{dy}{dt}$ (positive upward).

When $y = 3$ m we get $x = \sqrt{25 - 3^2} = \sqrt{16} = 4$ m. So

$$4\,v_B + 3\,v_A = 0 \quad \Rightarrow \quad v_B = -\frac{3}{4}\,v_A.$$

Given $|v_A| = 4\ \mathrm{m/s}$. Taking the usual picture interpretation (the figure shows A moving **down** at $4\ \mathrm{m/s}$), that means $v_A = -4\ \mathrm{m/s}$. Substitute:

$$v_B = -\frac{3}{4}(-4) = +3\ \mathrm{m/s}.$$

So the speed of B is $3\ \mathrm{m/s}$. (Direction: to the right in this case. If instead A were moving **up** at $4\ \mathrm{m/s}$, then $v_B = -3\ \mathrm{m/s}$, i.e. B would move left with speed $3\ \mathrm{m/s}$.)

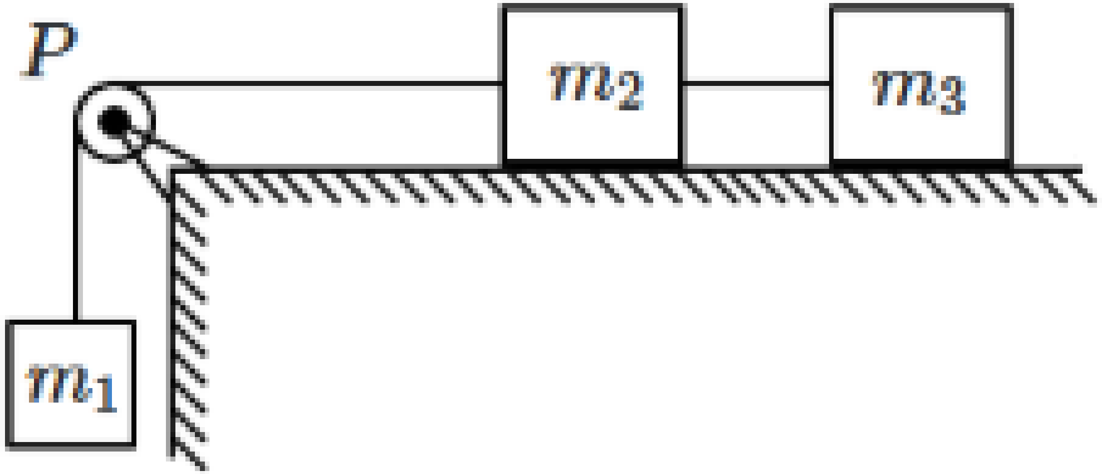
Answer: 3 m/s (option 2).

Q20:

A system consists of three masses m_1, m_2, and m_3 connected by a string passing over a pulley P. The mass m_1 hangs freely, and m_2 and m_3 are on a rough horizontal table (the coefficient of friction = μ). The pulley is frictionless and of negligible mass. The downward acceleration of mass m_1 is:
(Assume $m_1 = m_2 = m_3 = m$ and g is the acceleration due to gravity.)

Options:

1. $\frac{g(1-\mu)}{g}$
2. $\frac{2g\mu}{3}$
3. $\frac{g(1-2\mu)}{3}$
4. $\frac{g(1-2\mu)}{2}$



3. Write Newton's 2nd law for the hanging mass m_1 (downward positive):

$$mg - T = ma. \tag{1}$$

4. For the two blocks on the rough table: total mass on the table is $m_2 + m_3 = 2m$. They are pulled to the right by the string tension(s) and opposed by kinetic friction. The total kinetic frictional force equals

$$f_{\text{fric}} = \mu(m_2 + m_3)g = 2\mu mg,$$

acting to the left. The net horizontal equation for the combined blocks is therefore

$$T - 2\mu mg = (m_2 + m_3)\, a = 2ma. \tag{2}$$

(Effectively we treat the two blocks as a single body of mass $2m$ being pulled by tension T and opposed by total friction $2\mu mg$.)

5. Eliminate T by adding (1) and (2) (or substitute). From (1): $T = mg - ma$. Substitute in (2):

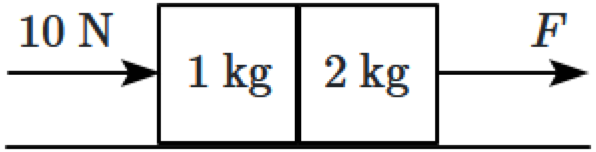
$$(mg - ma) - 2\mu mg = 2ma.$$

Rearrange:

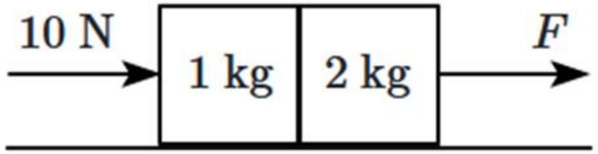
$$mg - 2\mu mg = 3ma \quad \Rightarrow \quad a = \frac{g(1 - 2\mu)}{3}.$$

Q1: Two blocks of weight **1 kg** and **2 kg** are placed in contact with each other on a smooth horizontal plane. Horizontal forces are applied to the blocks as shown. The blocks move together only if:

1. $F \leq 10\,\mathrm{N}$
2. $F > 10\,\mathrm{N}$
3. $F \leq 20\,\mathrm{N}$
4. $F > 20\,\mathrm{N}$



Let the common acceleration be a and the contact force magnitude be N (compressive).



