Newton's Laws of Motion

Exercise Solutions

Solution 1:

Here

time = t = 2s , distance = d = 10 m, mass = m = 2 kg and initial velocity = u = 0 m/s

We know,

$s = ut + 1/2\ at^2$ [equation of motion]

on substituting the values, we have

$10 = 1/2 \times a \times 4 = 2a$

$\Rightarrow a = 5\ m/s^2$

Now, the force = F = ma = 25 = 10N

Solution 2:

Here, initial velocity = u = 40 km/h or 11.12 m/s

mass of the car = 2000 kg

Distance = s = 4m

We know, $2as = v^2 - u^2$

[equation of motion]

$8a = 0 - 11.12^2 = -123.65$

$\Rightarrow a = 15.45\ m/s^2$

Now, the force = F = ma = $2000 \times 15.45 = 3.1 \times 10^4$ N

Solution 3:

From given information's:

initial velocity = u = 0 m/s

Final velocity = v = 5×10^6 m/s

mass of the electron= 9.1×10^{-31} kg

Distance = s = 1 cm

We know, $2as = v^2 - u^2$

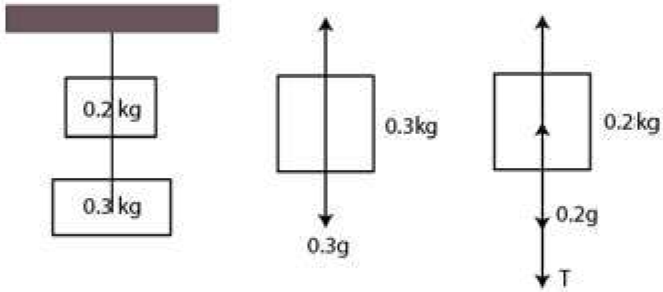
[equation of motion]

$2a \times 0.01 = (5 \times 10^6)^2 - 0 = 25 \times 10^{12}$

=> $a = 12.5 \times 10^{14}$ m/s^2

Now, the force = F = ma = $9.1 \times 10^{-31} \times 12.5 \times 10^{14} = 1.1 \times 10^{-15}$N

Solution 4:



The first string is being stretched due to the weight of both the blocks.

The tension in the first string = 1st block weight + 2nd block weight

= 0.2 x 10 + 0.3 x 10 = 5N

Second string is being stretched due to the weight of the second block

Tension in the first string = weight of block 2 = 0.3 x 10 = 3N

Therefore, tension in the two strings are 5 N and 3N respectively.

Solution 5:

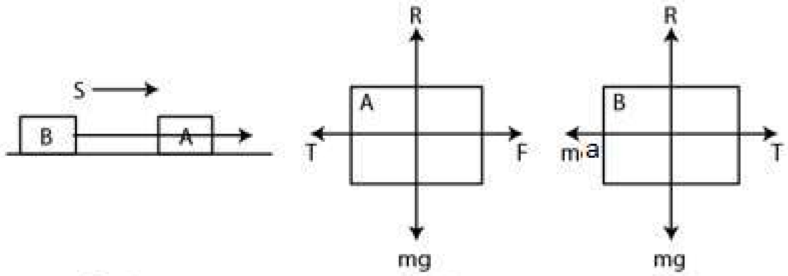


fig 1 fig 2 fig 3

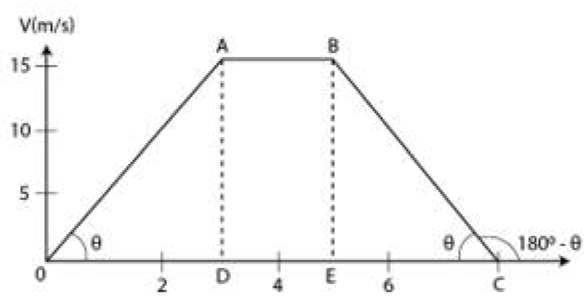
We know, equation of motion can be written as:
T + ma - F = 0 ...(1) or
T = ma ...(2)

