Newton's 1st Law of Motion

"An object continues in a state of rest or uniform motion unless acted upon by a resultant force."

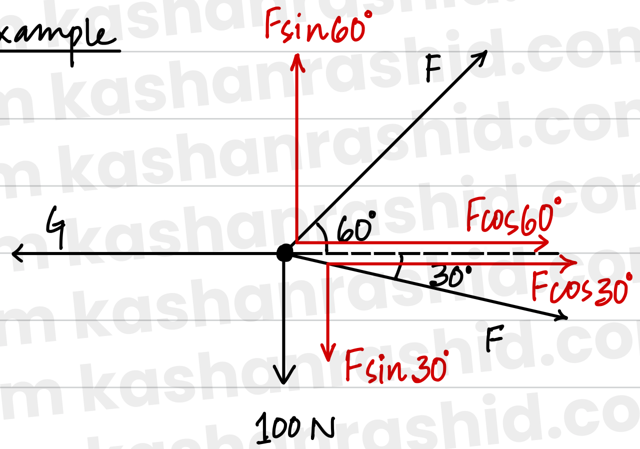
rest: speed = 0

uniform motion: • speed = constant
• straight line

$\Sigma F = 0$ → $\Sigma F_x = 0$ (forward forces = backward forces)
→ $\Sigma F_y = 0$ (upward forces = downward forces)

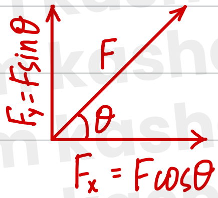
- It is one of the conditions of equilibrium.
- It is also called law of inertia.
  - ↳ A property of matter to resist sudden changes in the state of rest or motion.

Example



The body is in equilibrium. Find the values of F and G.

Resolve the forces along x-axis & y-axis.



$\Sigma F_x = 0$

$F\cos 60^\circ + F\cos 30^\circ = G$ — (1)

$\Sigma F_y = 0$

$F\sin 60^\circ = F\sin 30^\circ + 100$

$F\sin 60^\circ - F\sin 30^\circ = 100$

$F(\sin 60^\circ - \sin 30^\circ) = 100$

$F = 273.2\ N$

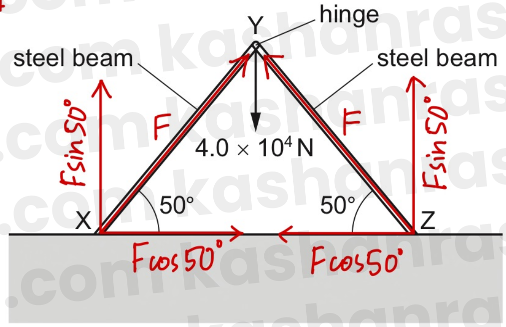
$G = 373.2\ N$

14 Two rigid steel beams XY and YZ are fixed at their lower ends and are hinged at Y. Each beam is inclined at 50° to the horizontal, as shown. A weight of 4.0×10^4 N hangs from Y. The structure is in equilibrium.

$F\sin 50° + F\sin 50° = 4\times10^4$

$F(\sin 50° + \sin 50°) = 4\times10^4$

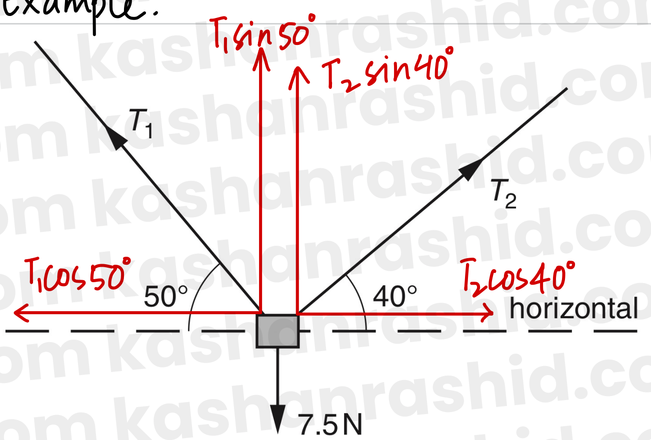
$F = 2.6\times10^4 N$



What is the force exerted by each beam on the hinge at Y?

