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Class 11
PHYSICS

Laws Of Motion
Daily Practice Problems
Solutions

Question 1.

State Newton’s laws of motion.

Answer:

Newton’s first law of motion:

- “Everybody continues to be in its state of rest or of uniform motion in a straight line, unless compelled by some external force to act otherwise”.
- “If external force on a body is zero, its acceleration is zero”.

Newton’s second law of motion:
“The rate of change of momentum of a body is proportional to the applied force and takes place in the direction in which the force acts”. Thus,
$\mathbf{F} = d\mathbf{P}/dt = m\mathbf{a}$.
Newton’s third law of motion:
“To every action, there is always an equal and opposite reaction”.

Question 2.

Give an expression for Newton’s second law of motion.

Answer:

Newton’s second law of motion states that, “The rate of change of momentum of a body is proportional to the applied force and takes place in the direction in which the force acts.” Therefore,

$$\mathbf{F} = k\, d\mathbf{P}/dt = k\, m\mathbf{a}$$

where $\mathbf{F}$ is the net external force on the body and $\mathbf{a}$ its acceleration. We set the constant of proportionality $k = 1$ in SI units. Then,

$$\mathbf{F} = d\mathbf{P}/dt = m\mathbf{a}$$

Question 3.

What do you understand by Impulse?

Answer:

- "Impulse is the product of force and time which equals change in momentum".

  Impulse = Force × time duration = Change in momentum
- A large force acting for a short time to produce a finite change in momentum is called an impulsive force.
- Units for impulse can be written as: kg-m-s^{-1} or N-s.

Question 4.

Give symbol, units and dimensions for static and kinetic friction.

Answer:

<u>For static friction:</u>
Symbol – f_s
Unit – N
Dimension – $[MLT^{-2}]$
<u>For kinetic friction:</u>
Symbol – f_k
Unit- N
Dimension- $[MLT^{-2}]$

Question 5.

What do you understand by friction?

Answer:

- Frictional force opposes (impending or actual) relative motion between two surfaces in contact. It is the component of the contact force along the common tangent to the surface in contact.
- Static friction f_s opposes impending relative motion; kinetic friction f_k opposes actual relative motion. They are independent of the area of contact and satisfy the following approximate laws:

  $$f_s \leq (f_s)_{max} = \mu_s R$$
  $$f_k = \mu_k R$$

  Here, μ_s is coefficient of static friction and μ_k is coefficient of kinetic friction.

Question 6.

A stone of mass 0.50 kg tied to the end of a string is whirled round in a circle of radius 2.0 m with a speed of 30 rev/min in a horizontal plane. What is the tension in the string? What is the maximum speed with which the stone can be whirled around if the string can withstand a maximum tension of 300N?

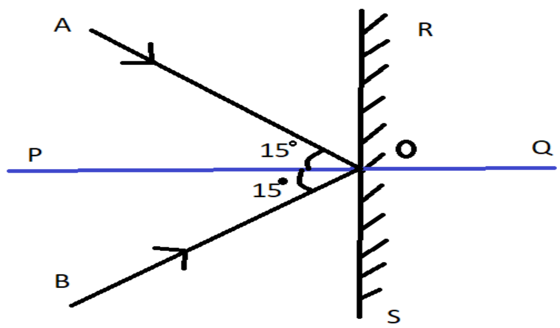
Answer:

Mass of the stone, m = 0.50 kg.
Radius of the circle, r = 2.0 m
Number of revolution per second, n = 30/60 = (1/2) rad/s
Angular velocity, $\omega = (v/r) = 2\prod n$
The centripetal force for the stone is provided by the tension T, in the string, i.e.,
$T = F_{centripetal} = (mv^2)/r = mr\omega^2 = mr(2\prod n)^2$.
$T = 0.50 \times 2.0 \times (2\times3.14\times1/2)^2 = 9.85$ N
Maximum tension in the string, $T_{max} = 300N$
$T_{max} = (mv_x^2/r)^{1/2}$
Therefore,
$v = (T_{max}\times r/m)^{1/2} = ((300 \times 2.0)/ (0.50))^{1/2}$
v = 34.64 m/s.
Therefore, the maximum speed of the stone is 34.64 m/s.

Question 7.

A batsman deflects a ball by an angle of 30^0 without changing its initial speed which is equal to 72 km/h. What is the impulse imparted to the ball? (Mass of the ball 0.20 kg).

