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+91-9939586130
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2ND FLOOR, SATKOUDI COMPLEX, THANA CHOWK, RAMGARH - 829122-JH

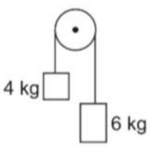
Laws of Motion

1. Calculate the maximum acceleration of a moving car so that a body lying on the floor of the car remains stationary. The coefficient of static friction between the body and the floor is 0.15 ($g = 10\ ms^{-2}$).
(a) $50\ ms^{-2}$
(b) $1.2\ ms^{-2}$
(c) $150\ ms^{-2}$
(d) $1.5\ ms^{-2}$

2. A shell of mass m is at rest initially. It explodes into three fragments having mass in the ratio 2 : 2 : 1. If the fragments having equal mass fly off along mutually perpendicular directions with speed v, the speed of the third (lighter) fragment is **(2022)**
(a) v
(b) $\sqrt{2}v$
(c) $2\sqrt{2}v$
(d) $3\sqrt{2}v$

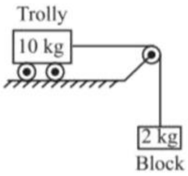
3. A small block slides down on a smooth inclined plane, starting from rest at time t = 0. Let Sn be the distance travelled by the block in the interval t = n – 1 to t = n. The, the ratio $\frac{S_n}{S_{n+1}}$ is: **(2021)**
(a) $\frac{2n-1}{2n+1}$
(b) $\frac{2n+1}{2n-1}$
(c) $\frac{2n}{2n-1}$
(d) $\frac{2n+1}{2n}$

4. Two bodies of mass 4 kg and 6 kg are tied to the ends of a massless string. The string passes over a pulley which is frictionless (see figure). The acceleration of the system in terms of acceleration due to gravity (g) is **(2020)**



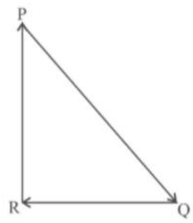
(a) g/2
(b) g/5
(c) g/10
(d) g

5. Calculate the acceleration of the block and trolly system shown in the figure. The coefficient of kinetic friction between the trolly and the surface is 0.05. ($g = 10\ m/s^2$, mass of the string is negligible and no other friction exists). **(2020 Covid Re-NEET)**



(a) $1.50\ m/s^2$
(b) $1.66\ m/s^2$
(c) $1.00\ m/s^2$
(d) $1.25\ m/s^2$

6. A particle moving with velocity $\overline{V}$ is acted by three forces shown by the vector triangle PQR. The velocity of the particle will: **(2019)**



(a) Increase
(b) Decrease
(c) Remain constant
(d) Change according to the smallest force

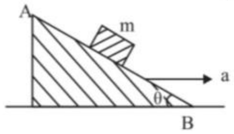
7. A block of mass 10 kg is in contact against the inner wall of a hollow cylindrical drum of radius 1 m. The coefficient of friction between the block and the inner wall of the cylinder is 0.1. The minimum angular velocity needed for the cylinder to keep the block stationary when the cylinder is vertical and rotating about its axis, will be: ($g = 10\ m/s^2$) **(2019)**

(a) $\sqrt{10}$ rad/s
(b) $\frac{10}{2\pi}$ rad/s
(c) 10 rad/s
(d) 10π rad/s

8. Which one of the following statements is incorrect? **(2018)**
(a) Frictionless force opposes the relative motion.
(b) Limiting value of static friction is directly proportional to normal reaction.
(c) Rolling friction is smaller than sliding friction
(d) Coefficient of sliding friction has dimensions of length.

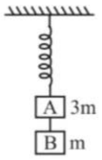
9. A moving block having mass m, collides with another stationary block having mass 4m. The lighter block comes to rest after collision. When the initial velocity of the lighter block is v, then the value of coefficient of restitution(e) will be **(2018)**
(a) 0.8
(b) 0.25
(c) 0.5
(d) 0.4

10. A block of mass m is placed on a smooth inclined wedge ABC of inclination θ as shown in the figure. The wedge is given an acceleration 'a' towards the right. The relation between a and θ for the block to remain stationary on the wedge is: **(2018)**



(a) $a = g\cos\theta$
(b) $a = \frac{g}{\sin\theta}$
(c) $a = \frac{g}{\operatorname{cosec}\theta}$
(d) $a = g\tan\theta$

11. Two blocks A and B of masses 3 m and m respectively are connected by a massless and inextensible string. The whole system is suspended by a massless spring as shown in figure. The magnitudes of acceleration of A and B immediately after the string is cut, are respectively: **(2017-Delhi)**