A 2.6×10^4 N **B** 3.1×10^4 N **C** 5.2×10^4 N **D** 6.2×10^4 N

Example.



$\Sigma F_x = 0$

$T_1\cos 50° = T_2\cos 40°$

$T_1\cos 50° - T_2\cos 40° = 0$ — ①

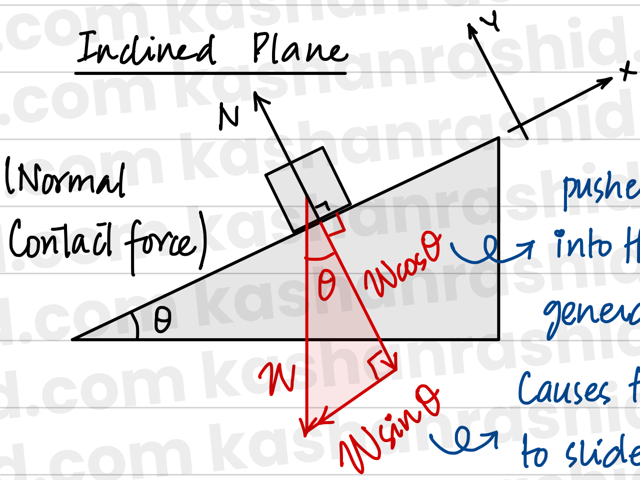
$\Sigma F_y = 0$

$T_1\sin 50° + T_2\sin 40° = 7.5$ — ②

solving simultaneously...

$T_1 = 5.7$ N $T_2 = 4.8$ N

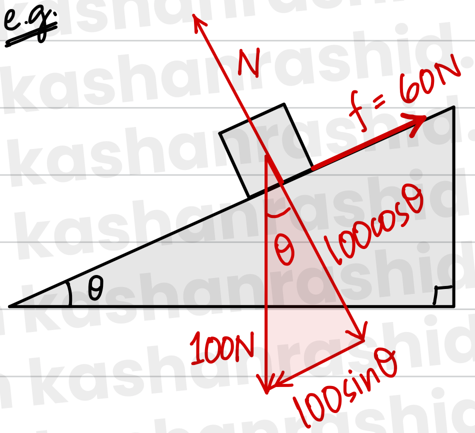
Inclined Plane



Wcosθ: pushes the body into the plane and generates a contact force.

Wsinθ: Causes the body to slide down the plane.

e.g.



The block placed on the surface is about to slide down the plane. It's weight is 100N. If the max friction force between box and surface is 60N, determine

a) the angle of inclination beyond which the block slides down

b) the normal contact force on the block at this angle.

a) $100\sin\theta = 60$

$\sin\theta = \frac{60}{100}$

$\theta = 36.87 \simeq 37°$

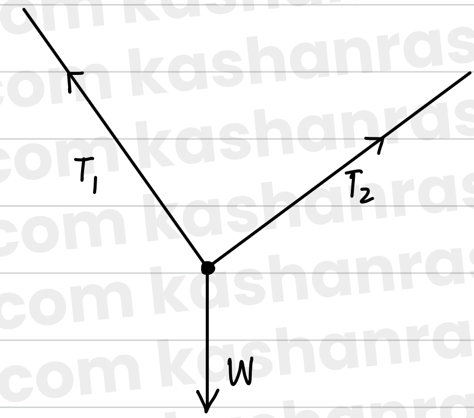
b) $N = 100\cos\theta$

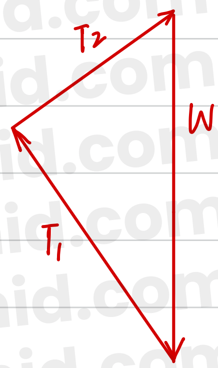
$N = 100\cos(36.87)$

$N = 80N$

"If a body is in equilibrium, a closed vector triangle is formed where the head of one vector touches the tail of other."