Answer:



Given;
Mass of the ball, m = 0.20 kg.
Speed of the ball, u = 72 km/h = 20 m/s.
Initial momentum of the ball = (m × v) = (0.20 × 20) kg-m/s = 4 kg-m/s.
The angle between the initial and final direction of the ball = 30^0
Horizontal component of the initial velocity = vcosΘ along RO.
Vertical component of the initial velocity = vsinΘ along PO.
Horizontal component of the final velocity = vcosΘ along OS.
Vertical component of the final velocity = vsinΘ along OP.
The horizontal components of velocities having no change and the vertical components of the velocities are in the opposite directions.
So, the impulse imparted to the ball = change in the linear momentum of the ball.
Impulse imparted to the ball = (mvcosΘ – (-mvcosΘ)) = 2mvcosΘ.
Therefore, Impulse = (2 × 4 $\cos 15^0$) = 2 × 4 × 0.9659 = 7.73 kg-m/s.

Question 8.

Eight five-rupee coins are put on top of each other on a table. Each coin has a mass m. Give the magnitude and direction of

(a) The force on the fifth coin (counted from the bottom) due to all the coins on its top,
(b) The reaction of the 4^{th} coin on the 5^{th} coin.

Answer:

(a) The force on the 5^{th} coin is due to the weight of the three coins kept above it. Weight of one coin is (mg). So, the weight of the three coins are (3mg). Force exerted on the fifth coin is (3mg) N and the force acts vertically downwards.
(b) The 4^{th} coin is under the weight of four coins above it and experiences a downward force due to the four coins. The total downward force on the 4^{th} coin is (4mg) N. So, according to the Newton's third law of motion; the 4^{th} coin will exert a reaction force upwards. Therefore, the force exerted by the 4^{th} coin on the 5^{th} coin is equal to (4mg) N and acts in the upward direction.

Question 9.

A shell of mass 0.025 kg is fired by a gun of mass 200 kg. If the muzzle speed of the shell is 75 m/s. What is the recoil speed of the gun?

Answer:

Mass of the gun, M = 200 kg.
Mass of the shell, m = 0.025 kg.
Muzzle speed of the shell, v = 75 m/s.
Let recoil speed of the gun is V.
Since, both the gun and the shell are at rest initially.
So, initial momentum of the system = 0.
And, the final momentum of the system = (mv – MV)
According to the law of conservation of momentum:
Final momentum = Initial momentum
(mv – MV) = 0.
Therefore,
$V = -(mv)/(M)$.
$V = -(0.025 \times 75)/200 = -0.0094$ m/s.
Negative sign shows that the gun moves in opposite direction of motion of the shell.

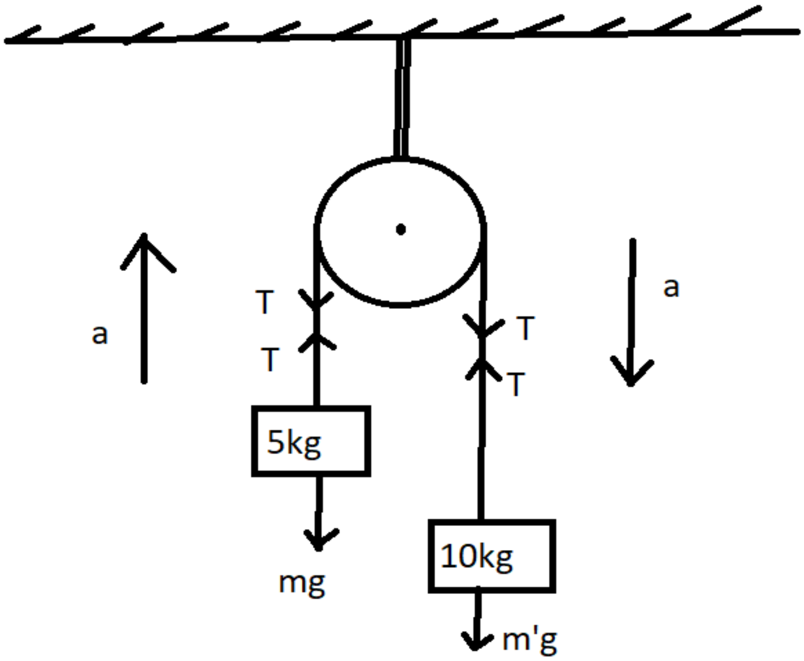
Question 10.

Two masses 5 kg and 10 kg are connected at the two ends of a light inextensible string that goes over a frictionless pulley. Find the acceleration of the masses, and the tension in the string when the masses are released.