Equations of motion:

- For the $1\,\mathrm{kg}$ block (right positive):
  $10 - N = 1 \cdot a \quad \Rightarrow \quad N = 10 - a.$
- For the $2\,\mathrm{kg}$ block:
  $F + N = 2 \cdot a \quad \Rightarrow \quad N = 2a - F.$

Equating N:

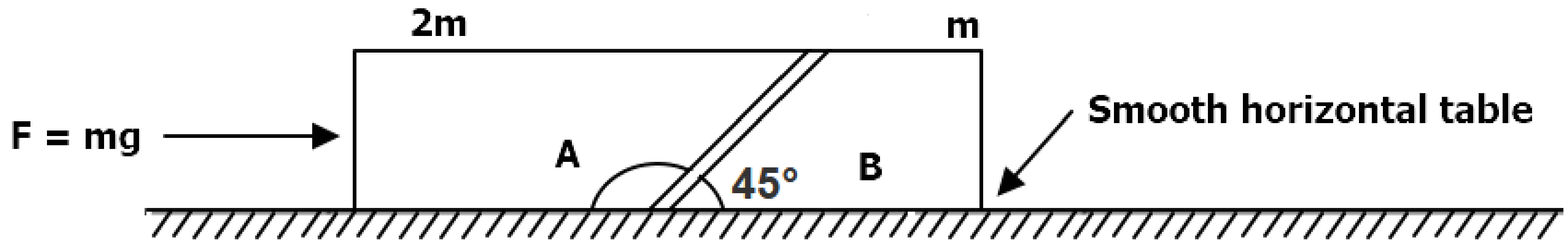
$$10 - a = 2a - F \Rightarrow 3a = 10 + F \Rightarrow a = \frac{10 + F}{3}.$$

The surfaces cannot sustain tension; hence contact is maintained only if $N \geq 0$.

$$N = 10 - a = 10 - \frac{10 + F}{3} = \frac{20 - F}{3} \geq 0 \Rightarrow F \leq 20\,\mathrm{N}.$$

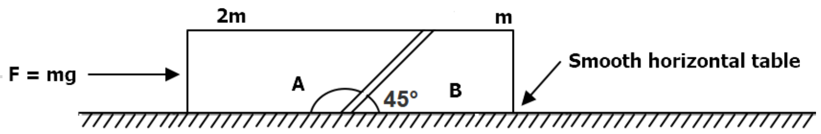
Q2: Two blocks of masses $2m, m$ are placed on a smooth horizontal table and they are in contact on their smooth slanted surfaces. A horizontal force F, equal to mg, is applied to the system from the left, which causes them to accelerate. Let N_A be the normal reaction from the table on A, and N_B on B. Then,

1. $N_A = 2mg,\ N_B = mg$
2. $N_A > 2mg,\ N_B < mg$
3. $N_A < 2mg,\ N_B > mg$
4. $N_A < 2mg,\ N_B < mg$



Given. Two blocks A and B of masses $2m$ and m respectively lie on a smooth horizontal table. Their contacting surfaces are smooth and inclined so that the normal between them is along the line at 45° to the horizontal (sloping upward to the right). A horizontal force $F = mg$ is applied to the left side of block A, causing both blocks to accelerate to the right. Let N_A and N_B denote the normal (reaction) forces exerted by the table on A and B.

We must determine how N_A and N_B compare to their values in the absence of mutual contact (i.e. $2mg$ and mg).



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1. Kinematics — common acceleration

The total mass of the system is $2m + m = 3m$. The net horizontal external force acting on the two-block system is $F = mg$. Hence the common acceleration a of both blocks is

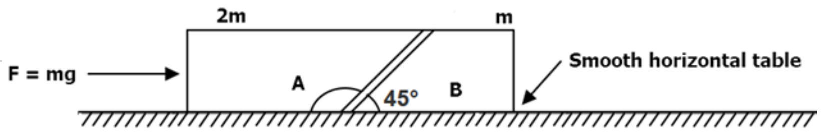
$$a = \frac{F}{3m} = \frac{mg}{3m} = \frac{g}{3}.$$

2. Contact normal and its components

Let R denote the magnitude of the normal force between the blocks (along the slanted surface at 45°). Resolve R into horizontal and vertical components:

$$R_x = R\cos 45^\circ = R\frac{1}{\sqrt{2}}, \qquad R_y = R\sin 45^\circ = R\frac{1}{\sqrt{2}}.$$

By the geometry of the contact (slopes up to the right), the contact force on block A due to B has components: horizontal leftwards R_x and vertical **upwards** R_y. The equal and opposite force acts on B: horizontal rightwards R_x and vertical **downwards** R_y.



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3. Horizontal equilibrium (Newton's 2nd law) for each block

- For block B (mass m), the only horizontal force is the contact horizontal component to the right:

$$R_x = ma.$$

  Therefore

$$R\frac{1}{\sqrt{2}} = ma \quad \Rightarrow \quad R = \sqrt{2}\,ma.$$

- Using $a = g/3$:

$$R = \sqrt{2}\,m\left(\frac{g}{3}\right) = \frac{\sqrt{2}}{3}\,mg > 0.$$

4. Vertical equilibrium and table reactions

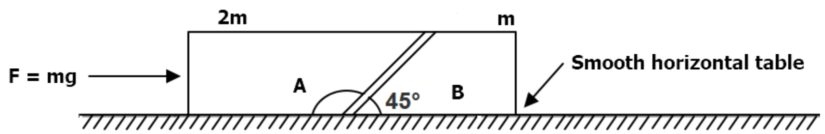
Both blocks have no vertical acceleration, so for each block vertical forces sum to zero.

- Block A (mass $2m$): upward forces are the table reaction N_A and the upward component of the contact R_y; downward force is weight $2mg$. Thus

$$N_A + R_y = 2mg \quad \Rightarrow \quad N_A = 2mg - R_y.$$

- Block B (mass m): upward force is N_B; downward forces are its weight mg and the downward component of the contact R_y. Thus

$$N_B - R_y = mg \quad \Rightarrow \quad N_B = mg + R_y.$$



But $R_y = R/\sqrt{2}$. From step 3 we found $R/\sqrt{2} = ma = m(g/3)$. Hence

$$R_y = m\frac{g}{3}.$$

Therefore

$$N_A = 2mg - m\frac{g}{3} = \frac{6mg - mg}{3} = \frac{5}{3}mg < 2mg,$$

and

$$N_B = mg + m\frac{g}{3} = \frac{4}{3}mg > mg.$$

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5. Conclusion (inequalities)

- $N_A < 2mg$.
- $N_B > mg$.

This corresponds exactly to option **3** in the given list.

Q3:

Given below are two statements:

- **Statement I:** Given that the magnitude of the acceleration of a body is constant, the force acting on it must be constant.
- **Statement II:** Newton's second law leads to the statement that the acceleration of a body is directly proportional to the net force acting on it.

