Solution

LAWS OF MOTION IMP QUESTIONS

Class 11 - Physics

Section A

1.

(c) $10\sqrt{2}$ m/sec

Explanation:

Two parts having same masses move in perpendicular directions. So, the resultant is the third one having mass 3 times of the two masses.

So, the resultant is = $\sqrt{(30)^2 + (30)^2}$ = $\sqrt{1800}$ = $30\sqrt{2}$

Since, the bigger part is thrice in mass of the other two parts.

So, ⇒ $30\sqrt{23}$ = $10\sqrt{2}$ ms^{-1}

The velocity of bigger part is $10\sqrt{2}$ ms^{-1}

2.

(c) Three equations, one for each component of the vectors

Explanation:

$F_x = ma_x$, $F_y = ma_y$, $F_z = ma_z$

3.

(b) zero

Explanation:

m_A = 10 kg and m_B = 40 kg

In this case, $f_L = 0.5 \times 40 \times 10 = 200N$

But F = 40 N

Hence, $F < f_L$

Hence, m_B cannot move with respect to m_A.

4.

(c) 5 N

Explanation:

Radial acceleration (centripetal acceleration)

= $\frac{v^2}{r} = \frac{5\times5}{10}$ = 2.5 ms^{-2}

Force acting = mass × acceleration

= 2 × 2.5 = 5 N

5.

(b) first increase and then become zero

Explanation:

To jump outside the platform, the man pushes the platform, so the reading of the spring balance first increases and then becomes zero.

6. **(a)** 1000 N

Explanation:

v = 36 km $h^{-1} = 36 \times \frac{5}{18}\ ms^{-1}$ = 10 ms^{-1}

$F = \frac{mv^2}{r} = \frac{500\times10\times10}{50}$ = 1000 N

7.

(b) more than actual weight

Explanation:

Measured weight = m(g + a). It is more than actual weight (mg).

8.

(c) the acceleration is that of the centre of mass

Explanation:

A rigid body is characterized by the fact that the distances between any two particles that make up the body are constant in time. This means that instead of talking about the motion of each particle, we can talk about the motion of any one point in the body and of the body as a whole with reference to this one particle. The most convenient choice for this one point is the Centre of Mass

$\vec{a}_{cm} = \frac{m_1\vec{a}_1 + m_2\vec{a}_2 + ...}{M}$

$M\vec{a}_{cm} = \sum m\vec{a}$

$\vec{F} = \sum m\vec{a}$, here F refers to the total external force

9. **(a)** $\mu = 2\tan\theta$

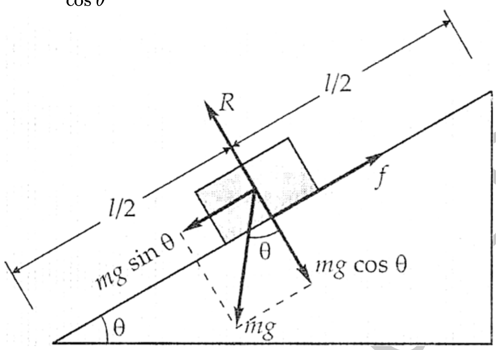
Explanation:

Work done by component mg sin θ along length l

= Work done against f along length $\frac{l}{2}$

mg sin $\theta \times$ l = μ mg cos $\theta \times (\frac{l}{2})$

$\mu = \frac{2\sin\theta}{\cos\theta} = 2\tan\theta$



10.

(c) bob will fall vertically downwards

Explanation:

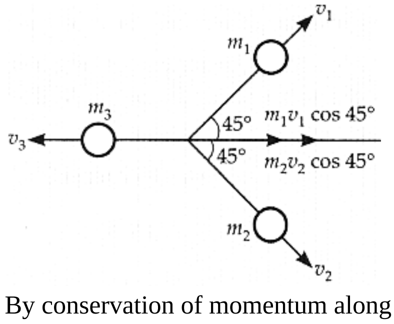
At the extreme position of the oscillation, the speed of the bob is zero. So the bob is momentarily at rest. If the string is cut, the bob will fall vertically downwards.

11.

(d) $7\sqrt{2}$

Explanation:

Clearly, m_1 = 1 kg, m_2 = 1 kg, m_3 = 3 kg.



By conservation of momentum along horizontal direction,

$m_3v_3 = m_1v_1$ cos45° + $m_2v_2$cos45°

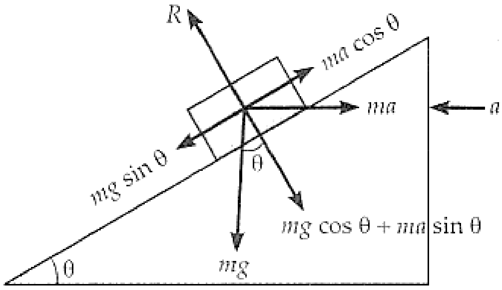
$3v_3 = 1 \times 21 \times \frac{1}{\sqrt{2}} + 1 \times 21 \times \frac{1}{\sqrt{2}}$

$v_3 = \frac{7}{\sqrt{2}} + \frac{7}{\sqrt{2}} = 7\sqrt{2}\ \mathrm{ms}^{-1}$.

12.