From (1) F = T + ma

or F = T + T = 2T [Using (2)]

=> T = F/2

Solution 6:
Mass = 50 g = 5×10^{-2} kg



Slope for region at t = 2s:
Slope of OA = tan θ = BE/EC = 15/3 =5 m/s^2

Force along the motion, $F = ma = 5 \times 10^{-2} \times 5 = 0.25N$

Slope for region at t = 4s :
Slope of AB = 0 = acceleration
=> F = ma = 0

Slope for region at t = 6s:
acceleration=slope of BC
from figure, in triangle BEC, $\tan\theta = BE/EC = 15/ = 5$
Slope of BC = $\tan(180-\theta) = -\tan\theta = -5\ m/s^2$ (deceleration)

Force = $F = ma = 5 \times 10^{-2} \times 5 = 0.25$ N [opposite to the motion]

Solution 7:
Let F be the contact force between masses, say m_1 and m_2 and f be the force exerted by experiment.

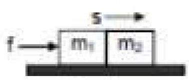


fig 1

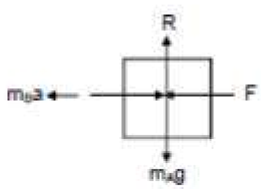


fig 2

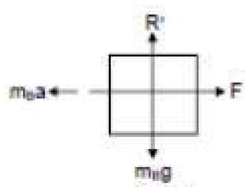


fig 3

$F + m_A a - f = 0$
or $F = f - m_A a$ ..(1)
and
$m_B a - F = 0$
=> $F = m_B a$ ...(2)

From both the above equations,
$f - m_A a = m_B a$

or $f = a(m_A + m_B)$
or $f = F/m_B (m_A + m_B)$
or $f = F(1 + m_A/m_B)$
[again using (2)]

Thus, the force exerted by the experimenter on A is
$F\left(1 + \frac{m_b}{m_a}\right)$

Solution 8:
Initial velocity = 0
Final velocity =30 m/s
Mass of the droplet= 4 mg = 4 x 10^{-6} kg
Radius of the droplet = 1mm = 10^{-3} m
Distance covered by the drop on the head, s = 10^{-3} m

Using the equation of motion

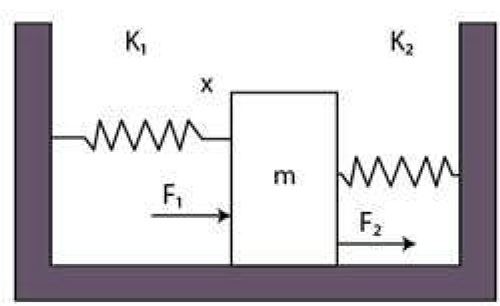
$2as = v^2 - u^2$
$2a \times 10^{-3} = 900$
=> $a = 45 \times 10^3\ m/s^2$
The force = F = ma = 1.8N

Solution 9:

Mass of the particle= 0.3 kg
Value of k = 15 N/m
x = 20 cm = 0.2 m
Now, Force = F = ma = kx

=> a = kx/m = 10 m/s^2

Solution 10: The Block m towards left through displacement x.



Thus, the net force = F = $k_1x + k_2x$
Where k_1 x force generate due to compression and force k_2 x due to expandation.
=> F = $(k_1+k_2)x$

So, the acceleration = a = F/m = $[(k_1+k_2)x]/m$ opposite to the displacement.

Solution 11:

Initial velocity of small block = 0 m/s

Given, F = 10 and m = 5

Acceleration = a = F/m = 2 m/s^2

Distance = s = 20 cm or 0.2 m

Using equation of motion, $s = ut + (1/2)\,at^2$

=> $0.2 = (1/2) \times 2 \times t^2$

Or t = 0.45 s

Solution 12:

At the depth let the rope makes angle θ with the vertical.