Options:

1. **Statement I** is incorrect and **Statement II** is correct.
2. Both **Statement I** and **Statement II** are correct.
3. Both **Statement I** and **Statement II** are incorrect.
4. **Statement I** is correct and **Statement II** is incorrect.

Answer: (1) — Statement I is incorrect and Statement II is correct.

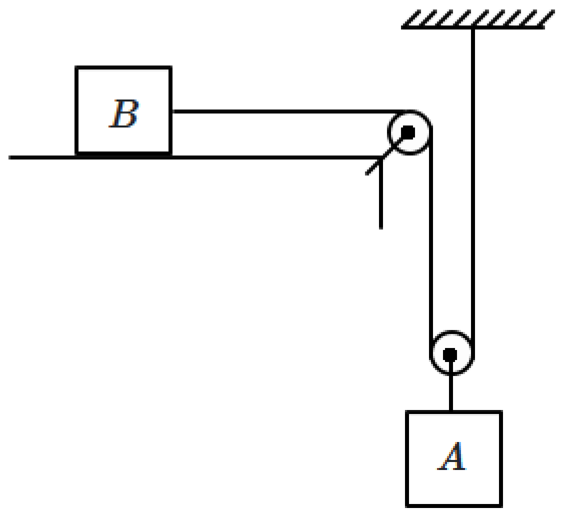
Reasoning.

- **Statement I:** *"Given that the magnitude of the acceleration of a body is constant, the force acting on it must be constant."* — **Incorrect.**
  Newton's second law in vector form is $\mathbf{F}_{\text{net}} = m\mathbf{a}$. If the **magnitude** $|\mathbf{a}|$ is constant but the **direction** of $\mathbf{a}$ changes with time (for example, uniform circular motion), the net force vector $\mathbf{F}_{\text{net}} = m\mathbf{a}$ also changes direction even though its magnitude $m|\mathbf{a}|$ is constant. Thus the **force vector** need not be constant. The statement as written (which reads as a claim about the force in general) is therefore false. A simple counterexample is uniform circular motion: $|\mathbf{a}|$ is constant but $\mathbf{F}_{\text{net}}$ continuously changes direction.
- **Statement II:** *"Newton's second law leads to the statement that the acceleration of a body is directly proportional to the net force acting on it."* — **Correct.**
  For constant mass m, $\mathbf{a} = \mathbf{F}_{\text{net}}/m$, so the acceleration (vector) is proportional to the net force (vector). This is exactly what Newton's second law implies.

Hence option **1** is the correct choice.

Q4: In the system shown in the figure, the strings and pulleys are ideal, and the block A moves downward while B moves to the right. A, B have equal masses. The acceleration of the block B is:

1. $\frac{g}{2}$
2. $\frac{g}{5}$
3. $\frac{2g}{5}$
4. g



Given. Strings and pulleys ideal, blocks A and B have equal masses (call each m). The geometry of the rope is: one end is attached to block B, the rope goes over the small fixed pulley at the table corner, then down around a movable pulley connected to block A, and the other end is fixed at the ceiling. When A moves downward a small amount, the horizontal segment (from B to the fixed pulley) shortens; thus the motions of A and B are kinematically related.

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1. Constraint (kinematic) relation

If the movable pulley (and block A) moves down by a distance x, both the downward and upward vertical segments of rope that go to the movable pulley lengthen by x each (total increase $2x$). To keep total rope length constant the horizontal segment must shorten by $2x$, so block B moves right by $2x$.

Therefore the accelerations obey

$$a_B = 2\,a_A,$$

where a_A is the downward acceleration of A and a_B is the rightward acceleration of B.

2. Dynamics (Newton's 2nd law)

Let the uniform tension in the rope be T.

- For block B (horizontal motion, mass m):

$$T = ma_B.$$

- For block A (vertical motion, mass m; downward positive):

  Two upward rope tensions act on the movable pulley supporting A, so net vertical equation is

$$mg - 2T = ma_A.$$

Substitute $a_B = 2a_A$ into the first equation to express T in terms of a_A:

$$T = ma_B = m(2a_A) = 2ma_A.$$

Insert this into the equation for A:

$$mg - 2(2ma_A) = ma_A \quad \Rightarrow \quad mg - 4ma_A = ma_A.$$

Divide by m and solve:

$$g = 5a_A \quad \Rightarrow \quad a_A = \frac{g}{5} \quad \text{(downward)}.$$

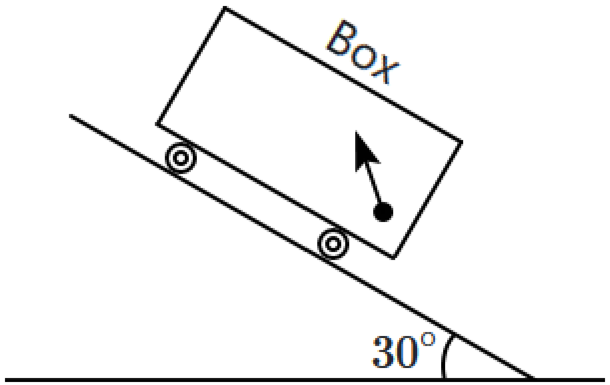
Then

$$a_B = 2a_A = \frac{2g}{5} \quad \text{(to the right)}.$$

Q5:

A box is moving down a frictionless 30° incline, and a particle is projected within the box. The acceleration of the particle relative to the box is:

1. g
2. $g \sin 30^\circ$
3. $g \cos 30^\circ$
4. $g \tan 30^\circ$



Problem Restatement:

- A box is moving down a smooth 30° incline.
- A particle is projected inside the box.
- We are asked: **What is the acceleration of the particle relative to the box?**

Step 1: Acceleration of the box

- Since the incline is smooth, the only acceleration of the box along the incline is due to gravity's component:

$$a_{\text{box}} = g \sin 30^\circ = \frac{g}{2}$$

Thus, the **box is accelerating down the incline with** $\frac{g}{2}$.

Step 2: Acceleration of the particle (absolute)

- The particle is inside the box but not constrained.
- Its absolute acceleration is simply **gravity**, i.e.,

$$a_{\text{particle}} = g \quad (\text{vertically downward})$$

Step 3: Relative acceleration

Relative acceleration is given by:

$$a_{\text{rel}} = a_{\text{particle}} - a_{\text{box}}$$

But since directions differ, we must resolve properly.