(c) $\frac{mg}{\cos\theta}$

Explanation:



macosθ = mg sinθ

a = g tanθ

Total reaction of the wedge on the block is

R = mgcosθ + masinθ

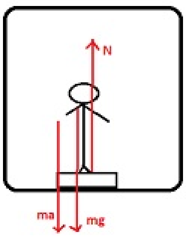
$= mg\cos\theta + m \cdot \frac{g\sin\theta}{\cos\theta} \cdot \sin\theta$

$= \frac{mg(\cos^2\theta + \sin^2\theta)}{\cos\theta} = \frac{mg}{\cos\theta}$

13. **(a)** 350 N

Explanation:

When the lift moves downward with acceleration = 5 ms^{-2} the net force acting downward. hence,



mg - R = ma

R = mg - ma

R = m(g - a)

R = 70(10 - 5)

R = 350 N

R = 350 N

14. **(a)** body acted on by no net force moves with constant velocity (which may be zero) and zero acceleration

Explanation:

If net force act on a body then the acceleration of the body will also be zero. Hence velocity will not be changed i.e. it continues in its existing state of rest or uniform motion in a straight line.

15.

(d) 15.24 km

Explanation:

Here, we have

θ = 15^{o}, g = 9.8ms^{-2}, v = 720kmh^{-1} = 200ms^{-1}

Now we have, $\tan\theta = \frac{v^2}{rg}$

$\therefore r = \frac{200 \times 200}{9.8 \times tan 15^o}$

radius of loop is ,r = 15.24km

16. **(a)** 35 ms^{-1}

Explanation:

Given that T_{max} = 200 N

$\frac{mv^2}{r} = T_{\max}$

$v_{\max} = \sqrt{\frac{T_{\max} \times r}{m}}$

$= \sqrt{\frac{200 \times 1.5}{0.25}}$

= 34.6 m s^{-1}

= 35 m s^{-1}

17.

(c) 735 m

Explanation:

Before the engine is switched off:

v = u + at = 0 + 19.6 $\times$ 5 = 98 ms^{-1}

s_1 = 0 + $\frac{1}{2}$ $\times$ 19.6 $\times$ 25 = 245 m

After the engine is switched off:

0 - $(98)^2$ = 2 $\times$ (-9.8)s_2

$s_2 = \frac{98 \times 98}{2 \times 9.8}$ = 490 m

Maximum height from the earth's surface

= 245 + 490 = 735 m

18.

(b) 1.6 cm/s

Explanation:

Mass of shell, m = 0.02kg

Mass of gun, M = 100kg

Speed of shell, v = $80ms^{-1}$

Let V be the recoil speed of the gun. According to the law of conservation of momentum,

Initial momentum = Final momentum

0 = mv + MV

V = $-\frac{mv}{M} = -\frac{0.02 \times 80}{100}$

recoil speed of the gun is ,V = $-0.016ms^{-1} = -1.6cms^{-1}$

A negative sign indicates that the gun moves backward as the bullet moves forward.

19.

(d) exactly in the hand of thrower

Explanation:

Both the person and the ball share the horizontal velocity of the car. Hence the ball falls exactly in the hand of the thrower.

20.

(b) 41%

Explanation:

p = mv $= m\sqrt{2gh}$

$p' = m\sqrt{2g \times 2h} = \sqrt{2}p$ = 1.414 p

% change $= \frac{p-p}{p} = \frac{1.414p-p}{p} \times 100$ = 41.4%

21.

(c) 3.25 $\times$ 10^4 N downwards

Explanation:

The reaction of the rotor on the surrounding air will be due to the mass of the helicopter as well as the passengers.
Let, the mass of helicopter, M = 1000 kg
Mass of crew and passengers, m = 300 kg
acceleration in upward direction a = 15 m s^{-2}
Action of the rotor of the helicopter on the surrounding air is
= (M + m)(g + a)
= (1000 + 300)(10 + 15)
= 32500N downward direction
Thus, the reaction force of the rotor on the surrounding air will be 32500 N

22.

(c) 1

Explanation:

Uniform speed does not affect the weight of a man.

Required ratio $= \frac{60 \text{ kgwt}}{60 \text{ kgwt}} = 1$

23.

(d) 0.4 m

Explanation:

u = 2 m/s, μ = 0.5, g = 10 ms^{-2}
$a = \frac{F}{m} = \frac{\mu mg}{m}$
= 0.5 $\times$ 10 = 5 m/s^2
Retardation, a = -5 m/s^2
$v^2 - u^2 = 2as$
$\therefore 0^2 - 2^2 = 2(-5) \times s$ or s = 0.4 m

24. **(a)** $45\hat{i} - 35\hat{k}$

Explanation:

By conservation of linear momentum,
$5m(40\hat{i} + 50\hat{j} - 25\hat{k}) = m(200\hat{i} + 70\hat{j} + 15\hat{k}) + 4m\vec{v}$
$\Rightarrow 200\hat{i} + 250\hat{j} - 125\hat{k} = 200\hat{i} + 70\hat{j} + 15\hat{k} + 4\vec{v}$
$\Rightarrow 4\vec{v} = 180\hat{j} - 140\hat{k}$
$\therefore \vec{v} = 45\hat{i} - 35\hat{k}$

25.