(a) $g, \frac{g}{3}$
(b) g, g
(c) $\frac{g}{3}, \frac{g}{3}$
(d) $\frac{g}{3}, g$

12. One end of string of length l is connected to a particle of mass 'm' and the other end is connected to a small peg on a smooth horizontal table. If the particle moves in circle with speed 'v', the net force on the particle (directed towards center) will be:
(T Represents the tension in the string)) **(2017-Delhi)**
(a) $T + \frac{mv^2}{l}$
(b) $T - \frac{mv^2}{l}$
(c) zero
(d) T

13. A girl jumps down from a moving bus, along the direction of motion of the bus, tilting slightly forward. She falls on
(A) a sheet of ice (B) a patch of glue. **(2017-Gujarat)**
(a) In case (A) she falls backward and in case (B) she falls forward
(b) In both cases (A) and (B) she falls forward
(c) In both cases (A) and (B) she falls backward
(d) In case (A) she falls forward and in case (B) she falls backward

14. A cyclist on a level road takes a sharp circular turn of radius 3 m ($g = 10\ ms^{-2}$). If the coefficient of static friction between the cycle tyres and the road is 0.2, at which of the following speeds will the cyclist not skid while taking the turn? **(2017-Gujarat)**
(a) $14.4\ km\ h^{-1}$
(b) $8.8\ km\ h^{-1}$

(c) $9\ \text{km h}^{-1}$
(d) $10.8\ \text{km h}^{-1}$

15. A car is negotiating a curved road of radius R. The road is banked at an angle θ. The coefficient of friction between the tyres of the car and the road is μs . The maximum safe velocity on this road is: **(2016 - I)**

(a) $\sqrt{gR^2 \frac{\mu_s+\tan\theta}{1-\mu_s\tan\theta}}$
(b) $\sqrt{gR \frac{\mu_s+\tan\theta}{1-\mu_s\tan\theta}}$
(c) $\sqrt{\frac{g\mu_s+\tan\theta}{R\,1-\mu_s\tan\theta}}$
(d) $\sqrt{\frac{g}{R^2}\frac{\mu_s+\tan\theta}{1-\mu_s\tan\theta}}$

16. Three blocks A, B and C of masses 4 kg, 2 kg and 1 kg respectively, are in contact on a friction less surface, as shown. If a force of 14 N is applied on the 4 kg block, then the contact force between A and B is: **(2015)**

(a) 6 N
(b) 8 N
(c) 18 N
(d) 2 N

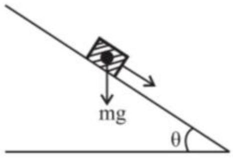
17. A block A of mass m_1 rests on a horizontal table. A light string connected to it passes over a frictionless pulley at the edge of table and from its other end another block B of mass m_2 is suspended. The coefficient of kinetic friction between the block and table is μ_k. When the block A is sliding on the table, the tension in the string is: **(2015)**

(a) $\frac{(m_2-\mu_k m_1)g}{(m_1+m_2)}$
(b) $\frac{m_1 m_2(1+\mu)g}{(m_1+m_2)}$
(c) $\frac{m_1 m_2(1-\mu_k)g}{(m_1+m_2)}$
(d) $\frac{(m_2+\mu_k m_1)g}{(m_1+m_2)}$

18. Two stones of masses m and 2 m are whirled in horizontal circles, the heavier one in a radius r/2 and the lighter one in radius r. The tangential speed of lighter stone is n times that of the value of heavier stone when they experience same centripetal forces. The value of n is: **(2015 Re)**

(a) 1
(b) 2
(c) 3
(d) 4

19. A plank with a box on it at one end is gradually raised about the other end. As the angle of inclination with the horizontal reaches 30°, the box starts to slip and slides 4.0 m down the plank in 4.0 s. The coefficients of static and kinetic friction between the box and the plank will be, respectively: **(2015 Re)**



(a) 0.4 and 0.3
(b) 0.6 and 0.6
(c) 0.6 and 0.5
(d) 0.5 and 0.6

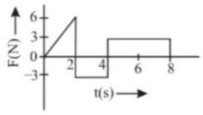
20. A nucleus of uranium decays at rest into nuclei of thorium and helium. Then: **(2015 Re)**

(a) The helium nucleus has less kinetic energy than the thorium nucleus.
(b) The helium has more kinetic energy than the thorium nucleus.
(c) The helium nucleus has less momentum than the thorium nucleus.
(d) The helium nucleus has more momentum than the thorium nucleus.