"Following vectors"





Newton's 2nd Law of Motion

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

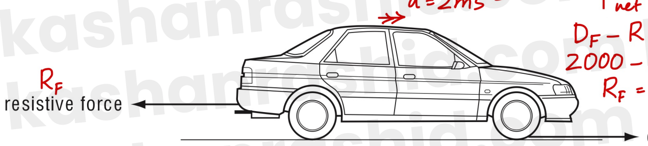
$F_{net} \propto \frac{\Delta p}{\Delta t} \rightarrow$ $F_{net} = \frac{\Delta p}{\Delta t}$

$F_{net} = ma$

$F_{net} = \dot{m}v$

forward force − backward force = ma

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 $2.0\,\mathrm{m\,s^{-2}}$



$F_{net} = ma$

$D_F - R_F = ma$

$2000 - R_F = (750)(2)$

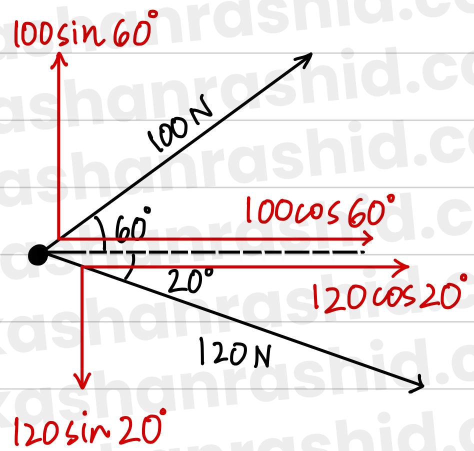
$R_F = 500N$

$D_F = 2000N$

What is the resistive force acting horizontally?

(A) 0.5 kN **B** 1.5 kN **C** 2.0 kN **D** 3.5 kN

e.g.



Find the resultant of these two forces.

ΣF_x

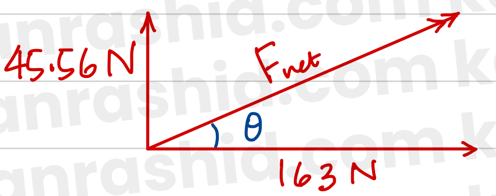
$100\cos 60° + 120\cos 20°$

$162.8 \simeq 163\,N$

ΣF_y

$100\sin 60° - 120\sin 20°$

$45.56\,N$



$h^2 = p^2 + b^2$

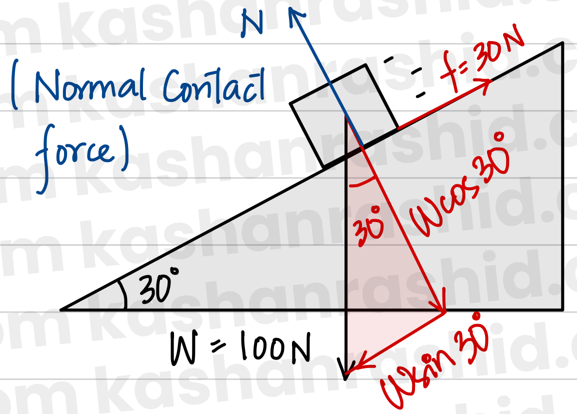
$= \sqrt{45.56^2 + 162.8^2}$

$F_{net} = 169\,N$

$\tan\theta = \left(\frac{45.56}{162.8}\right)$

$\theta = 15.6°$

Inclined Plane



A box of weight 100N slides down an inclined plane tilted at 30° to the horizontal. Determine the acceleration of the box if,

a) the plane is smooth (no friction)

b) the plane has a constant friction of 30N.