(d) 4.2 kg ms^{-1}

Explanation:

Let $\overrightarrow{v_1}$ and $\overrightarrow{v_2}$ be the velocities of the ball before and after deflection, which is equal to 54 km h^{-1} = 15ms^{-1} as the speed of the ball does not change after a deflection.
$v = \sqrt{v_1^2 + v_2^2 + 2v_1v_2 \cos 45^\circ}$
$= \sqrt{15^2 + 15^2 + 2 \times 15 \times 15 \times (\frac{1}{\sqrt{2}}}$
= 27.72 ms^{-1}
Impulse imparted to the ball = Mass $\times$ change in velocity of the ball
0.15 $\times$ 27.72 = 4.2kgms^{-1}

26.

(d) low friction force

Explanation:

If friction is low, the car will skid off the road.

27.

(d) -10 N

Explanation:

As the object is moving with a uniform velocity, the net force on it is zero.

Force of friction = - Applied force = - 10 N

28.

(b) 6 kg ms^{-1}

Explanation:

v = u + at = 0 + 3 $\times$ 1 = 3 ms^{-1}

$\Delta p = p_2 - p_1 = 2 \times 3 - 0 = 6$ kg ms^{-1}

29. **(a)** 20%

Explanation:

Suppose length x of the chain hangs over one edge of the table.

Mass per unit length of the chain $= \frac{M}{L}$

Weight of the hanging part, $W = \frac{M}{L}xg$

Weight of the hanging part applies force on the remaining part of the chain. The chain will not slide further if the limiting friction balances the weight W.

$\therefore f_s^{\max} = W = \frac{M}{L}xg$

Normal reaction = Weight of length (L - x) of the chain

$R = W' = \frac{M}{L}(L - x)g$

Now $f_s^{\max} = \mu R$

or $\frac{M}{L}xg = \mu\frac{M}{L}(L - x)g$

or $x = \mu(L - x)$ or $x = \frac{\mu L}{1+\mu}$

Given $\mu = 0.25$

$\therefore \frac{x}{L} \times 100 = \frac{0.25}{1+0.25} \times 100$ = 20%

30.

(c) f

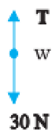
Explanation:

Force of friction does not depend on the area of contact.

Section B

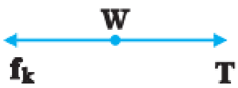
31. Static friction is the force of friction which comes into play between the surfaces of contact of two bodies when there is no relative motion between the bodies inspite of applying an external force on them. Force of static friction is self-adjusting. Its value may vary from zero to limiting friction depending on the value of applied force.

32. As the string is inextensible, and the pully is smooth, the 3 kg block and the 20 kg trolley both have the same magnitude of acceleration. Applying the second law to the motion of the block (Figure).



30 - T = 3a

Apply the second law to the motion of the trolley (figure)



T - f_k = 20a

Now $f_k = \mu_k N$

Here $\mu_k = 0.04$

$N = 20 \times 10$

= 200 N

Thus the equation for the motion of the trolley is

T - 0.04 $\times$ 200 = 20a or T - 8 = 20a

These the equation give $a = \frac{22}{23}\text{ms}^{-2}$ = 0.96 ms^{-2} and T = 27.1 N

Hence, acceleration = 0.96 ms^{-2} and Tension = 27.1 N

33. Velocity attained by the stone as it falls through a height of 50 m is given by

$v^2 - u^2 = 2as$

or $v^2 - 0^2 = 2 \times 9.8 \times 50$

or $v = \sqrt{980}\ \text{ms}^{-1}$

Now the stone starts burying into the sand with a velocity of $\sqrt{980}$ ms^{-1} and finally comes to rest after travelling a distance, s = 1 m.

$\therefore 0^2 - 980 = 2a \times 1$

or a = -490 ms^{-2}

Average resistance offered by sand,

F = ma = 5 $\times$ 490 = 2450 N

Time is taken by stone to penetrate sand,

$t = \frac{v-u}{a} = \frac{0-\sqrt{980}}{-490}$ = 0.064 s

34. Speed of the cyclist

$v = 18\text{km/h} = 18 \times \frac{5}{18} = 5\text{m/s}$

Given: Radius $r = 3m \quad \mu = 0.1$

The safe limit of velocity $v_s = \sqrt{\mu r g}$

So, $v_s = \sqrt{0.1 \times 10 \times 3} = 1.732\text{m/s}$

Since, cyclist rides at a faster speed than safe limit. So, the cyclist slips.

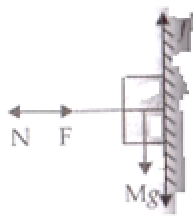
35. We first draw the free body diagram to see what forces are acting on the system. Here, we can see that the weight of the body is acting downwards and given by "mg". The corresponding tension on the string AB is given by "T". In addition to these forces, we apply a third force via string CD in the downward direction given by "F". So,

T = F + mg

As the tension is the greatest force, given by the sum of the weight and the additional force applied, string AB will break.

36. Let F force is applied by the finger on a body of mass M to hold rest against the wall.

Under the balanced condition



F = N

And f = Mg

$\Rightarrow \mu F = Mg$

or $F = \frac{Mg}{\mu}$ is the minimum force to hold the block against the wall at rest.

37. i. Net downward force i.e. (the weight of the rain drop - the buoyancy offered by air on the drop) is balanced with the upward resistive force i.e. the viscous force offered by the air on the drop. Hence the drop falls with its constant terminal velocity. Now, according to first law of motion F = 0 as a = 0 (particle moves with constant speed)
    ii. Since kite is stationary, net force on the kite is also zero. In this case the upward force acting on the kite is balanced by the tension in the string.