From the free body diagram, we have

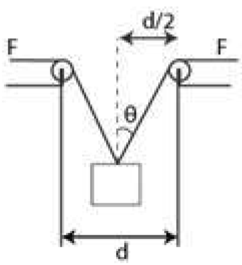


fig 1

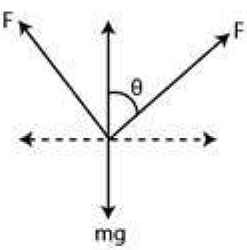


fig 2

$F\cos\theta + F\cos\theta - mg = 0$

=> $F = mg/(2\cos\theta)$

As the man moves up. θ increase means cos θ decreases. Thus, F increases.

When the man is at depth h

$$\cos\theta = \frac{h}{\sqrt{(d/2)^2 + h^2}}$$

$$\text{Force} = \frac{mg}{\dfrac{h}{\sqrt{\dfrac{d^2}{4} + h^2}}} = \frac{mg}{4h}\sqrt{d^2 + 4h^2}$$

Solution 13:

From the free body diagram,

The apparent weight of the box = 0.5 x 10-2x0.5 = 4N

Now, the reaction force on the box B due to A is = apparent weight of box A= 4N

Solution 14:

Mass of the bob = 50g or 0.05 kg

When the elevator is at rest the tension in the string weight of the bob = 9.8 x 50/1000 = 0.49N

a) When it goes up with an acceleration in upward direction a pseudo force acts on the bob in downward direction.

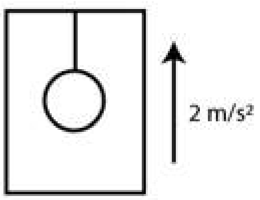


fig 1

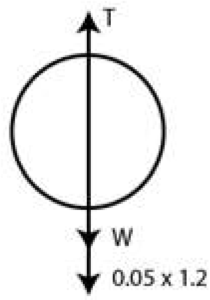


fig 2

The tension in the string becomes = T =0.49+0.05x1.2 = 0.55N

b) When it goes up with a deceleration in upward direction a pseudo force acts on the bob in downward direction with negative sign.

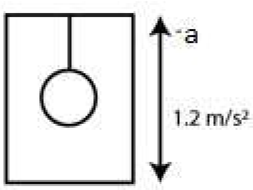


fig 3

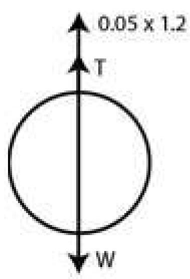


fig 4

The tension in the string becomes= T = 0.49-0.05x1.2=0.43N

c) When the elevator makes uniform motion: T – W = 0

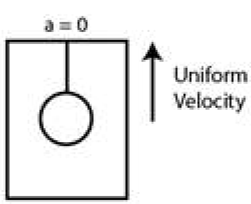


fig 5

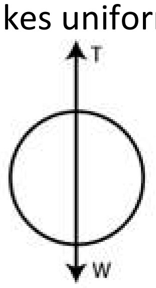


fig 6

The tension in the string becomes = T =0.05 x 9.8 = 0.49N

d) T + 0.05 x 1.2 – W = 0

=> The tension in the string becomes = T = 0.49 - (0.05 x 1.2) = 0.43 N

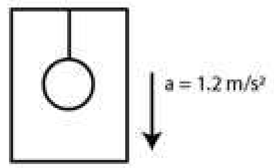


fig 7

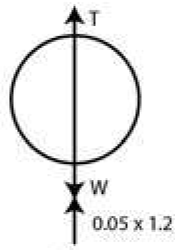


fig 8

e) When it goes down with a deceleration in downward direction a pseudo force acts on the bob in upnward direction with negative sign.

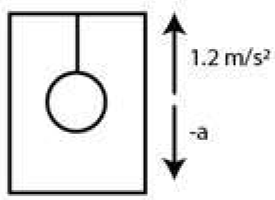


fig 9

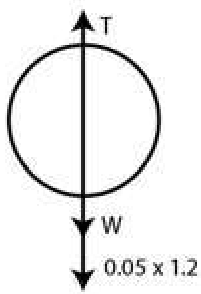


fig 10

The tension in the string becomes = T =0.49 + 0.05x1.2=0.55N

f) When it goes up with uniform velocity in downward direction no pseudo force.