- Express gravity g in components **parallel** and **perpendicular** to incline:

$$g_{\parallel} = g \sin 30^\circ = \frac{g}{2}, \quad g_{\perp} = g \cos 30^\circ$$

So the particle's **absolute acceleration along incline** is $\frac{g}{2}$.
The box's acceleration along incline is also $\frac{g}{2}$.

→ Hence, **relative acceleration along the incline = 0**.

But perpendicular to incline, the particle still has component $g \cos 30^\circ$ (since the box is frictionless, it cannot provide constraint perpendicular to incline).

Step 4: Final Result

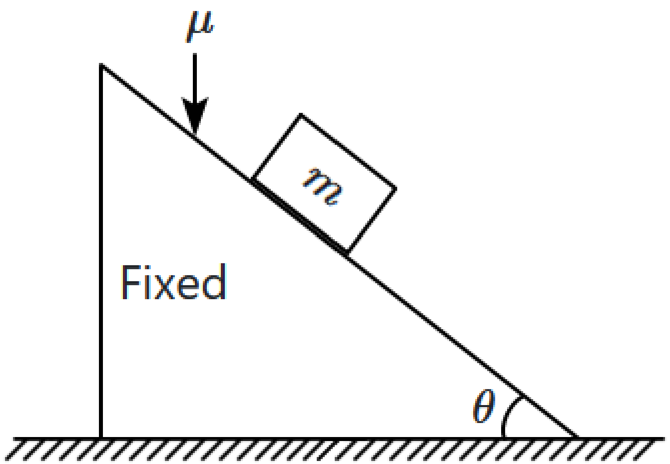
Therefore, the **relative acceleration** of the particle with respect to the box is:

$$a_{\text{rel}} = g \cos 30^\circ$$

Q6: A block of mass m, placed on a rough incline (as shown), is observed to remain at rest. The coefficient of friction is μ. The net force exerted by the incline on the block equals (in magnitude):

Options:

1. $mg\cos\theta + \mu mg\cos\theta$
2. $mg\cos\theta\sqrt{1+\mu^2}$
3. $mg\sin\theta$
4. mg



1. Choose axes: tangent to the plane (positive up the plane) and normal to the plane (outward from the surface).
   The only forces on the block are its weight $\mathbf{W} = m\mathbf{g}$ (vertical), the normal reaction $\mathbf{N}$ (perpendicular to plane), and the static friction $\mathbf{f}$ (along the plane).
2. Resolve the weight into components relative to the plane:
   - Normal component: $W_n = mg\cos\theta$ (into the plane).
   - Tangential component: $W_t = mg\sin\theta$ (down the plane).
3. Equilibrium (block remains at rest) implies the plane's reactions exactly balance the weight components:

$$N = mg\cos\theta, \qquad f = mg\sin\theta.$$

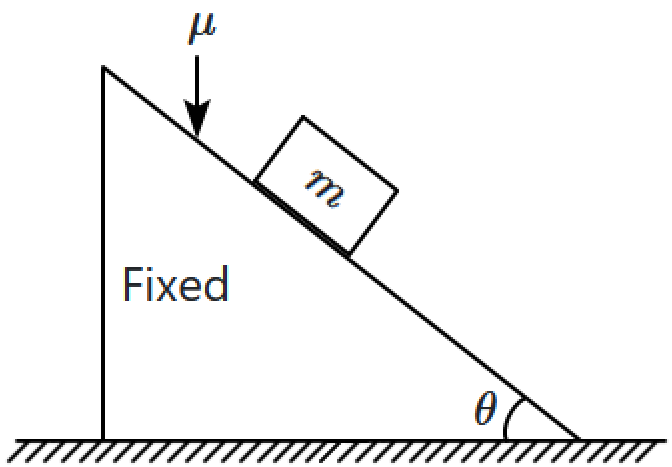
   (Here f is the static frictional force; existence of such f requires $f \le \mu N$, i.e. $\tan\theta \le \mu$.)
4. The net force exerted by the incline on the block is the vector sum

$$\mathbf{R} = \mathbf{N} + \mathbf{f}.$$

   Its magnitude is

$$R = \sqrt{N^2 + f^2} = \sqrt{(mg\cos\theta)^2 + (mg\sin\theta)^2} = mg\sqrt{\cos^2\theta + \sin^2\theta} = mg.$$

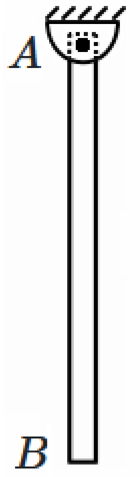
5. Interpretation: in static equilibrium the resultant of the contact forces from the plane must be equal and opposite to the weight; hence its magnitude equals the weight mg.



Therefore the correct choice is option **4.** mg.

Q7:

A uniform rod is pivoted at one of its ends, so that it can rotate freely in a vertical plane. Initially, it hangs vertically as shown in the figure. A sharp impulse is delivered to the rod at its lowest end B, towards the right. An impulse is exerted by the pivot at A, due to the constraint. The impulse at A acts:



Options:

1. to the right
2. to the left
3. upward
4. downward

1. Let an impulsive force at B act to the right with impulse J (N·s).

   The rod is uniform, length L, mass m, pivoted at the top end A.

2. **Angular impulse about A:**

   The pivot's impulse passes through A, so it gives **no** torque about A.

   Only the blow at B gives angular impulse $J \cdot L$. Hence

$$I_A \omega = J\,L, \qquad I_A = \frac{1}{3}mL^2 \Rightarrow \omega = \frac{3J}{mL}.$$

3. Just after the blow the motion is pure rotation about A (since A is fixed).

   The CM is at $L/2$ below A, so its speed is

$$v_{\text{CM}} = \omega\frac{L}{2} = \frac{3J}{2m}$$

   and it is **to the right** (perpendicular to the rod).