38. According to the principle of conservation of linear momentum, total momentum remains constant.

Before disintegration linear momentum = zero

After disintegration linear momentum = $m_1\overline{v_1} + m_2\overline{v_2}$

$\Rightarrow m_1v_1 + m_2v_2 = 0 \Rightarrow v_2 = -\frac{m_1v_1}{m_2}$

39. Here $\frac{dm}{dt}$ = 100 kg wt/s

u = 6×10^3m/s

i. Thrust $F = u\frac{dm}{dt} = 6 \times 10^3 \times 100$

= 6×10^5 N

ii. v = ?, $m = \frac{1}{40}m_0$

$\frac{m_0}{m} = 40$

$v = (2.303)u\log_{10}\left(\frac{m_0}{m}\right)$

$2.303 \times 6 \times 10^3 \times \log_{10} 40$

$= 2.303 \times 6 \times 10^3 \times 1.602$

= 22.13×10^3 m/s

40. Given, mass of the man, m = 72.2 kg

Acceleration due to gravity, g = 9.8 m /s^2

To find : Scale reading = apparent weight = Reaction force = R in the following two cases,

i. While descending with constant velocity, a = 0

R = mg

R = 72.2×9.8

$\Rightarrow$ R = 707.56 N

ii. While ascending with a = 3.2 m / s^2

R = m (g + a)

R =72.2 (9.8+ 3.2) = 938.6 N

41. For neutron:

$m_1 = 1.67 \times 10^{-27}$ kg, $u_1 = 10^8 ms^{-1}$

For deutron:

$m_2 = 3.34 \times 10^{-27}$ kg, $u_2 = 0$

Let v be the speed of the combination. Then by conservation of momentum,

$m_1u_1 + m_2u_2 = (m_1 + m_2)v$

$1.67 \times 10^{-27} \times 10^8 + 3.34 \times 10^{-27} \times 0$

$= (1.67 + 3.34) \times 10^{-27} \times v$

or $v = \frac{1.67\times10^{-27}\times10^8}{5.01\times10^{-27}}$ = 0.333×10^8 ms^{-1}

42. A cyclist leans while going along curve because a component of normal reaction of the ground provides him the centripetal force he requires for turning. He has to lean inwards from his vertical position i.e. towards the centre of the circular path.

43. Let T be the tension in the string. Then the equation of motion for A can be written as

T = ma

Let a' be the acceleration of B. Then for motion of B, ma' = F - T = F - ma

or $a' = \frac{F}{m} - a$

44. The speed will be same for both block

so let us consider the block 1

Here the force on the block is

F = (m_1-m_2) g = (12 - 10) $\times$ 9.8 = 19.6 N

So the acceleration of the system is a = $\frac{F}{m_1-m_2}$= 0.6125

So the speed after 3 s will be 0.6125 $\times$ 3 = 1.84ms^{-1}

45. Mass of bullet, m = 50 g = 0.05 kg

Velocity of bullet, v = 150 ms^{-1}

Mass of tiger, M = 60 kg

Velocity of tiger, V = 10 ms^{-1}

Let n be the number of bullets required to be pumped into the tiger to stop him in his track.

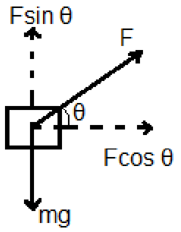
According to the law of conservation of momentum,

Magnitude of the momentum of n bullets

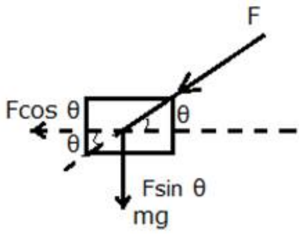
= Magnitude of the momentum of tiger

or n $\times$ mv = MV or $n = \frac{MV}{mv} = \frac{60 \times 10}{0.05 \times 150}$ = 80.

46. When we pull a lawn mower, a force at some angle is applied on it. The vertical component is in the upward direction. This upward component reduces the effective weight of the mower, thus making it easier to pull.



Whereas, when we push a lawn mower, a force acting at some angle is applied on it, the vertical components is in the downward direction and act thus, increases the effective weight of the land mower.



Due to the less effective weight in the first case, the land mower is easier to pull than push.

47. i. Horizontal velocity of the bus or the stone at t = 10 s is

v_x = u + at = 0 + 4 $\times$ 10 = 40 ms^{-1}

Horizontal velocity will be same at t = 10.2 s because it is not affected by g.

For vertical motion of the stone,

u = 0, a = g = 10 ms^{-2}, t =10.2 - 10 = 0.2 s

$\therefore$ v_y = 0 + 10 $\times$ 0.2 = 2 ms^{-1}

Magnitude of the resultant velocity of the stone is

$v = \sqrt{v_x^2 + v_y^2} = \sqrt{40^2 + 2^2} = \sqrt{1604}$ = 40.04 ms^{-1}.

ii. After the stone is dropped, its acceleration along the horizontal is zero. It has only a vertical acceleration of 10 ms^{-2}.

48. Mass of elevator, M = 4000 kg

Weight of elevator = Mg = 4000 kg wt = 4000 $\times$ 9.8 = 39200 N

Upward tension, T = 48000 N

Net upward force on the elevator,

F' = T - Mg = 48000 - 39200 = 8800 N

Upward acceleration, $a = \frac{F'}{m} = \frac{8800}{4000}$ = 2.2 ms^{-2}

For upward motion : u = 0, a = 2.2 ms^{-2}, t = 3 s

$\therefore s = ut + \frac{1}{2}at^2 = 0 \times 3 + \frac{1}{2} \times 2.2 \times 3^2$ = 9.9 m

49. Concurrent forces are those that intersect at a single point. When dealing with concurrent forces, we can add them as vectors to get the net resultant.