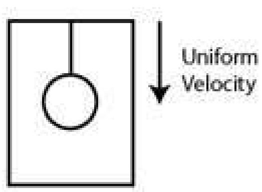


fig 11

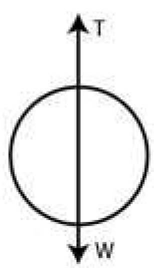


fig 12

In this case, uniform velocity acceleration = 0

T – W = 0

The tension in the string becomes = T = W = 0.49N

Solution 15:

Maximum weight = 72Kg

Minimum weight = 60 kg

When the elevator moves with acceleration, pseudo force acts on the person in the downward direction.

In this case the weight is maximum as measured by the weighing machine,

$72x9.9=W+ma$ -----(1)

Where a = acceleration of the elevator.

When the elevator moves with deceleration, pseudo force acts on the person in the upward direction.

In this case the weight is minimum as measured by the weighing machine,

$60x9.9=W-ma$ -----(2)

Adding (1) and (2) we get,

$132x9.9 = 2mg = 2mx9.9$

Thus, the weight W = 66 kg

Again, Subtracting (2) from (1)

$12x9.9=2ma=2x66xa$

Thus, the magnitude of acceleration = a = 0.9 m/s^2

Solution 16:

Mass of block A =1.5 kg

Mass of block B = 3 kg

From the free body diagram,

The tension in the string of block A = 1.5g + 11g/10 g N

The tension in the string of block A = 3g x 11g/10 N

Solution 17:

Given:

Mass of the block = m = 2 kg

Spring constant = k = 100 N/m

The block is in equilibrium the force due to spring must be equal to the weight of the block

mg = kx ; Where x is the required extension,

on putting values, we get

=> x = 0.2 m

Now when 1 kg more is added to the block, the weight of the block increases to 30N (given)

Now, mg = kx

[Using the equation of equilibrium]

or x = 0.3 m

Again, Elongation = elongation due to 3kg - elongation due to 2kg

= 0.3-0.2 = 0.1m

Solution 18:

Acceleration of the elevator =a= 2 m/s^2

Mass of the block =m= 2 kg

Apparent weight due to pseudo force = 23.6 N

In equilibrium, we have, apparent weight = kx

=> 23.6 = 100x

or x = 0.24 m

When 1kg body is added total mass, we have 3 kg

Now, Apparent weight of the block becomes = 2 x 9.8 + 3x2 + 1x98 = 35.4 N

The apparent weight=kx

=> 35.4 N=100x

Or x = 0.36m

Now as per the question we are asked to find further elongation,

Further elongation = elongation due to 3kg - elongation due to 2kg

= 0.36 - 0.24

= 0.12 m

Solution 19:

Let velocity in both cases is "u" and the Buoyancy force be " B".

The resistive force = ku, where k is proportionality constant.

Case I:

When balloon is falling down with constant velocity,

Then equation for equilibrium becomes,

$$B + ku = Mg$$

$$k = \frac{Mg - B}{u}$$

Case II: For the balloon to rise with a constant velocity v (upward)

$$B = mg + ku$$

$$B = mg + \frac{Mg - B}{u} \times u$$

$$2B = (M + m)g$$

$$m = \frac{2B}{g} - M$$

Therefore, Removed mass = M - m

$$M - m = M - \left(\frac{2B}{g} - M\right) = 2\left(M - \frac{2B}{g}\right)$$

Solution 20:
Mass = m
Case I: When it accelerates upward with acceleration “g/6”
Let B be the buoyant force, we have

$$B - mg = \frac{mg}{6}$$

$$B = \frac{7mg}{6}$$

Case II: When it accelerates downward with acceleration “g/6” after addition of sand of mass “s” kg.

$$(m + s)g - B = \frac{(m + s)g}{6}$$

$$(m + s)g - \frac{7mg}{6} = \frac{(m + s)g}{6}$$

$$\frac{5(m + s)g}{6} = \frac{7mg}{6}$$

$$s = \frac{2m}{5g}$$

Solution 21:
For a particle to move undeflected with constant velocity, net force will be zero.
=> v x A + mg = 0
Velocity must be in direction perpendicular to plane in which gravity acts.

