



FORCES

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Newton's 1st Law of Motion

- An object continues in a state of rest or uniform motion, unless acted upon by a resultant force.
- It tells about a system in Equilibrium i.e. when the result of all the forces acting on the body is zero!

$$\sum F = 0$$
$$\sum F_x = 0$$
$$\sum F_y = 0$$

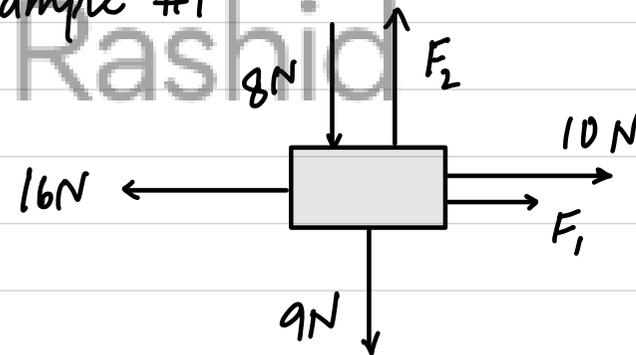
Equilibrium

Static Equilibrium
AT REST

Dynamic Equilibrium
CONSTANT VELOCITY

- speed constant
- direction constant

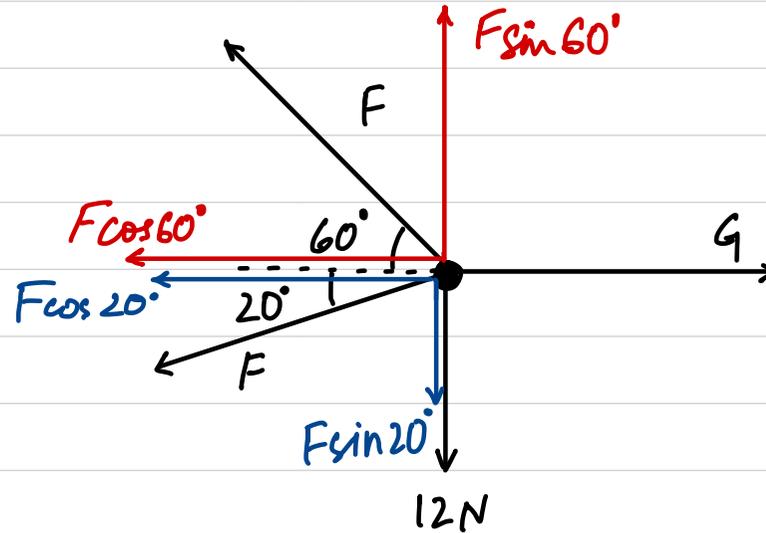
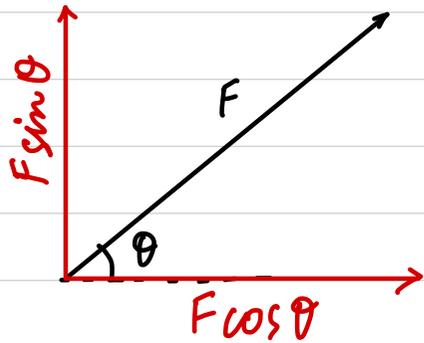
• Example #1



$$\sum F_x = 0$$
$$16 = 10 + F_1$$
$$F_1 = 6 \text{ N}$$

$$\sum F_y = 0$$
$$8 + 9 = F_2$$
$$F_2 = 17 \text{ N}$$

Type #2



If the system is in equilibrium, find the value of F and G .

$$\sum F_x = 0$$

$$G = F \cos 60^\circ + F \cos 20^\circ$$

$$G = 1.44F$$

$$\sum F_y = 0$$

$$F \sin 60^\circ = F \sin 20^\circ + 12$$

$$F \sin 60^\circ - F \sin 20^\circ = 12$$

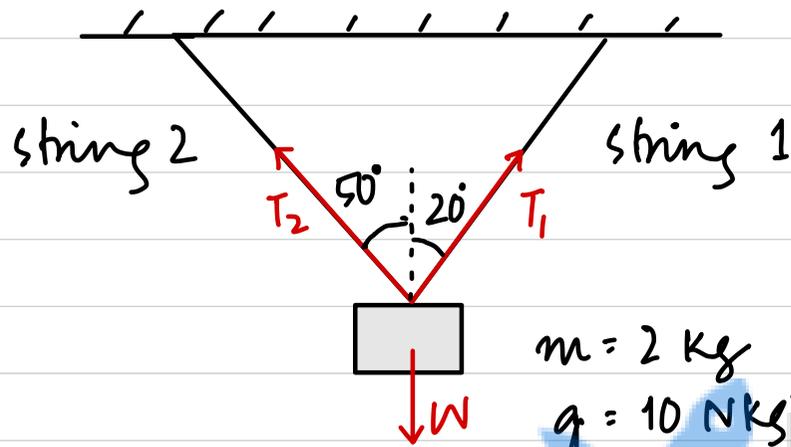
$$F = \frac{12}{(\sin 60^\circ - \sin 20^\circ)}$$

$$F = 22.9 \approx 23\text{N}$$

So $G = 1.44(22.9)$

$$G = 33.1 \approx 33\text{N}$$

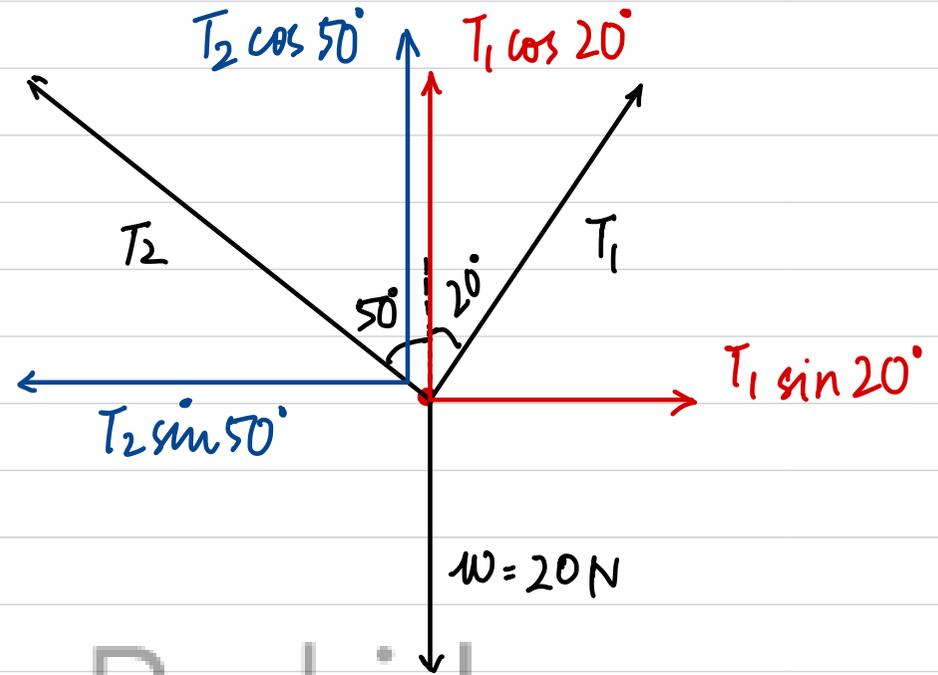
Type # 3



If the system is in equilibrium, determine the tension in the strings.