A body subjected to three concurrent forces is found to in equilibrium if the sum of these forces is equal to zero.

50. Here, v = 500 kmh^{-1}

$= \frac{500 \times 1000}{60 \times 60} m/s = \frac{5000}{36} m/s$

θ = 30°, r = ?

From $\tan\theta = \left(\frac{v^2}{rg}\right), r = \left(\frac{v^2}{g\tan\theta}\right)$

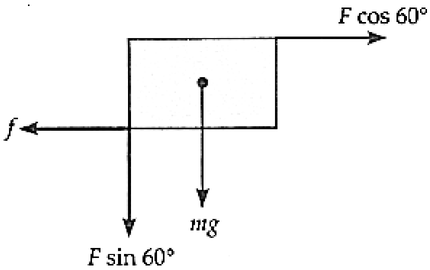
$r = \frac{5000}{36} \times \frac{5000}{36 \times 9.8 \tan 30^\circ}$

$r = \frac{25 \times 10^6 \sqrt{3}}{36 \times 36 \times 9.8}$ = 3.14 $\times$ 10^3m

51. The statement is correct relative to a non-inertial frame rotating with the particle. For example, consider an observer moving with the same acceleration (= v^2/r) as that of the particle. For him, the particle remains at rest. The centripetal force equals the centrifugal force. Centrifugal force is not a real force. It arises only because of the non-inertial nature of the observer himself.

The given statement is wrong relative to an inertial frame e.g., the laboratory frame. For an inertial observer (stationary observer), the particle in circular motion is not in equilibrium, it has a centripetal acceleration. There is no force such as centrifugal force.

52. The free-body diagram for the block is shown in the figure.



For no motion of the block,

$F\cos 60^{\circ} \leq f$

or $F\cos 60^{\circ} \leq \mu$N

or $F\cos 60^{\circ} \leq \mu\left(mg + F\sin 60^{\circ}\right)$

or $\frac{F}{2} \leq \frac{1}{2\sqrt{3}}\left(\sqrt{3}\times g + \frac{F\sqrt{3}}{2}\right)$

or $\frac{F}{2} \leq g$

$\therefore$ F_{max} = 2g = 2 $\times$ 10 = 20 N

53. Here m = 2000 quintals = 2 $\times$ 10^5 kg,

$\sin\theta = \frac{1}{50}$, a = 2 ms^{-2}

Force of friction = 0.5 newton per quintal

$\therefore$ Total force of friction = 0.5 $\times$ 2000 = 1,000 N

Force required against gravity in moving the train up the inclined plane

= mg sin θ = 2 $\times$ 10^5 $\times$ 9.8 $\times \frac{1}{50}$ = 39,200 N

Force required to produce an acceleration of 2 ms^{-2}

= ma = 2 $\times$ 10^5 $\times$ 2 = 400,000 N

$\therefore$ Total force required

= 1,000 + 39,200 + 400,000 = 440,200 N

54. Here u = 0, s = 100m,

v = 80 $kmh^{-1} = 80 \times \frac{5}{18} = \frac{200}{9}$ ms^{-1}

As $v^2 - u^2 = 2as$

$\therefore \quad \left(\frac{200}{9}\right)^2 - 0 = 2a\times 100$

or $a = \frac{40000}{81\times 200} = \frac{200}{81}$ ms^{-2}

Force required to produce acceleration a,

F_1 = ma $= 10^4 \times \frac{200}{81}$ = 2.47 $\times$ 10^4 N

Force required to overcome friction,

$F_2 = \mu R = \mu mg$ = 0.2 $\times$ 10^4 $\times$ 9.8 = 1.96 $\times$ 10^4 N

Maximum force required by the engine for take off,

F = F_1 + F_2 = 2.47 $\times$ 10^4 + 1.96 $\times$ 10^4 = 4.43 $\times$ 10^4 N.

55. Due to its small speed, the stone remains in contact with the windowpane for a longer duration. It transfers its motion to the pane and breaks it into pieces. But the particles of windowpane near the hole are unable to share the fast motion of the bullet and so remain undisturbed.

Section C

56. a. Given that each coin has a mass m kg. Thus, the force on 7^{th} coin is due to the weight of the three coins lying above it (i.e. the sum of weights of 8th, 9th and 10th coins).
Therefore, force is given by F = (3 m) kgf = (3 mg) N
Where g is the acceleration due to gravity. This force acts vertically downwards.

b. The eighth coin is already under the weight of two coins above it and it has its own weight too. Hence force on 7^{th} coin due to 8^{th} coin is the sum of the two forces is given by

F = weight of 9^{th} and 10^{th} coin + weight of 8^{th} coin = (2m + m) kgf = (3m) kgf = (3mg) N
Hence, The force acts vertically downwards.

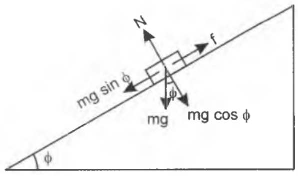
c. The sixth coin is under the weight of four coins (i.e. 7^{th}, $8^{th,}$ 9^{th} and 10^{th}) above it.
Now in this case reaction force on the 6th coin will equal and opposite to the sum of weights of mentioned four coins. Hence, reaction is given by , R = -F = -4 m (kgf) = - (4 mg) N
also, -ve sign indicates that reaction acts vertically upwards.