a) $F_{net} = ma$

$W \sin\theta = ma$

$mg \sin\theta = ma$

$a = g \sin\theta$

$a = 9.81 \sin 30°$

$a = 4.91 \text{ ms}^{-2}$

b) $F_{net} = ma$

$W \sin 30° - f = ma$

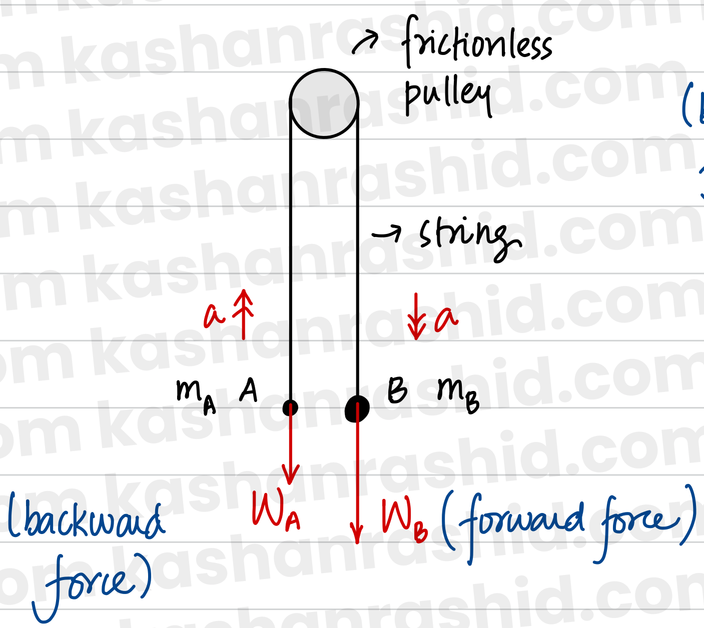
$100 \sin 30° - 30 = \left(\frac{100}{9.81}\right) a$