21. A balloon with mass m is descending down with an acceleration a (where a < g). How much mass should be removed from it so that it starts moving up with an acceleration a? **(2014)**

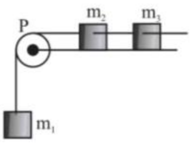
(a) $\frac{2ma}{g+a}$
(b) $\frac{2ma}{g-a}$
(c) $\frac{ma}{g+a}$
(d) $\frac{ma}{g-a}$

22. The force F acting on a particle of mass m is indicated by the force-time graph shown. The change in momentum of the particle over the time interval from zero to 8 s is: **(2014)**



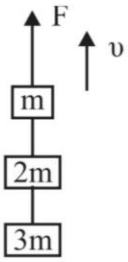
(a) 24 Ns
(b) 20 Ns
(c) 12 Ns
(d) 6 Ns

23. A system consists of three masses m_1, m_2 and m_3 is connected by a string passing over a pulley P. The mass m_1 hangs freely and m_2 and m_3 are on a rough horizontal table (the coefficient of friction = μ). The pulley is frictionless and of negligible mass. The downward acceleration of mass m_1 is: (Assume $m_1 = m_2 = m_3 = m$) **(2014)**



(a) $\frac{g(1-g\mu)}{9}$
(b) $\frac{2g\mu}{g}$
(c) $\frac{g(1-2\mu)}{3}$
(d) $\frac{g(1-2\mu)}{2}$

24. Three blocks with masses m, 2m and 3m are connected by strings, as shown in the figure. After an upward force F is applied on block m, the masses move upward at constant speed v. What is the net force on the block of mass 2m? (g is the acceleration due to gravity) **(2013)**



(a) 6 mg
(b) Zero
(c) 2 mg
(d) 3 mg

25. The upper half of an inclined plane of inclination θ is perfectly smooth while lower half is rough. A block starting from rest at the top of the plane will again come to rest at the bottom, if the coefficient of friction between the block and lower half of the plane is given by **(2013)**

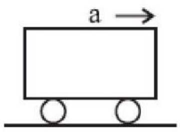
(a) $\mu = 2\tan\theta$
(b) $\mu = \tan\theta$
(c) $\mu = \frac{1}{\tan\theta}$
(d) $\mu = \frac{2}{\tan\theta}$

Answer Key

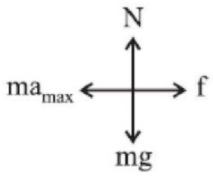
S1. Ans. (d)
S2. Ans. (c)
S3. Ans. (a)
S4. Ans. (b)
S5. Ans. (d)
S6. Ans. (c)
S7. Ans. (c)
S8. Ans. (d)
S9. Ans. (b)
S10. Ans. (d)
S11. Ans. (d)
S12. Ans. (d)
S13. Ans. (b)
S14. Ans. (b)
S15. Ans. (b)
S16. Ans. (a)
S17. Ans. (b)
S18. Ans. (c)
S19. Ans. (c)
S20. Ans. (b)
S21. Ans. (a)
S22. Ans. (c)
S23. Ans. (c)
S24. Ans. (b)
S25. Ans. (a)

Solutions

S1. Ans. (d)



In the frame of car



$N = mg$
and $f = ma$
$f \leq \mu N$
$\Rightarrow a \leq \mu g$
$\Rightarrow a \leq 1.5\, ms^{-2}$
or $a_{max} = 1.5\, ms^{-2}$

S2. Ans. (c)
Given, mass of the shell $= m$
Ratio of masses of the fragments is 2 : 2 : 1
Therefore, masses of three fragments are
$m_1 = \frac{m}{2}, m_2 = \frac{m}{2}$ and $m_3 = \frac{m}{4}$
Now fragments with equal masses i.e. m_1 and m_2 fly off perpendicularly with speeds $v_1 = v_2 = v$. Let the velocity of third fragment be v'.
Applying law of conservation of momentum,
$m_1 v_1 \hat{\imath} + m_2 v_2 \hat{\jmath} + m_3 \vec{v} = 0$
$\frac{mv}{2}\hat{\imath} + \frac{mv}{2}\hat{\jmath} + \frac{mv}{2}\vec{v}' = 0 \Rightarrow \vec{v}' = 2v(-\hat{\imath} - \hat{\jmath})$
$|\vec{v}| = 2v\sqrt{(-1)^2 + (-1)^2} = 2\sqrt{2}v$

S3. Ans. (a)