= Av sin θ, where θ is the angle between A vector and velocity of the particle.

Now, vxA = -mg

Or A v sinθ = -mg

Or v = -mg/Asin θ

Now, for the velocity to be minimum, sin θ must be maximum,

and maximum value of sinθ = 1
Minimum velocity of the particle = v = (-mg/A) m/s

Solution 22:

Mass m_1 = 300 g or 0.3 kg

Mass m_2 = 600 g or 0.6 kg

Let the mass 1 be moving upward and mass 2 moves downward
Equation for mass 1,

$T - m_1g = m_1a$ -----(1)

Equation for mass 2,

$m_2g - T = m_2a$ ------(2)

Adding (1) and (2), we get,

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

Now putting the values, we get,

$a = 1/3\ g$

a) Using the equation of motion, $2s = ut + (1/2)\ at^2$

Where u=initial velocity = 0 m/s and tie t=2s

s = 6.65 m

b) From equation (1), we get,

$T = m_1(g+a)$
$= 0.3 \times (13g+g)$
= 0.4 g or 3.92 N

c) Force on the clamp is due to tension from both side of the pulley, i.e., twice of tension

Therefore, required force = F = 2T = 7.8N

Solution 23:

When masses m_1 and m_2 are connected by a string passing over a pulley and when the pulley comes in motion, then mass m_2 is stopped in 2 seconds.

Equation of motion:
$T - m_1 g = m_1 a$ ……..(1)

$m_2 g - T = m_2 a$ ………(2)

Solving (1) and (2), we have

$$a = \frac{(m1 - m2)g}{m1+m2} = \frac{300 * 10}{900} = \frac{10}{3} \text{ m/s}^2$$

In 2 sec the velocity acquired by mass m_1 is given by,

Applying first equation of motion, we have
$0 = v - 10/4 \times 2$
or $v = 20/3$ m/s

Now, the time value with acceleration due to gravity is
$20/3 - 10\,t$ or $t = 2/3$ sec

Solution 24:
Here, $m_1 = 3$ kg × (10/30) = 1 kg

$m_2 = 3$ kg × (20/30) = 2 kg

Force exerted by m_1 on m_2 = $m_1 a$ = 1 x 4 = 4 N = Force exerted by m_2 on m

Therefore, total force = 20 + 4 = 24 N

Solution 25:
From the free body diagrams,

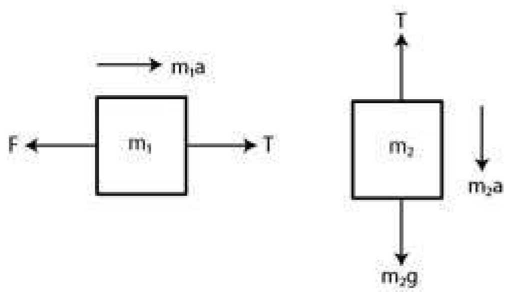
mg $\sin\theta_1$ – T = ma ....(1)
T – mg $\sin\theta_2$ = ma ....(2)
Adding (1) and (2)

mg($\sin\theta_1$– $\sin\theta_2$) = 2ma

=> 2a = g ($\sin\theta_1$ – $\sin\theta_2$)

=> a = g/5 × 12 = g/10

Solution 26:



From the free body diagram of block of mass m_1,
$m_1a = T - F$ …………(1)

For block of mass m_2,

$m_2a = m_2g - T$ ……….(2)

Adding (1) and (2), we get:

$a(m_1 + m_2) = m_2g - F$

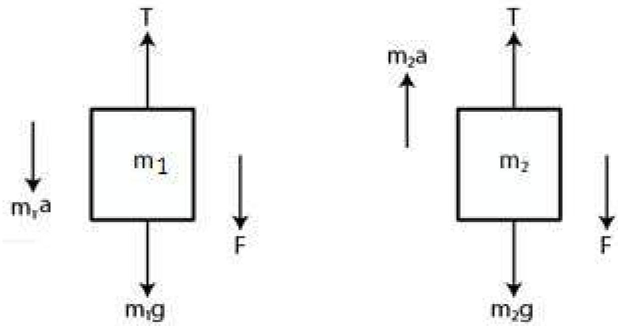
$F = \frac{m_2 g}{2}$

and

$$a = \frac{m_2 g}{2(m_1 + m_2)}$$

The above equation is the acceleration of mass m_1 towards the right.

Solution 27:



$m_1 = 5$ kg, $m_2 = 2$ kg and F = 1 N

Let the acceleration of the blocks be a.

From the free-body diagram,

$m_1a = m_1g + F - T$ ....(1)

Again, $m_2a = T - m_2g - F$ ....(2)

Adding (1) and (2):

$$a = g\left(\frac{m1 - m2}{m1 + m2}\right)$$

=>a = 4.2 m/s^2 = acceleration of the block

After the string breaks, m_1 moves downward with force F acting downward. Then,

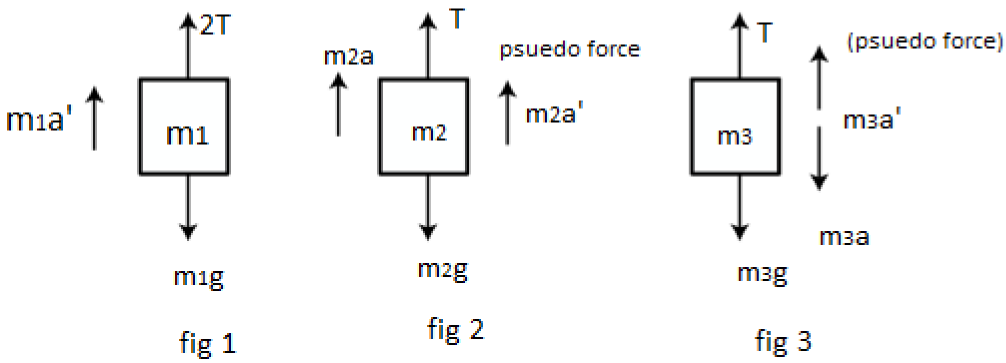
$m_1a = F + m_1g$

5a = 1 + 5g

or g = 0.2 m/s^2

Solution 28:

Let $m_1 = 1$ kg, $m_2 = 2$ kg and $m_3 = 3$ kg (Given)



Actual acceleration of the blocks m_1, m_2 and m_3 will be: a_1, $(a_1 - a_2)$ and $(a_1 + a_2)$

From figure 2, $T - g - a_1 = 0$ ……..(1)

From figure 3, $T/2 - 2g - 2(a_1 - a_2) = 0$ …….(2)

From figure 4, $T/2 - 3g - 3(a_1 + a_2) = 0$ ………(3)

Eliminate T using equations (1) and (2),

$g + a_2 = 4g + 4(a_1 + a_2)$

$5a_2 - 4a_1 = 3g$ ………..(4)

From equations (2) and (3), we get:

$2g + 2(a_1 - a_2) = 3g - 3(a_1 - a_2)$

$5a_1 + a_2 = g$ ………..(5)

Solving (4) and (5), we get

$a_1 = 2g/29$ and $a_2 = g - 5a_1$

$$a_2 = g - \frac{10g}{29} = \frac{19g}{29}$$

Then

$$a_1 - a_2 = \frac{2g}{29} - \frac{19g}{29} = -\frac{17g}{29}$$

and

$$a_1 + a_2 = \frac{2g}{29} + \frac{19g}{29} = \frac{21g}{29}$$

So, accelerations of m_1, m_2 and m_3 are 19g/29 up, 17g/29 down and 21g/29 down, respectively.