Tension force acts away from the point and towards the center of the cord.



$$\sum F_x = 0$$

$$T_1 \sin 20^\circ = T_2 \sin 50^\circ$$

$$T_1 \sin 20^\circ - T_2 \sin 50^\circ = 0$$

$$\sum F_y = 0$$

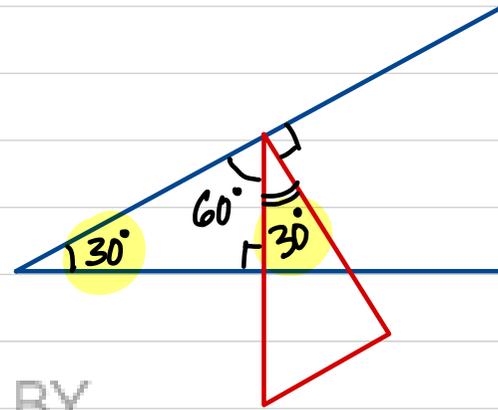
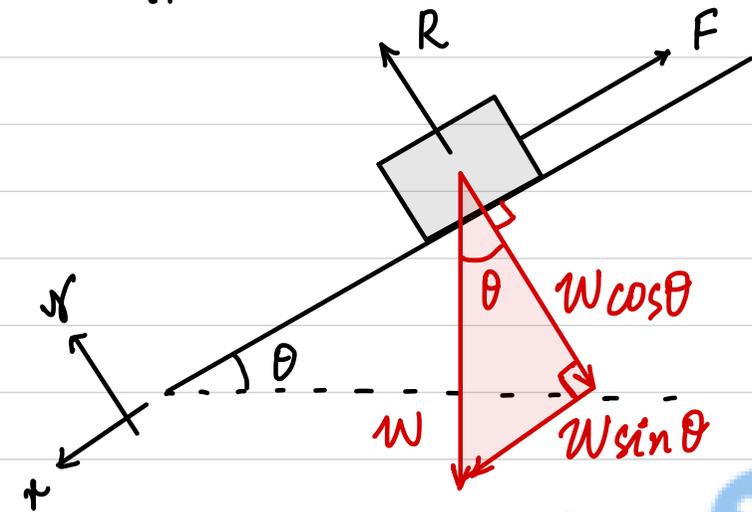
$$T_1 \cos 20^\circ + T_2 \cos 50^\circ = 20$$

$$T_1 = 16.3 \text{ N}$$

$$T_2 = 7.28 \text{ N}$$

Type # 4 : Inclined Plane

F could be tension, push or pull force, friction etc.



* The line/component along the angle θ is the cos component (Angle k sath vala component) cos component hai)

Box is in equilibrium

$$\sum F_x = 0$$

$$W \sin \theta = F$$

↓

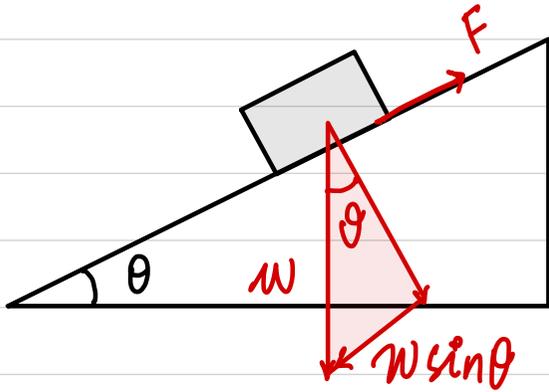
- responsible for sliding down the plane.

$$\sum F_y = 0$$

$$R = W \cos \theta$$

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example.



A block of mass 2 kg rests on a rough inclined surface as shown. The maximum friction force between block and surface is 17 N. Calculate the maximum angle of slope before the block starts to slip.

$$W = 2 \times 9.8$$

$$W = 19.6 \text{ N}$$

$$W \sin \theta = \text{Friction max}$$

$$19.6 \sin \theta = 17$$

$$\theta = 60.15^\circ$$



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Drag Force

→ Force exerted on a body moving in a fluid.

→ Drag force depends upon

1. Viscosity (Thick ness of fluid)
the thicker the fluid, the greater will be the drag force.

air water oil glycerine
→
viscosity increases
drag force increases

2. Velocity of object or fluid
at higher speed, molecules collide with the body more forcefully, exerting more drag force.

3. Surface Area

The greater the surface area, the larger is the drag force as more molecules collide.



more
Area

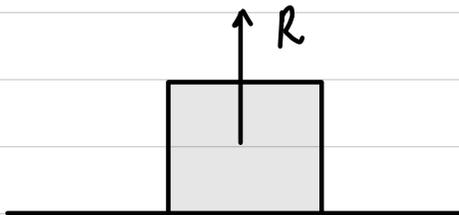
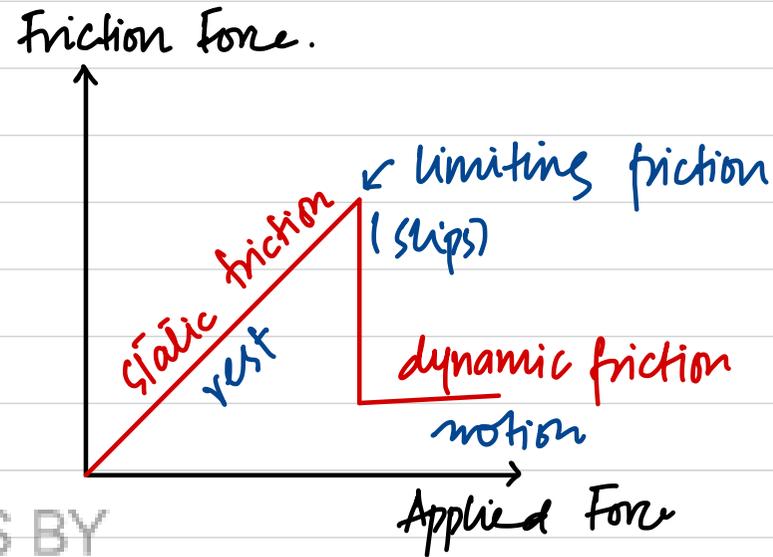
(falls slow)
(more drag)