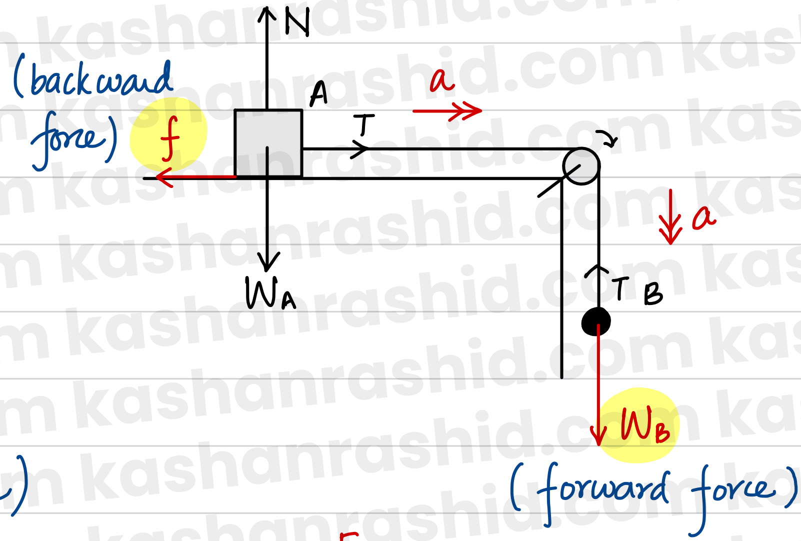
$a = 1.96 \text{ ms}^{-2}$

$N = W \cos 30°$

$N = 100 \cos 30°$

Connected Bodies





$F_{net} = ma$

$W_B - f = (m_A + m_B)a$

$m_B > m_A$

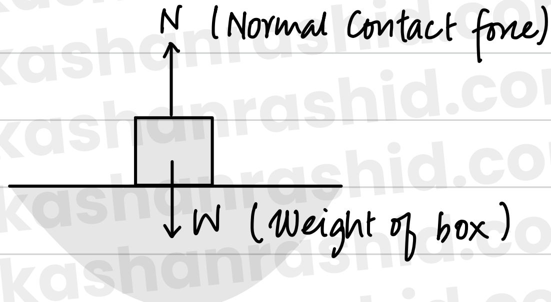
$F_{net} = ma$

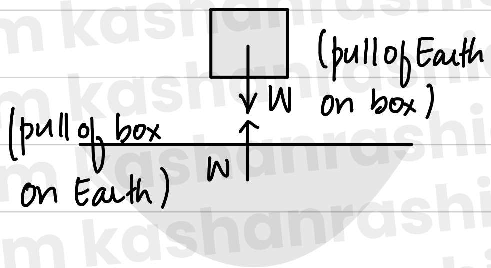
$W_B - W_A = (m_A + m_B)a$

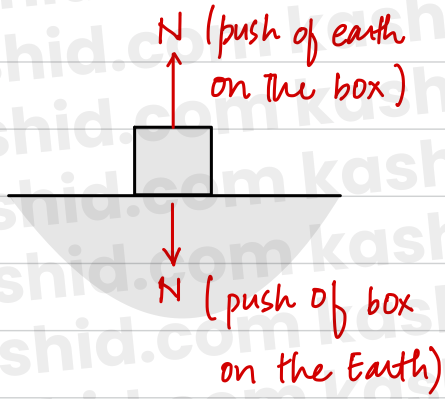
Newton's 3rd Law of Motion

"If body A exerts a force on body B, B exerts the same force on A, which is equal in magnitude but opposite in direction."

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

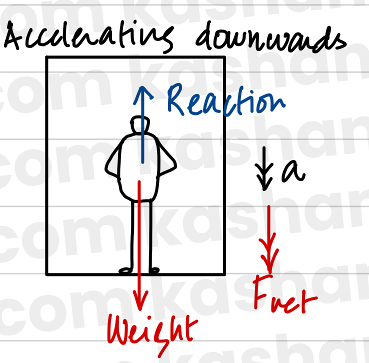






- ☒ Same type of forces
- ☒ Acting on different bodies

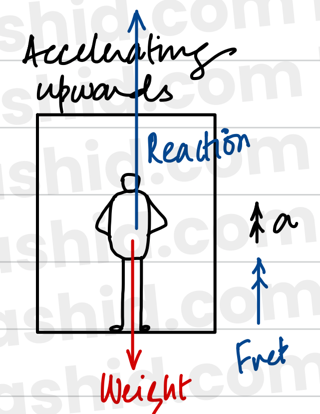
- Weight = Reaction if body is either at rest or moving at constant speed.