Now, u = 0, s = 20 cm = 0.2 m

$$a_2 = \frac{19g}{29}$$

$$s = ut + \frac{1}{2at}$$

$$0.2 = \frac{1}{2} \times \frac{19}{29} gt^2$$

$$t = 0.25 \text{ sec}$$

Solution 29:

m_1= 1kg, m_2= 2kg, and m_3 = 3kg

For m_1 to be at rest, a_1 = 0.

$T - m_1 g = 0$

$T = m_1 g$ ……(1)

For mass m_2, $T/2 - 2g = 2a$

$T = 4a + 4g$ …….(2)

For mass m_3, $3g - T/2 = 2a$

$T = 6g - 6a$ …(3)

From (2) and (3), we get:

$3T - 12g = 12g - 2T$

$T = 24g/5 = 4.08g$

Again (1) => we get: $m_1 = 4.8kg$

Solution 30:

$T + ma = mg$ ……..(1)

And $T = ma$ ……..(2)

From (1) and (2), we get:

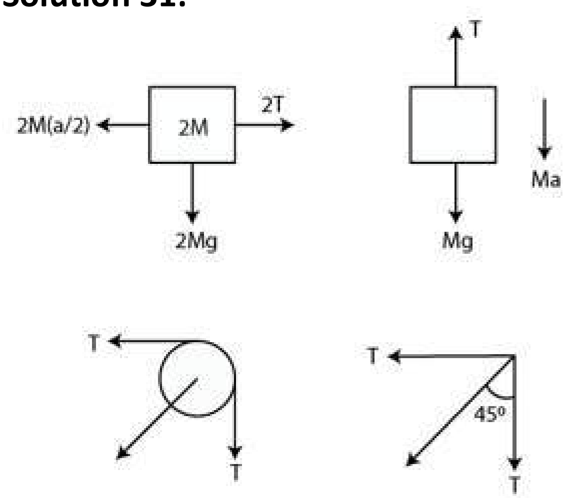
$ma + ma = mg$

$\Rightarrow 2ma = g$

$\Rightarrow a = g/2 = 5\ m/s^2$

And (2)=> $T = ma = 5$ N

Solution 31:



Let the acceleration of mass M be “a”.
So, the acceleration of mass 2M will be “a/2”

(a) $2M(a/2) - 2T = 0$

$\Rightarrow Ma = 2T$
$T + Ma - Mg = 0$
$\Rightarrow Ma2+Ma=Mg$
$\Rightarrow 3Ma=2Mg$

or $a = 2g/3$

(b) Tension, $T = Ma/2 = Mg/3$

(c) Let T' = resultant of tensions
$T' = \sqrt{(T^2+T^2)} = \sqrt{2}\, T$
$T'=\sqrt{2}T = \sqrt{(2Mg)}/3$

Again, $\tan\theta = T/T = 1$

or $\theta = 45°$

So, the force exerted by the clamp on the pulley is $\sqrt{(2Mg)}/3$ at an angle of 45° with the horizontal.

Solution 32:
Let acceleration of the block of mass 2M be a.
So, acceleration of the block of mass M will be 2a.

$M(2a) + Mg \sin\theta - T = 0$

$\Rightarrow T = 2Ma + Mg \sin\theta$ ....(1)

$2T + 2Ma - 2Mg = 0$

From (1)
$2(2Ma + Mg \sin\theta) + 2Ma - 2Mg = 0$

$4Ma + 2Mg \sin\theta + 2Ma - Mg = 0$

$6Ma + 2Mg\sin 30° + 2Mg = 0$

$6Ma = Mg$

$\Rightarrow a = g/6$

Hence, the acceleration of mass, $M = 2a = 2g/6 = g/3$