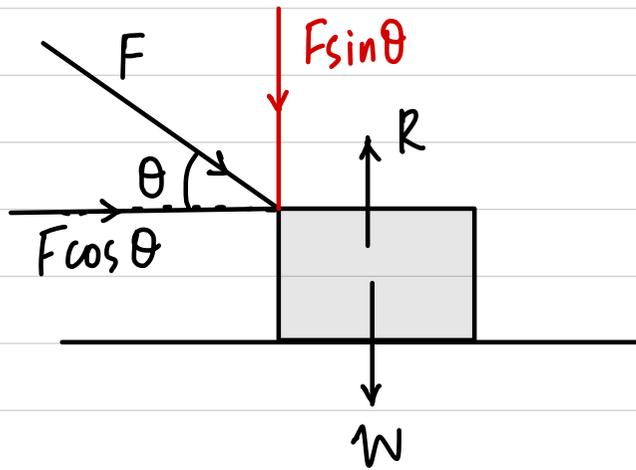
less
Area

(falls fast)
(less drag)

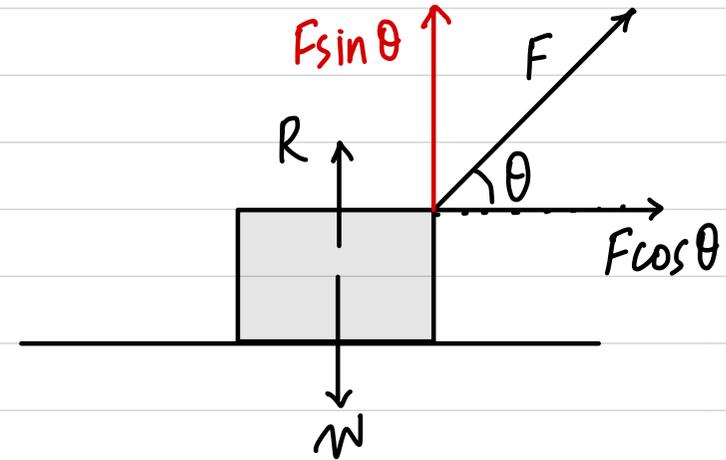
Friction

- It is an opposing force that tends to slow down moving objects.
- Its value increases with applied force until the body starts to slip.
- It depends upon the surfaces in contact and the Normal reaction force.





$$F \propto R$$



$\sum F_y = 0$
 $R = W + F \sin \theta$
 greater Normal Contact Force
GREATER FRICTION

$\sum F_y = 0$
 $R + F \sin \theta = W$
 $R = W - F \sin \theta$
 Lesser Normal Contact Force
LESSER FRICTION.



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Newton's 2nd Law of Motion

Rate of change of momentum is directly proportional to resultant force.

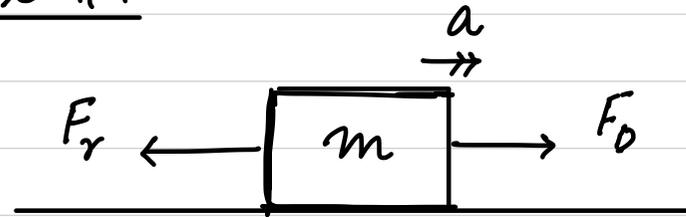
$$F_{\text{net}} \propto \frac{\Delta p}{\Delta t}$$

$$F_{\text{net}} = \frac{\Delta p}{\Delta t}$$

$$F_{\text{net}} = m \cdot v$$

$$F_{\text{net}} = m \cdot a$$

Case #1

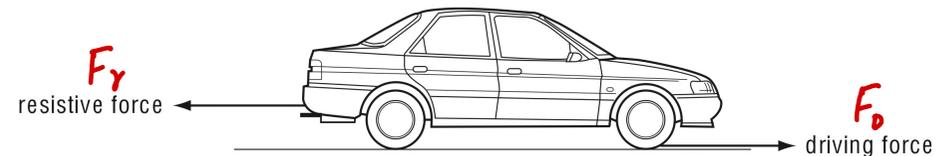


$$F_{\text{net}} = m \cdot a$$

$$\text{forward force} - \text{backward force} = m \cdot a$$

$$F_o - F_r = m \cdot a$$

- 11 A car of mass 750 kg has a horizontal driving force of 2.0 kN acting on it. It has a forward horizontal acceleration of 2.0 ms^{-2}



What is the resistive force acting horizontally?