4. **Linear impulse–momentum:** The total external impulse equals the change of linear momentum of the rod:

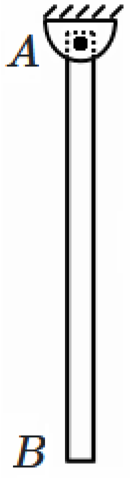
$$J + J_A = m v_{\text{CM}} = \frac{3J}{2}.$$

   Therefore the impulse at the pivot is

$$J_A = \frac{3J}{2} - J = \frac{J}{2},$$

   directed **to the right**. (There is no vertical impulse since the CM acquires no vertical momentum.)

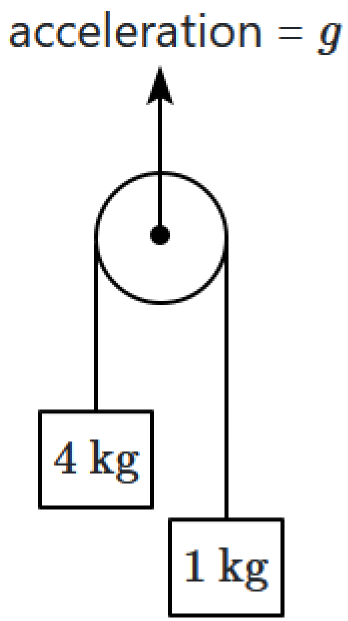
Hence, the impulse exerted by the pivot at A acts **to the right**.



Q8:

The acceleration of the 4 kg block is:

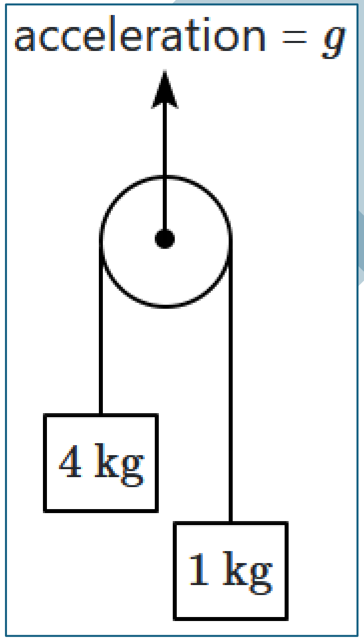
(acceleration = g)



1.	$\frac{3g}{5}$ down.
2.	$\frac{6g}{5}$ down.
3.	$\frac{g}{5}$ down.
4.	$\frac{11g}{5}$ down.

System: A pulley with two hanging blocks — one of mass $4\,\mathrm{kg}$ and the other of mass $1\,\mathrm{kg}$.

Interpretation: the pulley (and support) is accelerating **upward** with acceleration $a_{\text{pulley}} = g$ (arrow in the figure). We want the acceleration of the 4 kg mass (take downward as positive for that block).



Method (use the non-inertial frame moving with the pulley).

1. Work in the frame fixed to the accelerating pulley (so the pulley is momentarily at rest). In this non-inertial frame each mass experiences an extra **pseudo-force** $-ma_{\text{pulley}}$ acting opposite to the frame acceleration (here that pseudo-force is **downward** because the frame accelerates upward).
2. Real gravity on each mass is mg downward. Adding the pseudo-force (also downward) gives an **effective weight**

$$mg_{\text{eff}} = m(g + a_{\text{pulley}}) = m(g+g) = 2mg.$$

So in this frame the two masses behave like an Atwood machine with effective gravity $g_{\text{eff}} = 2g$.

3. For an Atwood machine with masses $m_1 = 4$ kg (heavier) and $m_2 = 1$ kg (lighter), the acceleration magnitude (heavier side down) is

$$a = \frac{m_1 - m_2}{m_1 + m_2}\, g_{\text{eff}} = \frac{4-1}{4+1} \cdot 2g = \frac{3}{5} \cdot 2g = \frac{6g}{5}.$$

4. Direction: the heavier 4 kg block moves **downward**.

Answer: $a = \dfrac{6g}{5}$ downward (option 2).

Q9: Given below are two statements:

Statement I:

When a railway engine pulls a train and the system moves forward, the force exerted by the engine on the train is greater than that exerted by the train on the engine.

Statement II:

The normal force exerted by the ground on a man is the reaction force of the weight of the man.

Options:

1. *Statement I is incorrect and Statement II is correct.*
2. *Both Statement I and Statement II are correct.*
3. *Both Statement I and Statement II are incorrect.*
4. *Statement I is correct and Statement II is incorrect.*

- **Statement I (engine vs train forces):** The force exerted by the engine on the train and the force exerted by the train on the engine are an action–reaction pair and must have equal magnitudes and opposite directions (Newton III). The fact the system accelerates is due to other unbalanced external forces on the train as a whole, not because the two coupler forces differ. So Statement I is **false**.
- **Statement II (normal force = reaction of weight):** The weight is the gravitational force of Earth on the man; its Newton-III reaction is the gravitational force of the man on the Earth. The normal force is a contact force (ground on man) whose reaction is the contact force of the man on the ground. Thus the normal force is **not** the reaction of the weight. Statement II is **false**.

Therefore answer remains **(3) — both incorrect.**

Q10:

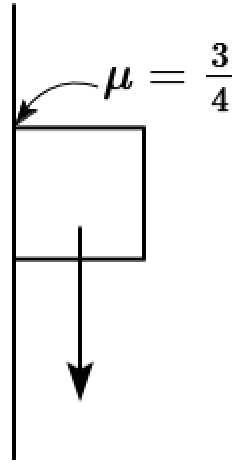
A 3 kg-block is pressed against a vertical wall with a coefficient of friction, μ = 3/4.

What minimum force should be applied to the block in order to prevent it from falling down?

Take g = 10 m/s².