Weight > Reaction

$F_{net} = ma$

Weight - Reaction = ma

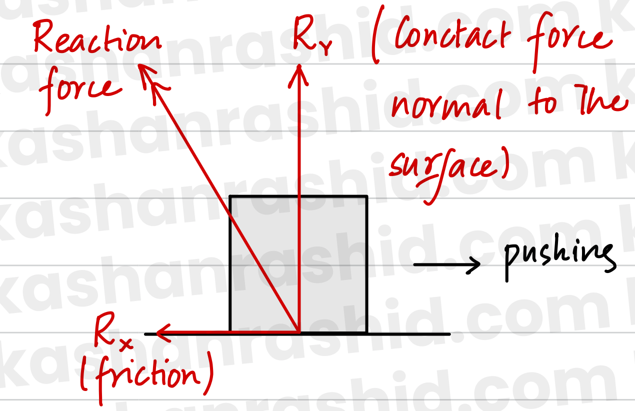


Reaction > Weight

$F_{net} = ma$

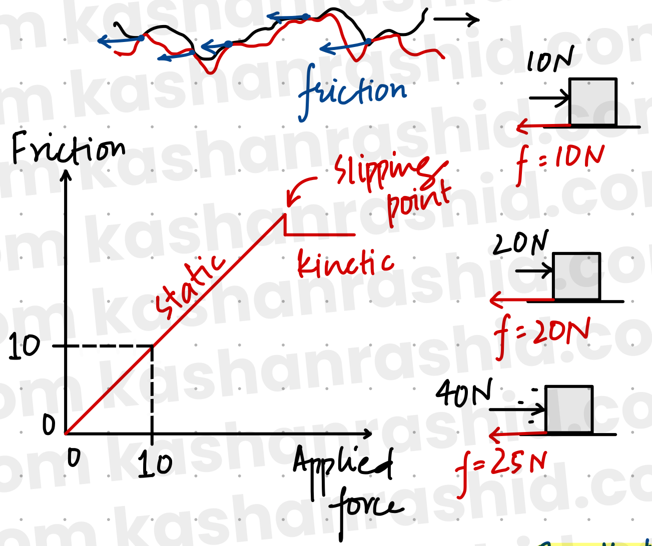
Reaction - Weight = ma

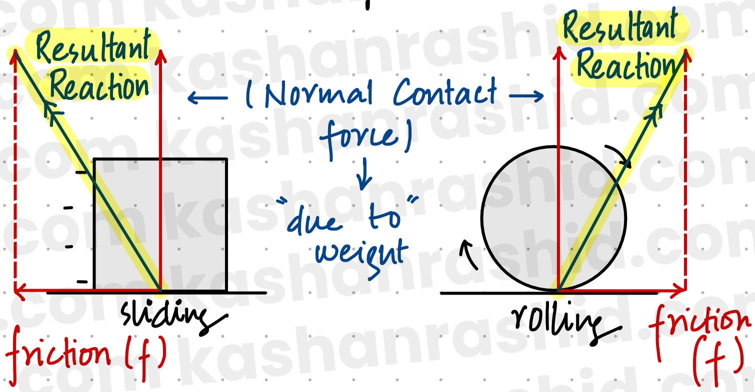
{Contact}



Friction Force

- It is a resistive force that tends to slow down moving objects.
- It is a contact and a reaction force.





Mass

It is the measurement of inertia.

More inertia → More mass in the body!

Inertia is a property of matter such that it resists sudden changes in its state of rest or motion.

- SI Unit: kg
- Scalar

Drag Force

When object moves in a fluid, it experiences a drag force.

drag force → viscous drag

- Air resistance
- Viscous drag (water, oil, glycerine)

Factors effecting Drag force

1. Viscosity of fluid

more viscosity → thicker fluid
↓
more drag force

drag force ∝ viscosity

2. Surface Area

greater surface area → more drag force

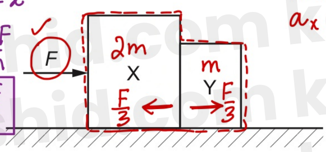
more molecules collide with the body so cumulative force inc.

3. Speed of object

greater speed → greater drag force.

{Air resistance increases on a falling body until the body reaches Terminal velocity when Weight = Air resistance.}

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.

2 **(a)** State the two conditions for a system to be in equilibrium.

1. Sum of all the forces acting on the system must be zero.

2. Sum of all the moments acting on the body must be zero.

[2]

(b) A paraglider P of mass 95 kg is pulled by a wire attached to a boat, as shown in Fig. 2.1.