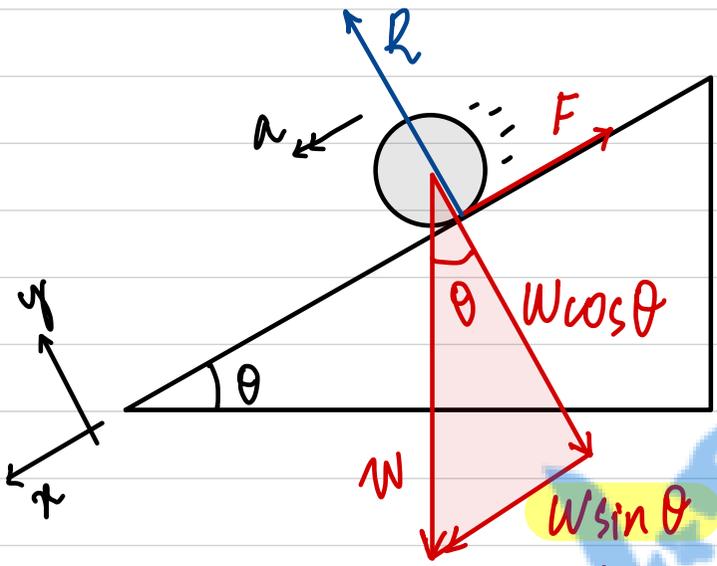
- A 0.5 kN B 1.5 kN C 2.0 kN D 3.5 kN

$$F_{\text{net}} = m \cdot a$$

$$F_o - F_r = m \cdot a$$

$$2000 - F_r = (750)(2) \quad F_r = 500 \text{ N}$$

Case #2 : Inclined Plane



rough: friction exists

smooth: No friction

Responsible for sliding object down the plane

If the plane is rough

$$F_{net} = ma$$

$$W \sin \theta - F = ma$$

$$\sum F_y = 0$$

R: contact force to plane so the forces along that axis

$$R = W \cos \theta$$

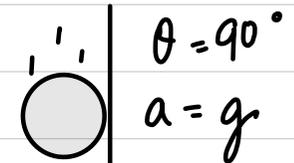
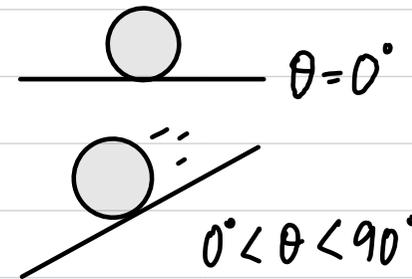
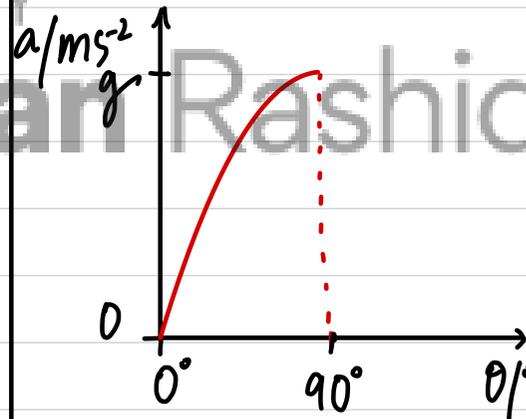
If the plane is smooth

$$F_{net} = ma$$

$$W \sin \theta = ma$$

$$mg \sin \theta = ma$$

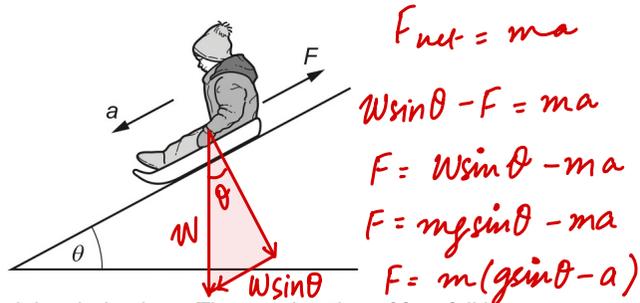
$$a = g \sin \theta$$



* No movement perp.

forces along that axis are balanced.

- 12 A child on a sledge slides down a hill with acceleration a . The hill makes an angle θ with the horizontal.



$$F_{\text{net}} = ma$$

$$W \sin \theta - F = ma$$

$$F = W \sin \theta - ma$$

$$F = mg \sin \theta - ma$$

$$F = m(g \sin \theta - a)$$

The total mass of the child and the sledge is m . The acceleration of free fall is g .

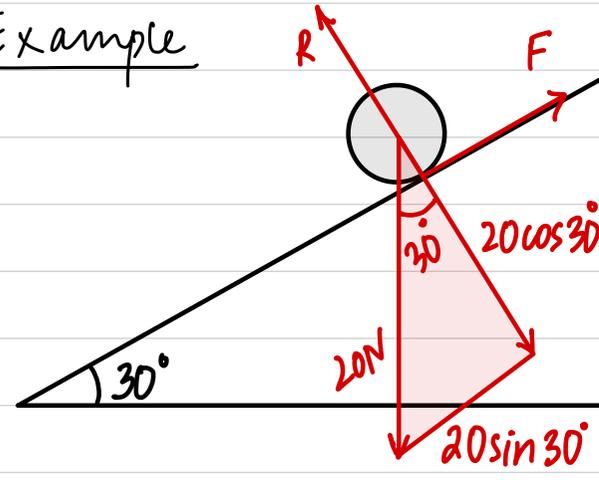
What is the friction force F ?

- A $m(g \cos \theta - a)$
- B $m(g \cos \theta + a)$
- C $m(g \sin \theta - a)$
- D $m(g \sin \theta + a)$



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Example



$$m = 2 \text{ kg}$$

$$F = 0.2R$$

$$g = 10 \text{ N kg}^{-1}$$

Calculate the value of acc.

$$F_{\text{net}} = ma$$

$$20 \sin 30^\circ - F = 2a$$

$$20 \sin 30^\circ - 3.46 = 2a$$

$$a = 3.27$$

$$a = 3.3 \text{ m/s}^2$$

$$F = 0.2R$$

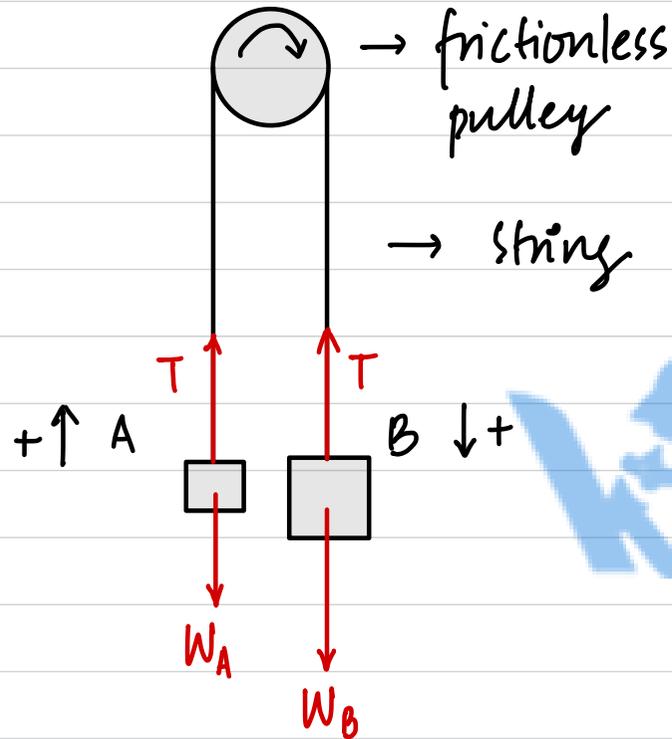
and \uparrow

$$R = 20 \cos 30^\circ$$

$$F = 0.2(20 \cos 30^\circ)$$

$$F = 3.46 \text{ N}$$

Case #3 : Connected Bodies
(Both bodies overhanging)