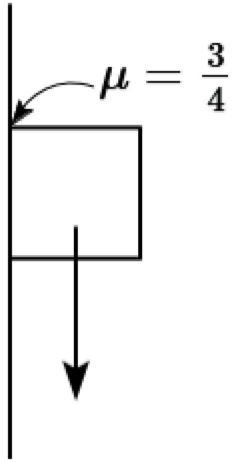
Options:

1. $\frac{3}{4} \times 30\,\mathrm{N}$
2. $\frac{4}{3} \times 30\,\mathrm{N}$
3. $\frac{3}{5} \times 30\,\mathrm{N}$
4. $\frac{4}{5} \times 30\,\mathrm{N}$



1. Draw forces on the block (vertical equilibrium requirement to prevent slipping):
   - Weight downward: mg.
   - Static friction upward: f_s (must hold the block).
   - Normal reaction from the wall horizontally: N.
   - Applied horizontal push F (into the wall).
2. Horizontal equilibrium (instant): the wall's normal balances the applied push, so

$$N = F.$$



3. To just prevent falling, the maximum static friction must at least equal the weight:

$$f_{\max} = \mu N \geq mg.$$

At the limiting (minimum F) case take equality:

$$\mu N = mg.$$

4. Substitute $N = F$ and solve for $F_{\min}$:

$$F_{\min} = \frac{mg}{\mu}.$$

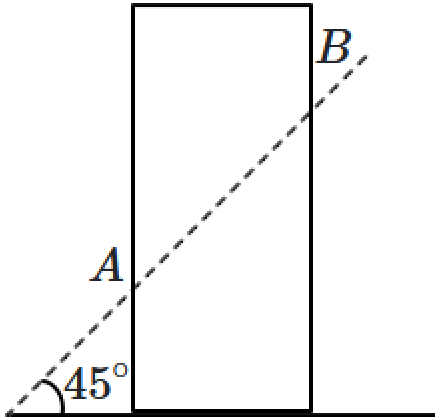
5. Put numbers: $m = 3\ \mathrm{kg},\ g = 10\ \mathrm{m/s^2},\ \mu = \frac{3}{4}$:

$$F_{\min} = \frac{3 \times 10}{3/4} = 30 \times \frac{4}{3} = 40\ \mathrm{N}.$$

So the minimum force is $40\ \mathrm{N}$, i.e. $\frac{4}{3} \times 30\ \mathrm{N}$ (option 2).

Q1: A 2 kg brick is placed on the ground as shown and it is symmetrically cut into two equal pieces by a plane **AB**, which is at 45° with the horizontal. The system remains at rest. The force of friction on the upper piece due to the lower is: $(\text{Take } g = 10\,\text{m/s}^2)$

Options:



1. $10\,\text{N}$
2. $10\sqrt{2}\,\text{N}$
3. $5\sqrt{2}\,\text{N}$
4. $5\,\text{N}$

1. The brick is cut into two equal pieces → each piece has mass $m = \frac{2}{2} = 1\ \mathrm{kg}$.
   So the weight of the upper piece is $W = mg = 1 \times 10 = 10\ \mathrm{N}$.
2. The contact plane is inclined at $\theta = 45^\circ$ to the horizontal. Resolve the weight of the upper piece into components **normal** and **parallel** to the plane:
   - component **along the plane** (tending to make the upper piece slide down) is $W_{\parallel} = W \sin\theta$.
   - component **normal** to the plane is $W_{\perp} = W \cos\theta$.
3. For $\theta = 45^\circ$: $\sin 45^\circ = \cos 45^\circ = \dfrac{\sqrt{2}}{2}$. So

$$W_{\parallel} = 10 \sin 45^\circ = 10 \cdot \frac{\sqrt{2}}{2} = 5\sqrt{2}\ \mathrm{N}.$$

4. Since the system is at rest, the frictional force at the interface must balance the parallel component of weight. Therefore the friction on the upper piece due to the lower equals

$$\boxed{5\sqrt{2}\ \mathrm{N}}.$$

(Directed up the plane, opposing the tendency to slide down.)

Q2:

A ball of mass m falls from a height h onto the ground and rebounds to a height $\frac{h}{4}$.

The impulse on the ball from the ground has the magnitude:

1. $\frac{3}{4}m\sqrt{2gh}$
2. $\frac{5}{4}m\sqrt{2gh}$
3. $\frac{3}{2}m\sqrt{2gh}$
4. $\frac{1}{2}m\sqrt{2gh}$

Step-by-step:

1. Velocity just before impact (downward):
   $v_i = \sqrt{2gh}$.
2. Velocity just after rebound (upward) to height $h/4$:
   $v_f = \sqrt{2g \cdot \frac{h}{4}} = \frac{1}{2}\sqrt{2gh} = \frac{v_i}{2}$.
3. Choose upward as positive. Initial momentum just before impact: $p_i = -mv_i$.
   Final momentum after impact: $p_f = +mv_f = m\frac{v_i}{2}$.
4. Impulse from the ground $J = \Delta p = p_f - p_i$:

$$J = m\frac{v_i}{2} - (-mv_i) = \frac{3}{2}mv_i = \frac{3}{2}m\sqrt{2gh}.$$

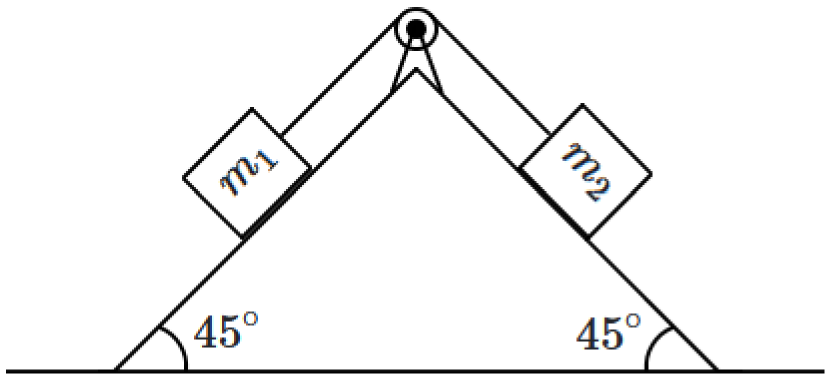
(Magnitude $= \frac{3}{2}m\sqrt{2gh}$. Direction of the impulse is upward.)

Answer: $\frac{3}{2}m\sqrt{2gh}$ (option 3).

Q3:

There is no friction anywhere, and the string and the pulley are ideal. Assume that $m_1 < m_2$. The acceleration of m_2 down the plane is a. Then,

1. as $\frac{m_1}{m_2} \to 1,\ a \to 0$
2. as $\frac{m_1}{m_2} \to 0,\ a \to g$
3. a varies linearly with $\frac{m_1}{m_2}$
4. all the above are true



Let both planes be smooth and at 45°. $m_2 > m_1$, so m_2 goes **down** its plane and m_1 goes **up** its plane with the same acceleration a.