57. In a closed cage, the inside air is bound with the cage.
    i. As the acceleration is zero, there is no change in the weight of the cage.
    ii. In this case, the reaction R is given by
    R - Mg = Ma or R = M (g + a)
    Thus the cage will appear heavier than before.
    iii. In this case, the reaction R is given by
    Mg - R = Ma or R = M (g - a)
    Thus the cage will appear lighter than before.

58. Mass of the block, m = 15 kg
Coefficient of friction between the block and the trolley, μ = 0.18
Acceleration of the trolley, a = 0.5 ms^{-2} , Time, t = 20 s
    a. As the block is placed on the trolley, therefore force applied on the block by the trolley
    F = ma = 15 $\times$ 0.5 = 7.5N
    Force on the block is the reaction applied by trolley on the block, therefore its direction is opposite to the direction of motion of the trolley.
    Due to the reaction force applied by the trolley on the block, it tries to move in the backward direction but limiting force opposes its motion. If limiting friction is greater than the applied force on the block than it will not move.
    Limiting friction force acting on the block (f) = μmg = 0.18 $\times$15 $\times$ 9.8 = 26.46 N
    As f > F, therefore static friction will adjust itself equal and opposite to the applied force (F). Therefore, the block will remain at rest on the trolley.
    Hence, the block will appear to be at rest relative to the trolley to a stationary observer on the ground.
    After 20 s, trolley moves with uniform velocity, therefore acceleration and hence force applied by the trolley on the block will be zero and hence no force of friction will act on the block. Now, the block will appear to be at rest relative to a stationary observer on the ground.
    b. An observer moving with the trolley will have acceleration and therefore the observer will be a non-inertial frame of reference for which law of inertia does not hold good. Therefore, the motion of the block cannot be observed by him and hence, the block will be at rest relative to the observer.

59. i. This happens due to inertia of motion. When the speeding bus stops suddenly, the lower part of the body in contact with the seat comes to rest at the very moment, but the upper part of the body of the passengers tends to maintain its uniform motion according to the inertia of motion. Hence the passengers are thrown forward from their seats.
    ii. From 2nd law of motion, we have
    F = ma = $m\frac{\Delta v}{\Delta t}$
    Where
    'F' is the force experienced by the cricketer as he catches the ball.
    'm' is the mass of the ball
    'Δt' is the short time of the impact with the hand of a cricketer.
    We can thus see from the equation that impact force is inversely proportional to the impact time, Thus, if the impact is for a shorter period of time then the force will be large.
    It also shows that the force experienced by the cricketer decreases with the increase in the impact time.
    Therefore, the cricketer moves his hand backwards while taking a catch to increase the impact time, and hence decrease the impact force on his hand and prevent it from getting hurt.
    iii. Initially, the total momentum of the boat and the man is zero. As the man jumps out of the boat, he gains momentum in the forward direction. To conserve momentum, the boat also gains an equal and opposite momentum. So the boat moves away from the shore.

60. **Angle of repose (θ):** The minimum angle of the plane at which the body kept on it starts to slide due to its own weight is called angle of repose



Consider a body of mass m placed over a surface of inclination angle equal to the angle of repose ϕ. Various forces acting have been shown in Figure. For equilibrium condition, we have

N = mg cosϕ ....(1)

and friction force f = mg sinϕ..................(2)

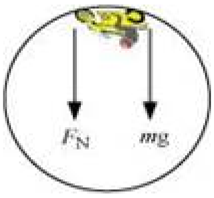
In limiting case, when the body just starts sliding down, f = f_l. Then dividing (2) by (1), we get

$\frac{f_l}{N} = \tan\phi$

or $\mu_l = \tan\phi$

where $\mu_l = \frac{f_l}{N}$ is the coefficient of limiting friction.

61. When the motorcyclist is at the highest point of the death-well, the normal reaction R on the motorcyclist by the ceiling of the chamber acts downwards. His weight mg also acts downwards. These two forces are balanced by the outward centrifugal force acting on him. This situation is shown in the following figure.



The net force acting on the motorcyclist is the sum of the normal force (FN) and the force due to gravity is given by (F_g = m g).

The equation of motion for the centripetal acceleration a_c, can be written as:

$F_{net} = ma_c$

$F_N + F_g = ma_c$

$F_N + mg = \frac{mv^2}{r}$

Here, v is the speed of the motorcyclist and m is the mass of the motorcyclist. Because of the balancing of the forces, the motorcyclist does not fall down. The minimum speed required to perform a vertical loop is given by the above equation when

$F_N = 0$

$mg = \frac{mv^2_{\min}}{r}$

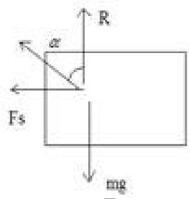
$\therefore v_{\min} = \sqrt{rg}$

$= \sqrt{25 \times 10} = 15.8\text{m/s}$

the required velocity is = 15.8m/s

62. Coefficient of static friction is defined as the ratio of static frictional force to the normal reaction.

Angle of friction is the angle between the resultant of limiting friction and normal reaction with the normal reaction. Here in the figure below, the angle of friction is denoted by α.