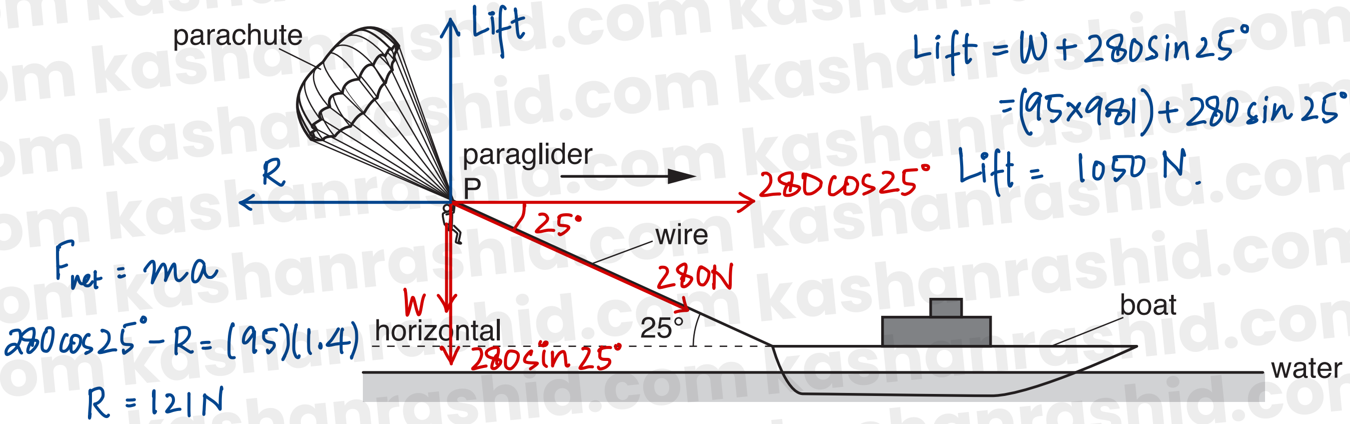


Fig. 2.1

The wire makes an angle of 25° with the horizontal water surface. P moves in a straight line parallel to the surface of the water.

The variation with time t of the velocity v of P is shown in Fig. 2.2.

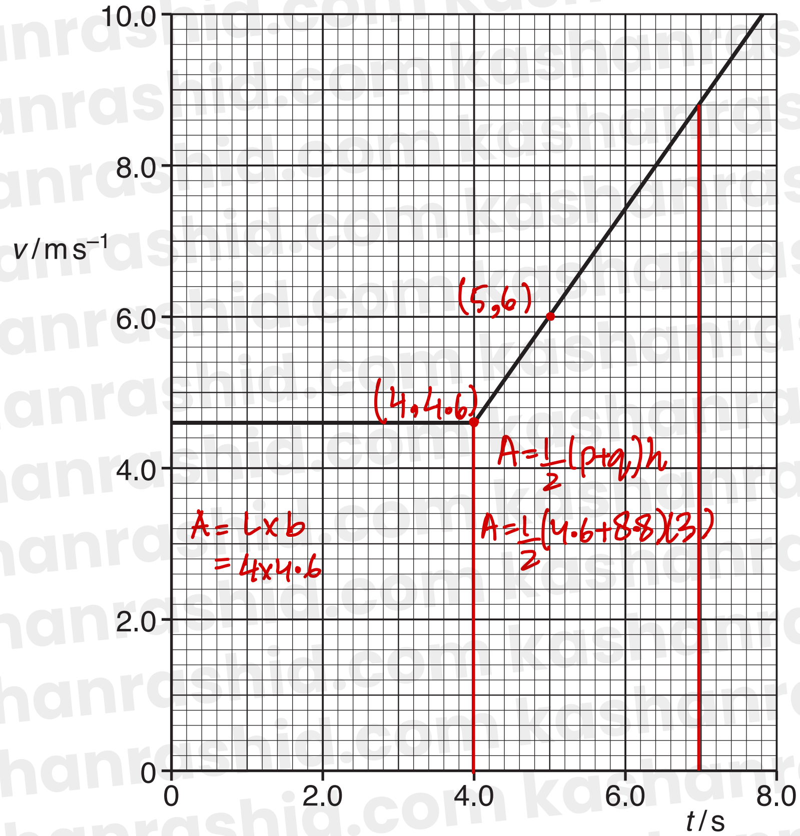


Fig. 2.2

(i) Show that the acceleration of P is $1.4\,m\,s^{-2}$ at time $t = 5.0\,s$.

grad = $\frac{6-4.6}{5-4}$

grad = a = 1.4 ms^{-2}

[2]

(ii) Calculate the total distance moved by P from time $t = 0$ to $t = 7.0\,s$.

distance = ...38.5........... m [2]

(iii) Calculate the change in kinetic energy of P from time $t = 0$ to $t = 7.0\,s$.

$\Delta KE = \frac{1}{2}m(v^2-u^2)$

$\frac{1}{2}(95)(8.8^2-4.6^2)$

2673 J

change in kinetic energy = ...2700 J........... J [2]

(iv) The tension in the wire at time $t = 5.0\,s$ is 280 N.