A.
 $F_{\text{net}} = ma$
 $T - W_A = m_A a$

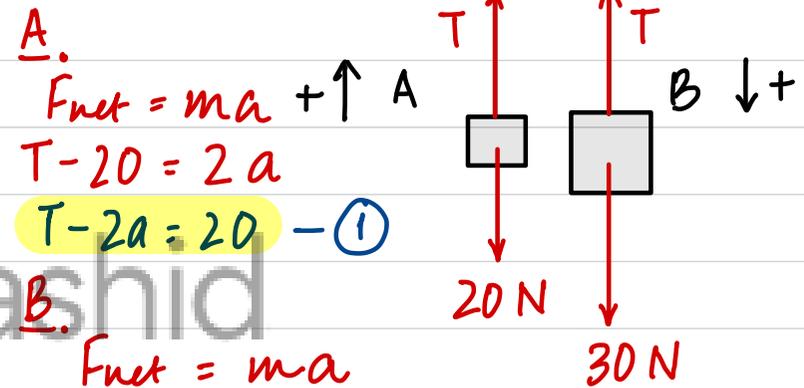
B.
 $F_{\text{net}} = ma$
 $W_B - T = m_B a$

Solving both equations simultaneously gives the value of "T" and "a".

Convention: Take the direction of motion as positive.

Example

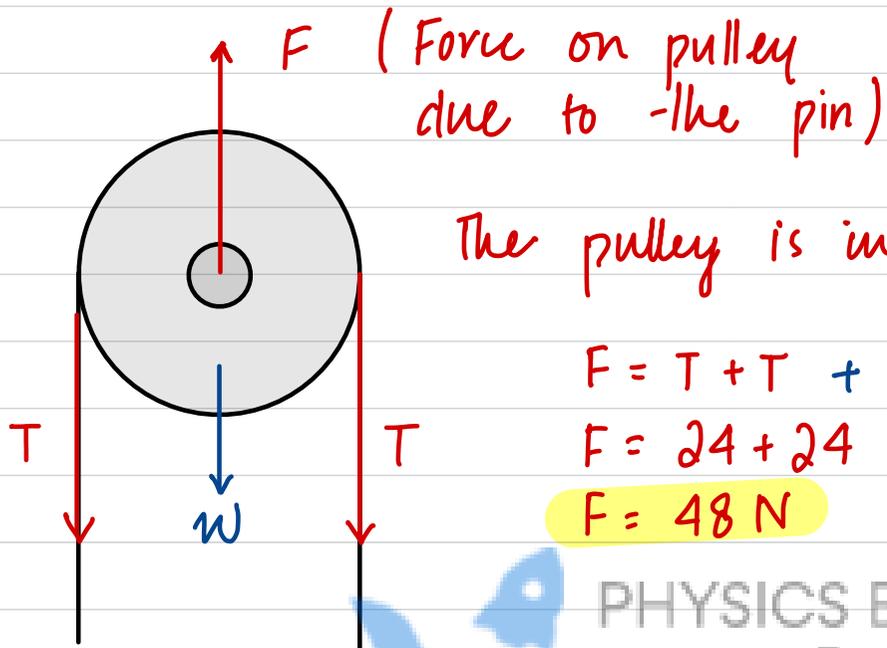
$m_A = 2 \text{ kg}$
 $m_B = 3 \text{ kg}$
 $g = 10 \text{ N kg}^{-1}$



A.
 $F_{\text{net}} = ma$ + \uparrow A
 $T - 20 = 2a$
 $T - 2a = 20$ - (1)

B.
 $F_{\text{net}} = ma$
 $30 - T = 3a$
 $T + 3a = 30$ - (2)

$T = 24 \text{ N}$ $a = 2 \text{ ms}^{-2}$



F (Force on pulley due to the pin)

The pulley is in equilibrium

$$F = T + T + W \rightarrow \text{if pulley had weight}$$

$$F = 24 + 24$$

$$F = 48 \text{ N}$$



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- 12 The diagram shows a barrel suspended from a frictionless pulley on a building. The rope supporting the barrel goes over the pulley and is secured to a stake at the bottom of the building.

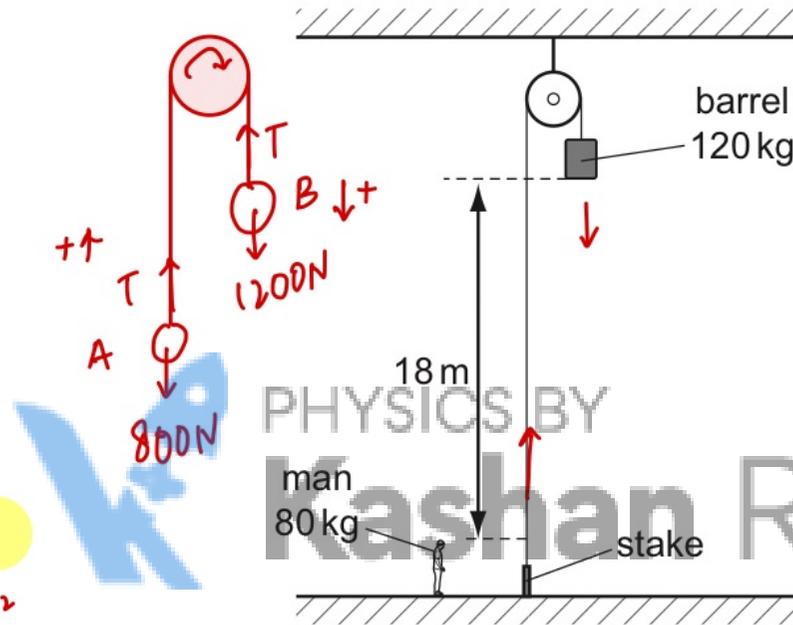
A
 $F_{\text{net}} = ma$
 $T - 800 = 80a$

$T - 80a = 800$

B
 $F_{\text{net}} = ma$
 $1200 - T = 120a$

$T + 120a = 1200$

$T = 960\text{N}$ $a = 2\text{ms}^{-2}$



$v = ?$
 $u = 0$
 $a = 2\text{ms}^{-2}$
 $s = 9\text{m}$

$v^2 - u^2 = 2as$
 $v^2 - 0 = 2(2)(9)$

$v = 6\text{ms}^{-1}$

A man stands close to the stake. The bottom of the barrel is 18 m above the man's head. The mass of the barrel is 120 kg and the mass of the man is 80 kg.