$\tan\alpha = \frac{Fs}{R}$ ...(i), F_s = force of static friction, R = normal reaction

Coefficient of static friction

The limiting value of static frictional force is directly proportional to the normal reaction i.e.

$F_s \alpha R \Rightarrow F_s = \mu_s R$, μ_s = constant of proportionality here known as coefficient of static friction

Or

$\mu_s = \frac{F_s}{R}$ ...(ii)

From (i) and (ii)

$\mu_s = \tan\alpha$.

This is the required relation between coefficient of static friction and angle of friction.

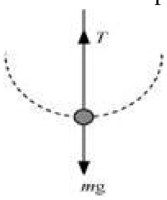
63. i. The earth revolves round the sun.The earth is also acted upon by the centripetal force which is provided by the gravitational force of attraction between the sun and the earth.
ii. The motion of moon around the earth is also in circular path.The necessary centripetal force is provided by the gravitational attraction of the earth on the moon.
iii. In an atom,electrons revolve around the nucleus in various circular orbits.The necessary centripetal force for circular motion, is exerted by the electrostatic force of attraction between the positively-charged nucleus and the negatively charged electrons.

64. Net upward force on the elevator F = T - mg ($\because$ F = ma)
ma = T - mg
T = m(a + g) ...(i)
T = 33000 N; m = 3000 kg; g =9.8 m/s^2
Substituting in Equation 1
33000 = 3000(a + 9.8)
$a = \frac{33000 - 3000 \times 9.8}{3000}$
a = 1.2 m/s^2

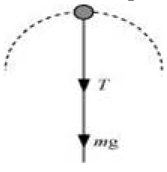
65. Every object has a rough surface, though the surface may appear to be smooth to the naked eyes. When we see through the microscope, it is found that the surface of all the objects has rough edges. When something (say A) is placed on the body (say B), the irregularities of two bodies are interlocked and at such points of interlocking (i.e., points of actual contacts of two bodies) atomic and molecular forces of attraction are acting. When body A tends to move over the surface of B, these intermolecular forces try to oppose the motion. In fact, the pressure at the points of actual contact is B very high and a type of cold welding takes place. Due to the motion of body A over B, the bonds between the molecules are continuously broken and new bonds are formed at other points. Friction is on account of the force needed to break these molecular bonds.
Hence, the friction is caused by the interlocking of irregularities in the surfaces of two objects which are in contact with each other.

66. Mass of the body, m = 3 kg
Initial speed of the body, u = 2 m/s
Final speed of the body, v = 3.5 m/s
Time, t = 25 s
Acceleration is given by
$a = \frac{v-u}{t}$
$= \frac{3.5-2}{25} = \frac{1.5}{25} = 0.06 \mathrm{m/s}^{-2}$
Using Newton's second law of motion, force is given as:
F = ma
$\therefore F = 3 \times 0.06 = 0.18N$
The force acts in the direction of the motion since the direction of the body remains unchanged.

67. The free body diagram of the stone at the lowest point is shown in the following figure. In this case tension, T in the string acts upwards and weight of the body, mg acts downwards. The net force T - mg, supplies required centripetal force to rotate the stone in the circular path.



According to Newton's second law of motion, the net force acting on the stone at this point is equal to the centripetal force, i.e.,
$F_{net} = T - mg = \frac{mv_1^2}{R}$ ...(i)
Where, v_1 = Velocity at the lowest point
The free body diagram of the stone at the highest point is shown in the following figure. In this case both the tension T in the string and weight mg of the stone act downwards. The net force T + mg provides required centripetal force to rotate the stone in the circular path.



Using Newton's second law of motion, we have:

$T + mg = \frac{mv_2^2}{R}$ ...(ii)

Where, v_2 = Velocity at the highest point

It is clear from equations (i) and (ii) that the net force acting at the lowest and the highest points are respectively (T - mg) and (T + mg).

68. mass of the monkey, m = 40kg,

Tensile strength of the rope, T = 600N (max tension rope can hold without breaking)

Here, the rope will break if reaction (R) exceeds the tension (T) applied, i.e. R > T

a. a = 6m/s^2

For upward accelerated motion the net acceleration is (g + a) instead of g, hence R = m (g + a) = 40 (10 + 6) = 640 N. Therefore the rope will break, as R > T

b. a = 4m/s^2

For downward accelerated motion the net acceleration is (g - a) instead of g, hence R = m (g – a) = 40 (10 – 6) = 240 N. Therefore the rope will not break as R < T

c. v= 5m/s (constant) a = 0

R = mg = 40 $\times$10 = 400 N. Therefore the rope will not break as R < T

d. For freefall, net acceleration on the body is zero, a = g; R = m (g – a) = m (g – g). Therefore R = zero (Rope will not break)

69. i. By using ball bearings between the moving parts of a machinery, the sliding friction gets converted into rolling friction. The rolling friction is much smaller than sliding friction. This reduces power dissipation.

ii. When the horse cart is stationary, the muscular force provided by the horse is used to overcome the static friction as well as to provide acceleration to the cart.

As the cart begins to move, the friction becomes lesser since it is rolling friction and the muscular force of the horse is utilised to only overcome this friction.

Hence, initially to set the cart in motion, the horse needs to do more work than, when the cart is in motion.

iii. When the circular track is banked, the horizontal component of the normal reaction of the road provides the necessary centripetal force for the vehicle to move it along the curved path. This reduces wear and tear of the tyres.