Free-body and equations along the planes

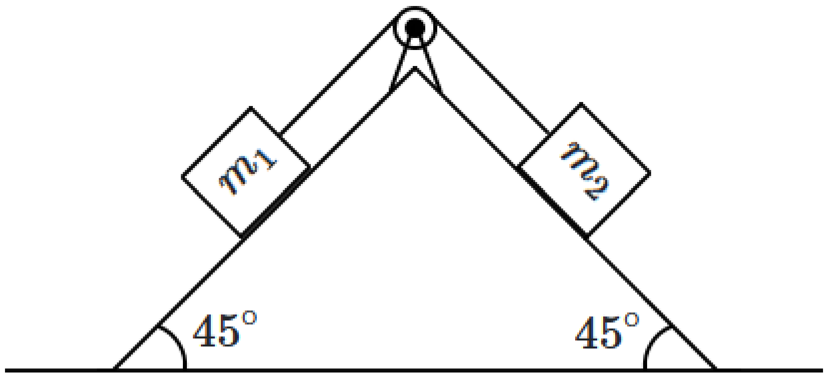
For each block, resolve along the incline ($\sin 45^\circ = 1/\sqrt{2}$):

- For m_2 (down the plane positive):

$$m_2 g \sin 45^\circ - T = m_2 a$$

- For m_1 (up the plane positive):

$$T - m_1 g \sin 45^\circ = m_1 a$$



Add:

$$(m_2 - m_1) g \sin 45^\circ = (m_1 + m_2) a$$

$$\boxed{a = \frac{g}{\sqrt{2}} \frac{m_2 - m_1}{m_1 + m_2}}$$

(Useful to remember: for equal angles and no friction,
$a = g \sin\theta \, (m_2 - m_1)/(m_1 + m_2)$.)

Check each statement

Let $r = \frac{m_1}{m_2}$ $(0 < r < 1)$. Then

$$a = \frac{g}{\sqrt{2}} \frac{1-r}{1+r}.$$

1. As $r \to 1$: $a \to \frac{g}{\sqrt{2}} \frac{0}{2} = 0$. **True.**
2. As $r \to 0$: $a \to \frac{g}{\sqrt{2}}$ (the maximum possible here). Not g. **False.**

   Trap: students often think "m_2 much heavier ⇒ $a \to g$", but along an incline the maximum is $g \sin \theta$, here $g/\sqrt{2}$.
3. "a varies linearly with m_1/m_2":
   $a = \frac{g}{\sqrt{2}} \frac{1-r}{1+r}$ is **not** linear in r (denominator depends on r). **False.**
4. "All the above are true" ⇒ **False.**

Final answer

Only statement **1** is correct.

Quick shortcut: Treat it as an "Atwood on twin 45° inclines":
$a = g \sin 45^\circ \, (m_2 - m_1)/(m_1 + m_2) = \frac{g}{\sqrt{2}} \frac{m_2 - m_1}{m_1 + m_2}$.
From this, all limits and monotonic behavior follow immediately.

Q4:

The average force needed to accelerate a car weighing **500 kg** from rest to **36 km/h** through a distance of **25 m**, up a **30° incline** is $(g = 10\,\mathrm{m/s^2})$:

1. 1000 N
2. 2500 N
3. 1500 N
4. 3500 N

Given:

$m = 500\ \text{kg},\ u = 0,\ v = 36\ \text{km/h} = 10\ \text{m/s},\ s = 25\ \text{m},\ \theta = 30^\circ,\ g = 10\ \text{m/s}^2.$

1. Convert final speed

$36\ \text{km/h} = 36 \times \frac{1000}{3600} = 36 \times \frac{5}{18} = 10\ \text{m/s}.$

2. Change in kinetic energy

$$\Delta K = \frac{1}{2}mv^2 = \frac{1}{2} \times 500 \times 10^2.$$

Compute stepwise: $10^2 = 100$. $\frac{1}{2} \times 500 = 250$. So $\Delta K = 250 \times 100 = 25\,000\ \text{J}$.

3. Change in potential energy (gain in height)

Height $h = s \sin 30^\circ = 25 \times \frac{1}{2} = 12.5\ \text{m}$.

$$\Delta U = mgh = 500 \times 10 \times 12.5.$$

Compute: $10 \times 12.5 = 125$. Then $500 \times 125 = 62\,500\ \text{J}$.

4. Total work done by the applied force

Work must supply both ΔK and ΔU:

$$W = \Delta K + \Delta U = 25\,000 + 62\,500 = 87\,500\ \text{J}.$$

5. Average force along the incline

Work $W = F_{\text{avg}} \times s \Rightarrow F_{\text{avg}} = \frac{W}{s} = \frac{87\,500}{25}$.

Compute: $87{,}500 \div 25 = 3{,}500\ \text{N}$.

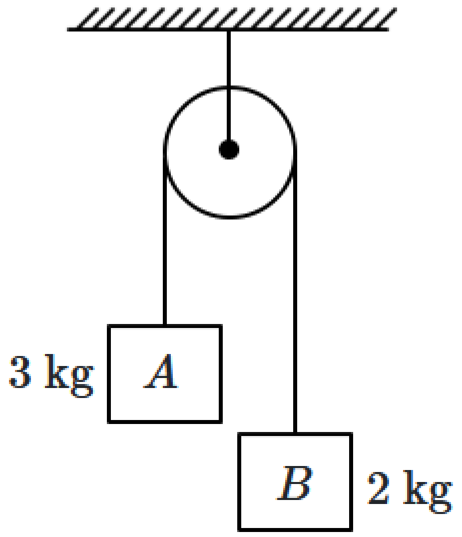
Shortcut / Trap points:

- Shortcut: Use energy directly — avoid kinematics. $F_{\text{avg}} = \dfrac{\frac{1}{2}mv^2 + mgh}{s}$.
- Trap: Don't forget potential energy gain on the incline. Many students forget the mgh term and get a smaller force.
- Note: If friction were present, include work against friction in the numerator.

Q5:

An Atwood's machine with blocks of masses **3 kg** and **2 kg** is set up in a laboratory. The string is taut and the blocks start moving at $t = 0$.