The man keeps hold of the rope after untying it from the stake and is lifted upwards as the barrel falls.

What is the man's upward speed when his head is level with the bottom of the barrel? (Use $g = 10\text{ms}^{-2}$.)

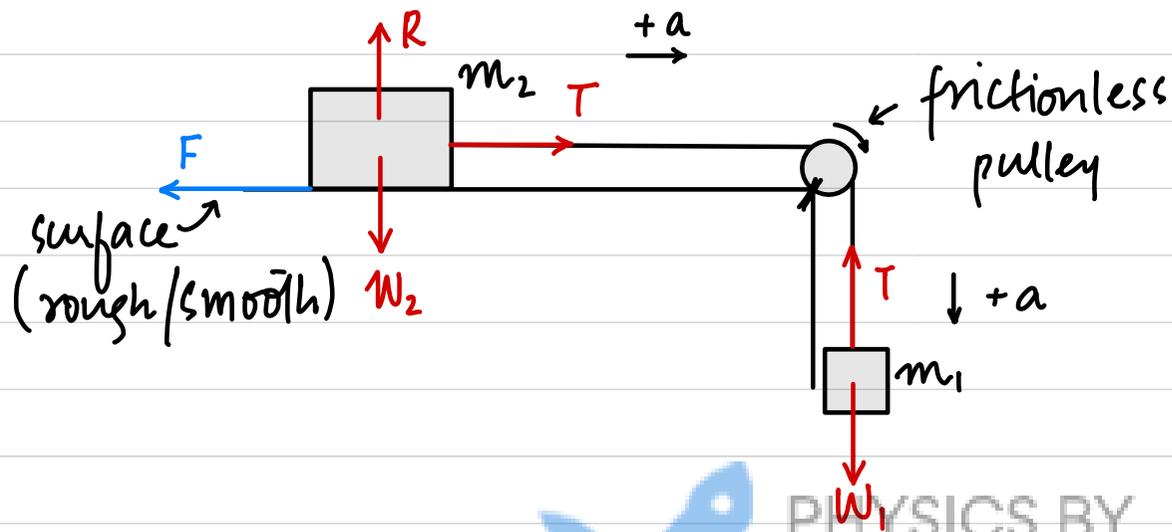
A 6ms^{-1}

B 8ms^{-1}

C 13ms^{-1}

D 19ms^{-1}

Case #4.



① $F_{net} = ma$
 $W_1 - T = m_1 a$

② $F_{net} = ma$
if smooth surface
 $T = m_2 a$

if rough surface
 $T - F = m_2 a$



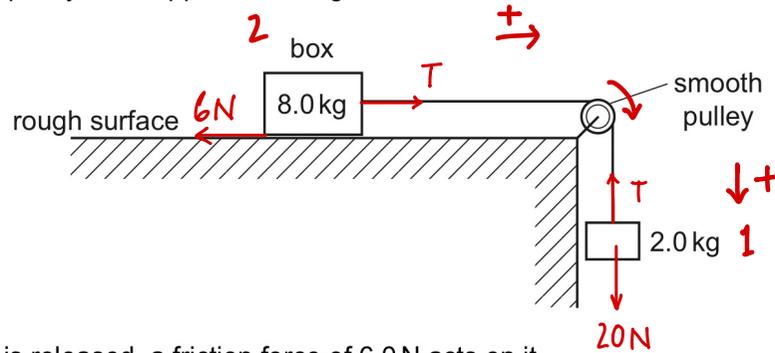
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$\Sigma F_y = 0$

$R = W_2$

- 11 A box of mass 8.0 kg rests on a horizontal, rough surface. A string attached to the box passes over a smooth pulley and supports a 2.0 kg mass at its other end.



When the box is released, a friction force of 6.0 N acts on it.

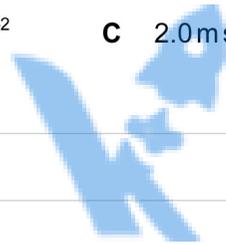
What is the acceleration of the box?

- A 1.4 ms^{-2} B 1.7 ms^{-2} C 2.0 ms^{-2} D 2.5 ms^{-2}

$$1. \quad F_{\text{net}} = ma$$
$$20 - T = 2a$$
$$T + 2a = 20$$

$$2. \quad F_{\text{net}} = ma$$
$$T - 6 = 8a$$
$$T - 8a = 6$$

$$T = 17.2 \text{ N} \quad a = 1.4 \text{ ms}^{-2}$$



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- 3 (a) State Newton's first law of motion.

An object continues in the state of rest or uniform motion unless acted upon by a resultant force [1]

- (b) A box slides down a slope, as shown in Fig. 3.1.

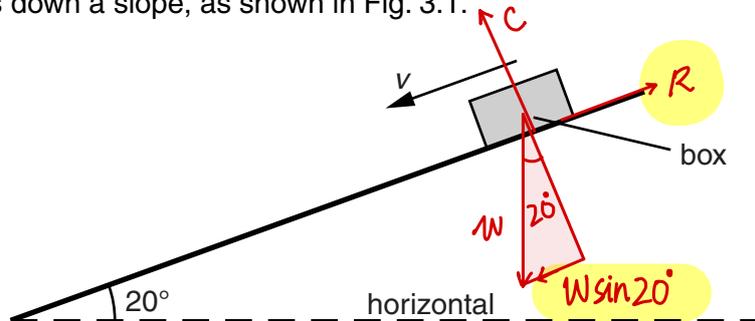


Fig. 3.1

The angle of the slope to the horizontal is 20° . The box has a mass of 65 kg. The total resistive force R acting on the box is constant as it slides down the slope.

- (i) State the names and directions of the other two forces acting on the box.

1. *Weight acting vertically downwards.*
2. *Normal contact acting perpendicular to plane.*

[2]

- (ii) The variation with time t of the velocity v of the box as it moves down the slope is shown in Fig. 3.2.