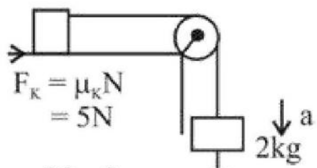
Hint: $\frac{S_n}{S_{n+1}} = \frac{\frac{a}{2}(2n-1)}{\frac{a}{2}(2(n+1)-1)} = \frac{2n-1}{2n+2-1} = \frac{2n-1}{2n+1}$

S4. Ans. (b)

Hint: $a = \frac{(m_2-m_1)g}{m_1+m_2}$ $\quad a = \frac{(6-4)g}{6+4} = \frac{2g}{10} = \frac{g}{5}$

S5. Ans. (d)

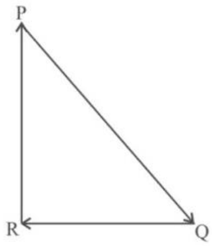
Hint:



$a = \frac{20-5}{12} = 1.25\ m/s^2$

S6. Ans. (c)

Hint:



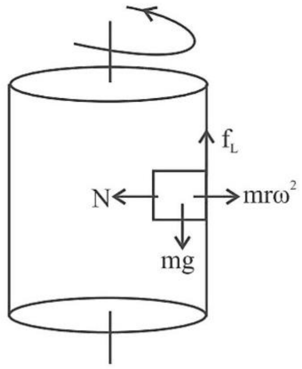
All these forces are forming closed loop in same order. So, net force is zero

Force = ma

$\Rightarrow m\frac{d\vec{v}}{dt} = 0 \Rightarrow \vec{v}$ constant

S7. Ans. (c)

Hint:



For equilibrium of the block limiting friction

$f_L \geq mg$

$\Rightarrow \mu N \geq mg$

$\Rightarrow \mu m r\omega^2 \geq mg$

$\omega \geq \sqrt{\frac{g}{r\mu}}$

Therefore,

$\omega_{min} = \sqrt{\frac{g}{r\mu}}$

$\omega_{min} = \sqrt{\frac{10}{0.1\times 1}} = rad/s$

S8. Ans. (d)

Hint: Coefficient of sliding friction is dimensionless

S9. Ans. (b)

Hint: $mv = 4mv' \Rightarrow v' = \frac{v}{4}$

S10. $e = \frac{v'}{4} = \frac{\frac{v}{4}}{v} = \frac{1}{4} = 0.25$

S8. Ans. (d)

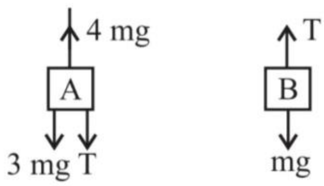
Hint: From wedge reference frame

For block to be at rest

ma $cos\theta = mg \sin\theta$

$a = g \tan\theta$

S11. Ans. (d)



When the string is cut T = 0

for block A

3 m a = 4 mg – 3 mg

$a = \frac{g}{3}$ for block B

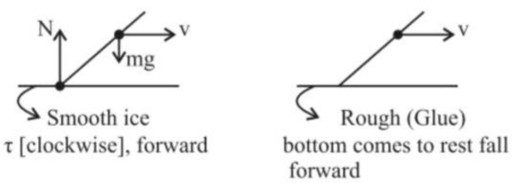
mg = ma ⇒ a = g

S12. Ans. (d)

Hint: In uniform circular motion, tension provides the necessary centripetal force required to keep particle in motion.

S13. Ans. (b)

Hint:



S14. Ans. (b)

Hint: $V_{max} = \sqrt{\mu r g}$

$= \sqrt{0.2 \times 3 \times 10}$

$= \sqrt{6}\ ms^{-1}$

$= \frac{\sqrt{6} \times 18}{5} \frac{km}{h} = 8.8\ km\,h^{-1}$

S15. Ans. (b)

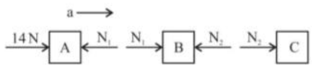
Hint: We know that $\frac{v^2}{gR} = \left(\frac{\mu_s + tan\theta}{1 - \mu_s\, tan\theta}\right)$

$v = \sqrt{vR\left(\frac{\mu_s + tan\theta}{1 - \mu_s\, tan\theta}\right)}$

S16. Ans. (a)

Hint: Acceleration of system $= \frac{F_{net}}{M_{total}}$

$= \frac{14}{4+2+1} = 2\ ms^{-2}$



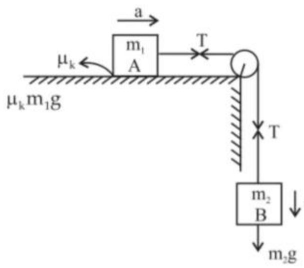
N_1 = Normal force between A and B

14 - N_1 = $m_A a$

14 - N_1 = 4 × 2

14 - N_1 = 8 ⇒ N_1 = 6 N

S17. Ans. (b)