The relative acceleration of the blocks has the magnitude:



1. $\frac{g}{5}$
2. $\frac{2g}{5}$
3. $\frac{3g}{5}$
4. $\frac{4g}{5}$

Setup & sign convention

Let $m_1 = 3\ \mathrm{kg}$ (left block A) and $m_2 = 2\ \mathrm{kg}$ (right block B). Since $m_1 > m_2$, m_1 **goes down** and m_2 **goes up**. Let the magnitude of each block's acceleration be a (down for m_1, up for m_2).

Equations from FBDs (along the string direction):

- For m_1 (down positive): $m_1 g - T = m_1 a$.
- For m_2 (up positive): $T - m_2 g = m_2 a$.

Add the two equations to eliminate T:

$$m_1 g - m_2 g = (m_1 + m_2)a$$

so

$$a = \frac{(m_1 - m_2)g}{m_1 + m_2} = \frac{(3-2)g}{3+2} = \frac{g}{5}.$$

Relative acceleration:

The relative acceleration of one block with respect to the other (magnitudes in opposite directions) is

$$a_{\text{rel}} = a_{(\text{down of } m_1)} - a_{(\text{up of } m_2)} = a - (-a) = 2a.$$

Hence

$$a_{\text{rel}} = 2 \cdot \frac{g}{5} = \frac{2g}{5}.$$

Numeric check (if $g = 10 \text{ m/s}^2$): $a = 2 \text{ m/s}^2$, so $a_{\text{rel}} = 4 \text{ m/s}^2$.

Answer: $\boxed{\frac{2g}{5}}$ — option **2**.

Shortcut / trap points

- Shortcut: memorize $a = \dfrac{(m_1 - m_2)g}{m_1 + m_2}$. Then multiply by 2 if the question asks *relative* acceleration.
- Trap: confusing the acceleration of a single mass with the relative acceleration — many pick $g/5$ (the single-block acceleration) instead of $2g/5$.

Q7:

An astronaut, in a space shuttle, orbiting close to the earth's surface (take $g = 10\,\mathrm{m/s}^2$), suddenly fires his engines so as to give him a forward acceleration of $\frac{3g}{4}$ along the direction of his motion. At that instant, his apparent weight is:

1. 25% more than his real weight.
2. 25% less than his real weight.
3. 75% more than his real weight.
4. 75% less than his real weight.

Given: orbiting close to Earth so that gravitational acceleration g provides the centripetal acceleration for circular motion. Engines give a forward (tangential) acceleration $a = \frac{3g}{4}$. Take $g = 10 \mathrm{~m/s}^2$ only if you need numbers.

Key idea (non-inertial frame / pseudo-force):
When the astronaut fires engines, in the astronaut's accelerating (non-inertial) frame a pseudo-force $m\mathbf{a}$ acts on him opposite to the shuttle's acceleration (i.e. backward along the direction of motion). He also feels gravity $m\mathbf{g}$ downward (toward Earth). The contact force from the seat (what he *feels* as apparent weight) is the vector resultant of these two equal-and-opposite effects (the seat supplies whatever contact force is needed to balance the vector sum).

Initially (before firing) the centripetal requirement is supplied by gravity and the normal was zero (weightless). At the instant engines fire, the tangential thrust produces a pseudo-force of magnitude ma backward. Gravity still points downward with magnitude mg. The seat must provide a resultant contact force equal and opposite to the vector sum $(m\mathbf{g} + m\mathbf{a}_{\text{pseudo}})$.

So the **magnitude** of the apparent weight W_{app} is

$$W_{\text{app}} = m\sqrt{g^2 + a^2}.$$

Substitute $a = \frac{3g}{4}$:

$$W_{\text{app}} = mg\sqrt{1 + \left(\frac{3}{4}\right)^2} = mg\sqrt{1 + \frac{9}{16}} = mg\sqrt{\frac{25}{16}} = mg \cdot \frac{5}{4}.$$

That is $1.25\,mg$, i.e. **25% more than his real weight.**

Answer: option **1** — *25% more than his real weight.*

Shortcut / trap points

- Shortcut: treat the situation in the accelerating frame and combine gravity and the pseudo-force vectorially: apparent weight $= m\sqrt{g^2 + a^2}$.
- Trap: do **not** try to treat the tangential acceleration as changing the radial (normal) force directly; you must combine vectors. Also don't assume initial weightlessness means the astronaut will stay weightless after a tangential thrust.

Q10:

A block of mass m is placed on a flat horizontal surface, and the coefficient of friction between the block and the surface is μ. A force F_A is applied to the block from above, and a force F_R is applied to the right. In all situations being considered below, the block remains at rest. Let *f* be the force of friction on the block.

Consider the statements:

(P) *f* increases if m is increased.

(Q) *f* increases if F_A is increased.

(R) *f* increases if F_R is increased.

Options:

1. Only P is True.
2. Only Q is True.
3. P, Q are True.
4. Only R is True.

We have a block of mass **m** on a horizontal surface.

- Vertical downward force: F_A
- Horizontal applied force: F_R
- Friction coefficient: μ
- Block remains **at rest** in all given cases.

Step 1: Normal Reaction

$$N = mg + F_A$$

Step 2: Maximum static friction

$$f_{\max} = \mu N = \mu(mg + F_A)$$

Step 3: Actual friction force

Since the block is **at rest**, friction force just balances the horizontal force:

$$f = F_R \quad (\text{provided } F_R \leq f_{\max})$$

Step 4: Analyze statements

(P) f increases if m is increased.

- If we increase mass, N and $f_{\max}$ increase.
- But actual friction f = F_R, which is fixed by the external horizontal force.
- As long as $F_R \leq f_{\max}$, friction doesn't change with mass.

✅ Statement (P) is **False**.

(Q) f increases if F_A is increased.

- Increasing F_A increases normal reaction → increases $f_{\max}$.
- But actual $f = F_R$ (still same), since block remains at rest.
- So f does not change.

✅ Statement (Q) is **False**.

(R) f increases if F_R is increased.

- Friction always adjusts to balance F_R (until limit).
- So if F_R increases, f also increases.

✅ Statement (R) is **True**.

THANK YOU