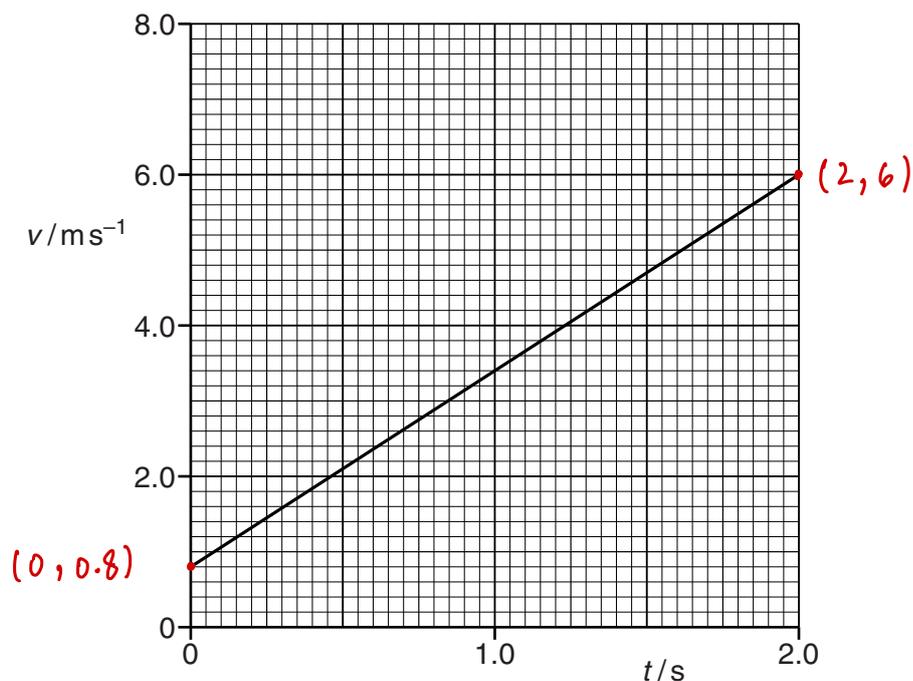


Fig. 3.2

1. Use data from Fig. 3.2 to show that the acceleration of the box is 2.6 ms^{-2} .

$$m = \frac{v_2 - v_1}{x_2 - x_1}$$

$$m = \frac{6 - 0.8}{2 - 0}$$

$$m = a = 2.6 \text{ ms}^{-2}$$

[2]

2. Calculate the resultant force on the box.

$$F_{\text{net}} = ma$$

$$= 65 \times 2.6$$

$$= 169 \text{ N}$$

resultant force = 170 N [1]

3. Determine the resistive force R on the box.

$$F_{\text{net}} = W \sin 20^\circ - R$$

$$169 = (65 \times 9.8) \sin 20^\circ - R$$

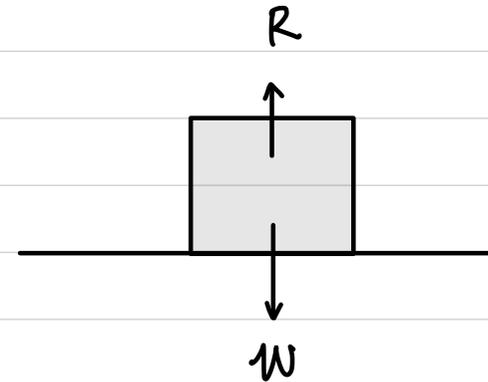
$$R = (65 \times 9.8) \sin 20^\circ - 169$$

$$R = 49 \text{ N}$$

$R =$ N [3]

Newton's 3rd Law

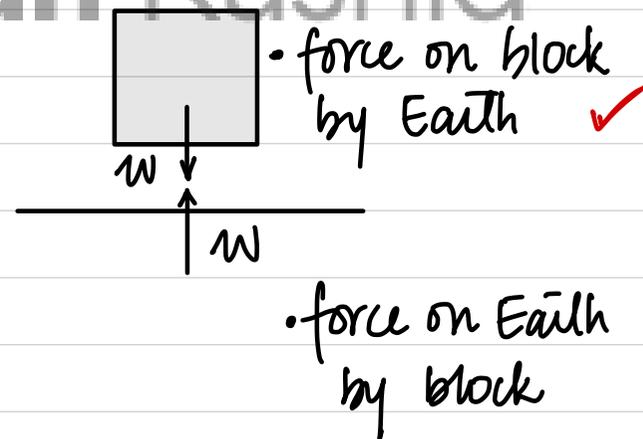
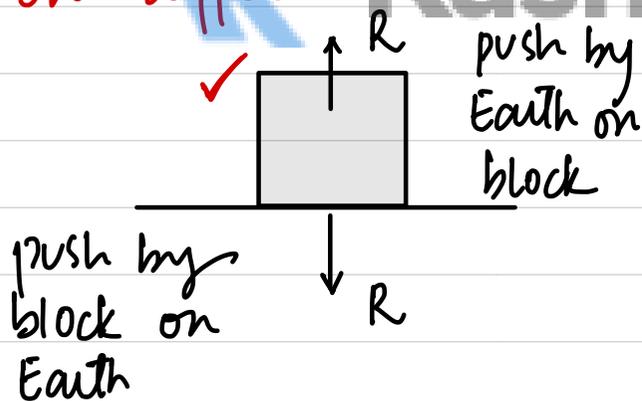
If body A exerts a force on body B, body B exerts an equal but opposite force on body A.



Action and Reaction pair of forces are

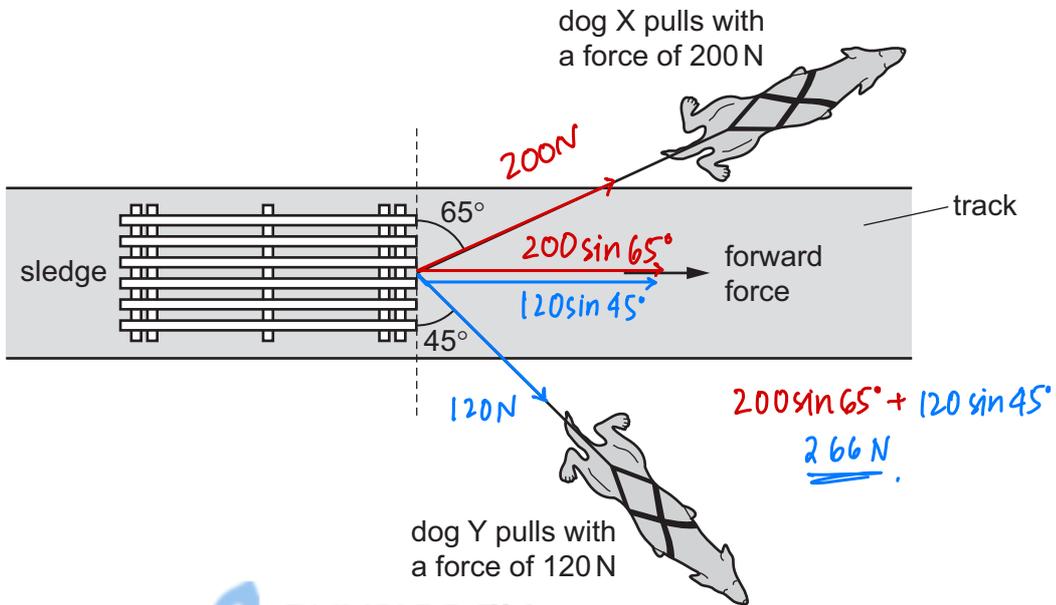
- Equal in magnitude
- Opposite in direction
- Same type of forces.
- Acting on different bodies.