Calculate, for the horizontal motion,

1. the vertical lift force F supporting P,

F = ... N [3]

2. the force R due to air resistance acting on P in the horizontal direction.

R = ... N [3]

[Total: 14]

3 A small remote-controlled model aircraft has two propellers, each of diameter 16 cm. Fig. 3.1 is a side view of the aircraft when hovering.

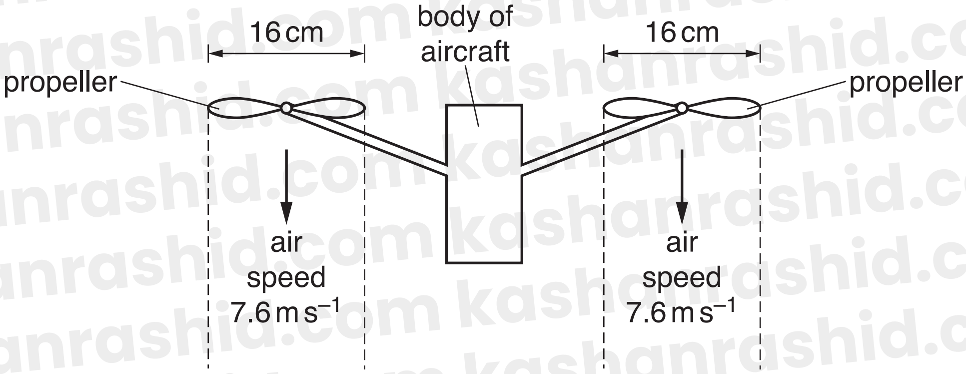


Fig. 3.1

Air is propelled vertically downwards by each propeller so that the aircraft hovers at a fixed position. The density of the air is 1.2 kg m^{-3}. Assume that the air from each propeller moves with a constant speed of 7.6 m s^{-1} in a uniform cylinder of diameter 16 cm. Also assume that the air above each propeller is stationary.

(a) Show that, in a time interval of 3.0 s, the mass of air propelled downwards by **one** propeller is 0.55 kg.

$\dot{m} = \rho A v$

$= 1.2 \times \pi (0.08)^2 \times (7.6)$

$\dot{m} = 0.183 \text{ kg s}^{-1}$

$\dot{m} = \frac{\Delta m}{\Delta t}$

$\Delta m = 0.183 \times 3$

$= 0.55 \text{ kg}$

[3]

(b) Calculate:

(i) the increase in momentum of the mass of air in **(a)**

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

$= 0.55(7.6 - 0)$

$= 4.18$

increase in momentum = 4.18 ≈ 4.2 N s [1]

(ii) the downward force exerted on this mass of air by the propeller.

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

$= \frac{4.18}{3} = 1.39$

force = 1.4 N [1]

(c) State:

(i) the upward force acting on **one** propeller

force = ...1.4.... N [1]

(ii) the name of the law that explains the relationship between the force in **(b)(ii)** and the force in **(c)(i)**.

....Newton's 3rd Law of Motion.... [1]

(d) Determine the mass of the aircraft.

$W = 1.4 + 1.4$

$mg = 2.8$

$m = \frac{2.8}{9.81}$ $m = 0.285$

mass = ...0.29.... kg [1]

(e) In order for the aircraft to hover at a very high altitude (height), the propellers must propel the air downwards with a greater speed than when the aircraft hovers at a low altitude. Suggest the reason for this.

....

.... [1]

(f) When the aircraft is hovering at a high altitude, an electric fault causes the propellers to stop rotating. The aircraft falls vertically downwards. When the aircraft reaches a constant speed of $22\,m\,s^{-1}$, it emits sound of frequency 3.0 kHz from an alarm. The speed of the sound in the air is $340\,m\,s^{-1}$.

Determine the frequency of the sound heard by a person standing vertically below the falling aircraft.

frequency = ... Hz [2]

[Total: 11]