70. Here it is given that, velocity v = 40 kmh^{-1} = $40 \times \frac{5}{18}\mathrm{m/s} = \frac{100}{9}\mathrm{m/s}$, radius r = 100 m, and g = 10 ms^{-2}

As we know that

$\tan\theta = \frac{v^2}{rg}$

$= \frac{\frac{100}{9}\times\frac{100}{9}}{100\times 10} = \frac{10}{81} = 0.1235$

Thus, the correct angle of banking of the road, $\theta = \tan^{-1}(0.1235) = 7^\circ$

If breadth of road b = 20 m, then let the outer edge of road be raised by h, so that

$\tan\theta = \frac{h}{b}$

$\Rightarrow \quad h = b\tan\theta$

$\Rightarrow \quad h = 20 \times 0.1235 = 2.47\mathrm{m}$

71. Tan θ = $200\sqrt{3}$

Tan θ = 20 $\times$ 10 = 200

Tan $\theta = \frac{200}{200\sqrt{3}} = \frac{1}{\sqrt{3}}$

The angle the rope makes with the horizontal in equilibrium

θ = 30^o

72. a. When stone is dropped just after from the window of a stationary train,

Force on stone is given by, F = Force due to gravity = mg = 0.1 kg $\times$ 10 m/s^2 = 1 N in the vertically downward direction.

b. As the train is running with constant velocity, acceleration is zero in horizontal direction i.e. direction of motion of train. Hence no force in horizontal direction. So, only force due to gravity in vertically downward direction exists. In this case too, force is same as in (a) i.e., F = 1 N downwards.

c. Net Force is given by, F = Force due to gravity = mg = 0.1 k g $\times$ 10 m/s^2 = 1 N

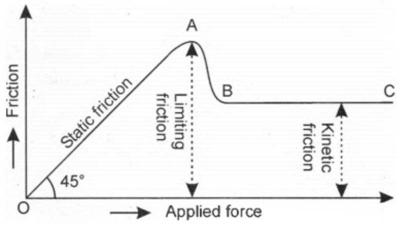
$\therefore$ F = 1 N vertically downwards

d. Here, acceleration is given by a = 1 ms^{-2} in horizontal direction towards the motion of train and the stone being at rest relative to the train, Hence, net force is given by F = ma = 0.1 $\times$ 1 = 0.1 N.

73. The laws of limiting friction are as follows:
    i. The value of limiting friction depends on the nature of the two surfaces in contact and on the state of their smoothness.
    ii. When two bodies are in contact the direction of the forces of Friction on one of them at its point of contact is opposite to the direction in which the point of contact tends to move relative to the other.
    iii. The value of limiting friction is directly proportional to the normal reaction between the two given surfaces.
    iv. For any two given surfaces and for a given value of normal reaction, the force of limiting friction is independent of the shape and surface area of surfaces in contact.
    v. If the bodies are in equilibrium, the force of Friction is just sufficient to prevent motion and may, therefore, be determined by applying the conditions of equilibrium of all the forces acting on the body.

    The coefficient of static (limiting) friction for two given surfaces in contact is defined as the ratio of the force of limiting friction f_l between them and the force of normal reaction N i.e.

    $\mu_s = \frac{f_l}{N}$

74. 

    We know that when the applied force on a body is small enough, it does not move. It means that force of friction is just balancing the applied force. However, as the applied force is increased beyond a limit, the body starts moving. Force of friction is present when the given body is in motion. From these considerations we classify friction in case of sliding motion in following three categories:
    i. **Static friction**: Static friction is a self-adjusting force because it comes into play when the body is lying over the surface of another body without any motion. If we have not applied any force on a body to move the body, the frictional force also becomes zero. In Figure, the region OA of the graph is the region of static friction.
    ii. **Limiting friction**: It is the maximum value of static friction. Thus, limiting friction is the force of friction at the moment when a body just tends to slide over the surface of another body i.e, when that body overcomes the force of static friction, the maximum value of static friction is reached which is known as limiting friction. In the figure, frictional force corresponding to point A represents the limiting friction.
    iii. **Kinetic friction**: Kinetic friction is that opposing (or retarding) force which comes into play when a body actually slides over the surface of another body. The value of kinetic friction for a given pair of surfaces is less than the corresponding value of limiting friction. Moreover, the force of kinetic friction throughout remains constant for a given body and does not depend upon the speed of motion of the body. In the figure, the region BC of the graph is representing kinetic friction.

75. When an object is thrown vertically upward or it falls vertically downward under gravity then an acceleration g $= 10m/s^{-2}$ acts downward due to the earth's gravitational pull.
    Mass of pebble (m) = 0.05 kg
    i. During upward motion
       Net force acting on pebble (F) = ma = 0.05 $\times$10
       = 0.50N (vertically downward)
    ii. During downward motion
       Net force acting on pebble (F) = ma = 0.05 $\times$10
       = 0.50N (vertically downward)
    iii. At the highest point
       Net force acting on pebble
       (F) = ma = 0.05 $\times$10
       = 0.50 N (vertically downward) If pebble was thrown at an angle of 45° with the horizontal direction then acceleration acting on it and therefore force acting on it will remain unchanged, i.e., 0.50 N (vertically downward). In case , at the highest point the vertical component of velocity will be zero but horizontal component of velocity will not be zero.