- Equal in magnitude
- Opposite in direction
- Same type of forces.
- Acting on different bodies.



Additional Materials:

- 3 Two dogs pull a sledge along an icy track, as shown.

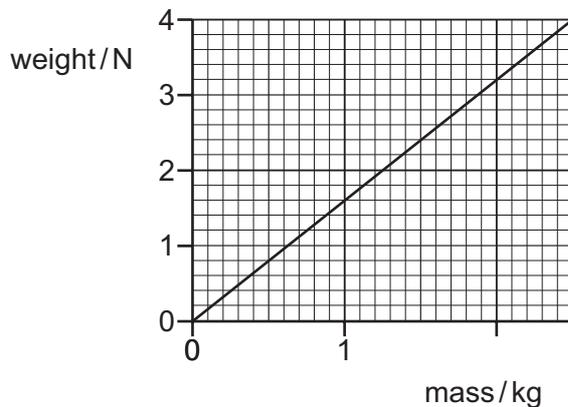


Dog X pulls with a force of 200 N at an angle of 65° to the front edge of the sledge. Dog Y pulls with a force of 120 N at an angle of 45° to the front edge of the sledge.

What is the resultant forward force on the sledge exerted by the two dogs?

- A 80 N B 170 N C 270 N D 320 N

- 7 The graph shows the variation with mass of the weight of objects on a particular planet.

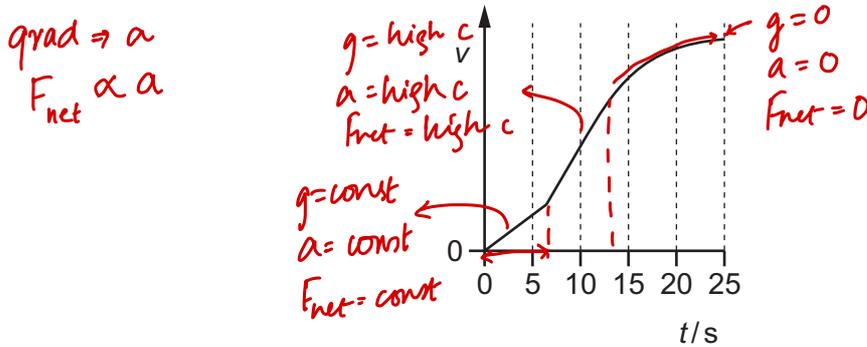


What is the value of the acceleration of free fall on the planet?

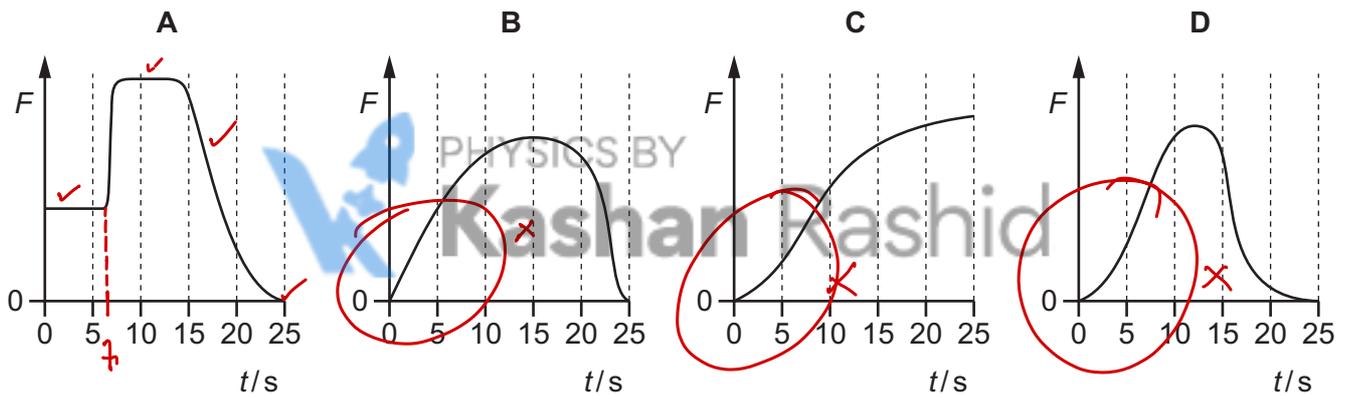
- A 0.63 ms^{-2} B 1.6 ms^{-2} C 3.2 ms^{-2} D 9.8 ms^{-2}

Additional Materials:

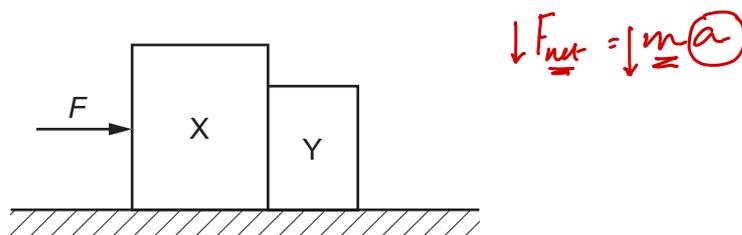
- 10 A bus takes a time of 25 s to reach a constant speed while travelling in a straight line. A graph of speed v against time t is shown.



Which graph shows the variation with t of the resultant force F on the bus?



- 11 A single horizontal force F is applied to a block X which is in contact with a separate block Y as shown.



The blocks remain in contact as they accelerate along a horizontal frictionless surface. Air resistance is negligible. X has a greater mass than Y.

Which statement is correct?

- A The acceleration of X is equal to force F divided by the mass of X.
- B The force that X exerts on Y is equal to F .
- C The force that X exerts on Y is less than F .
- ~~D~~ The force that X exerts on Y is less than the force that Y exerts on X.