For the motion of both blocks

$m_2 g - T = m_2 a$

$T - \mu_k m_1 g = m_1 a \Rightarrow a = \frac{(m_2 - \mu_k m_1)g}{m_1 + m_2}$

For the block of mass $'m_2'$

$m_2 g - T = m_2 \left[\frac{m_2 - \mu_k m_1}{m_1 + m_2}\right] g$

$T = m_2 g - \left[\frac{m_2 - \mu_k m_1}{m_1 + m_2}\right] m_2 g = m_2 g \left[\frac{m_2 + \mu_k m_1}{m_1 + m_2}\right]$

$\Rightarrow T = \frac{m_1 m_2 (1 + \mu_k) g}{m_1 + m_2}$

S18. Ans. (c)

Hint: $(F_C)_{heavier} = (F_C)_{lighter}$

$\Rightarrow \frac{2mV^2}{(r/2)} = \frac{m\,(nV)^2}{r} \Rightarrow n^2 = 4 \Rightarrow n = 2$

S19. Ans. (c)

Hint: Coefficient of static friction

$\mu_s = \tan 30° = \frac{1}{\sqrt{3}} = 0.6$

$a = g\sin 30° - \mu_k\, g\cos 30°$

$S = ut + \frac{1}{2}at^2 \quad [\because u = 0]$

$\Rightarrow 4 = \frac{1}{2}\left[\frac{g}{2} - \frac{\mu_k g\sqrt{3}}{2}\right] \times 16 \Rightarrow \mu_k = 0.5$

S20. Ans. (b)

Hint: According to conservation of linear momentum

$p_f = p_i = 0$

$\Rightarrow p_{He} - p_{Tn} = 0 \Rightarrow p_{He} = p_{Tn}$

but $K \propto \frac{1}{m}$ and $m_{He} < m_{Th} \Rightarrow So\ K_{He} > K_{Tn}$

S21. Ans. (a)

Hint:

For downward motion

$mg - F_a = ma \Rightarrow F_a = mg - ma$

If some mass Δ m is removed, then it starts accelerating upwards

$F_a - (m - \Delta m)g = (m - \Delta m)a$

mg – mg – mg + gΔm = ma – a Δ m

gΔm - ma = ma – aΔm ⇒ Δm [g + a] = 2 ma

Δm = $\frac{2ma}{g+a}$

S22. Ans. (c)

Hint: Change in momentum,

$\int \Delta p = \int$ Fdt = Area of F – t grah

$= \frac{1}{2} \times 2 \times 6 - 3 \times 2 + 4 \times 3 = 12$ Ns

S23. Ans. (c)

Hint: Acceleration = $\frac{\text{Net force in the direction of motion}}{\text{Total mass of system}}$

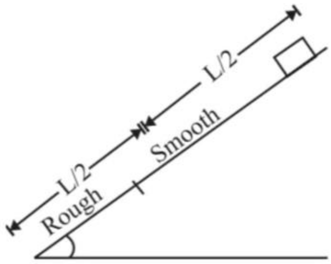
$= \frac{m_1 g - \mu(m_2+m_3)g}{m_1+m_2+m_3} = \frac{g(1-2\mu)}{3} [\because m_1 = m_2 = m_3]$

S24. Ans. (b)

Hint: As block of mass 2m moves with constant velocity so net force on it is zero.

S25. Ans. (a)

Hint:



Let m be mass of the block and L be length of the inclined plane.

For upper half smooth plane

Acceleration of the block, a = gsin θ

Here, u = 0 (∵ block starts from rest)

Using, $v^2 - u^2$ = 2as, we have

$v^2 - 0 = 2 \times g\ sin\theta \times \frac{L}{2}$

$v = \sqrt{gLsin\theta}$ ....(1)

For lower half rough plane Acceleration of the block, a' = gsin θ – μgcos θ where μ is the coefficient of friction between the block and lower half of the plane

Here, $u = v = \sqrt{gL\ sin\theta}$

v = 0 (∵ *block comes to rest*)

a = a' = gsin θ – μgcos θ, $s = \frac{L}{2}$

Again, using $v^2 - u^2$ = 2as, we have

$0 - \left(\sqrt{gL\ sin\theta}\right)^2 = 2 \times (g\sin\theta - \mu g\cos\theta) \times \frac{L}{2}$

–gLsin θ = (gsin θ – μg cos θ)L

–sin θ = sin θ – μcos θ

μ cos θ = 2sin θ ⇒ μ = 2tan θ