Answer:

Smaller mass, m = 5 kg.
Larger mass, m’ = 10 kg.
Tension in the string = T
The heavier mass m’ will move downwards and the smaller mass m will move upwards.
Applying Newton’s second law,
For mass m:
$T - mg = ma$ ___________________ (1)
For mass m’:

m'g – T = m'a_________________ (2)
Add (1) and (2):
(m' – m) g = (m + m') a
a = (m' – m) g/ (m + m') = (10 – 5) 10/ (10 + 5) = 50/15 = 3.33m/s^2.
Therefore, acceleration of the mass is 3.33 m/s^2.
Substituting this value in equation (2), we get
m'g – T = m' [(m' – m) g/(m+m')] = 2mm'g/(m+m')
T = 2×5×10×10/ (5+10)
T = 1000/15 = 66.66N
Therefore, the tension on the string is 66.66N.



Question 11.

A truck starts from rest and accelerates uniformly at 3.0 m/s^2. At t = 12 s, a stone is dropped by a girl standing on the top of the truck (8m high from the ground). What are the (a) velocity, and (b) acceleration of the stone at t = 13s.

Answer:

Initial velocity, u = 0
Acceleration, a = 3 m/s^2,
t = 12 s.
Using equation, v = u + at; we get,
v = 0+3×12 = 36 m/s.

The final velocity, v = 36 m/s.
At time, t = 13 s, the horizontal component of the velocity in the absence of the air resistance remains unchanged,
v_x = 36 m/s.
The vertical component of the velocity is given by the equation;
$v_y = u + a_y t$
Here, t = 13- 12 = 1s and $a_y = a = 12\ m/s^2$.
Therefore, the resultant velocity v of the stone is:
$v = (v_x^2 - v_y^2)^{1/2}$
$v = ((36)^2 - (12)^2)^{1/2}$
$v = (1296 - 144)^{1/2}$
$v = (1152)^{1/2} = 33.94$ m/s.
$\tan\Theta = v_y/v_x = 12/36 = 1/3 = 0.33$
$\Theta = \tan^{-1}(0.33) = 18.26^0$.
So, when the stone is dropped from the truck, the horizontal force of acting on it becomes zero. However, the stone continues to move under the influence of gravity.
Therefore, the acceleration of the stone is $12 m/s^2$ and acts vertically downwards and the path followed by it will be parabolic.

Question 12.

A constant retarding force of 40N is applied to a body of mass 15 kg moving initially with a speed of 10 m/s. How long does the body take to stop?

Answer:

Retarding force, F = -40N
Mass of the body, m = 15 kg.
Initial velocity of the body, u = 10 m/s.
Final velocity of the body, v = 0
Using Newton's second law of motion, the acceleration produced in the body can be calculated as:
F = ma
(-40) = 15 × a
Therefore, $a = (-40)/(15) = -2.67\ m/s^2$
Using the 1st equation of motion, the time taken (t) by the body to come to come to rest:
v = u + at

Hence, t = (-u)/(a) = (-10)/(-2.67) = 3.74 s.

Question 13.

Give the statement for "Law of conservation of Momentum".

Answer:

- In an isolated system (i.e. a system with no external force), mutual forces between pairs of particles in the system can cause momentum change in individual particles, but since the mutual forces for each pair are equal and opposite, the momentum changes cancel in pairs and the total momentum remains unchanged. This fact is known as the law of conservation of momentum.
- So, the total momentum of an isolated system of particles is conserved. The law follows from the second and third law of motion.

Question 14.

A circular racetrack of radius 500m is banked at an angle of 22.5^0 . If the coefficient of friction between the wheels of a race-car and the road is 0.15. What is the, (a) optimum speed of the race-car to avoid wear and tear on its tyres, and (b) maximum permissible speed to avoid slipping?

Answer:

On a banked road, the horizontal component of the normal force and the frictional force contribute to provide centripetal force to keep the car moving on a circular turn without slipping. At the optimum speed, the normal reaction's component is enough to provide the needed centripetal force, and the frictional force is not needed. The optimum speed v_o is given by:

$v_0 = (Rg\tan\Theta)^{1/2}$

Here, R = 500 m, g = 9.8 m/s^2, $\Theta = 22.5^0$

$v_0 = (4900\times\tan22.5^0)^{1/2} = (4900 \times 0.4142)^{1/2} = (2028.6)^{1/2} = 45.04$ m/s.

The maximum permissible speed, $v_{max} = [(Rg)(\mu_s+\tan\Theta/1-\mu_s\tan\Theta)]^{1/2}$

$v_{max} = [(500 \times 9.8)\ (0.15 + \tan 22.5^0/1-0.15\tan22.5^0)]^{1/2} = (2947.72)^{1/2}$

$v_{max} = 54.29$ m/s.

Question 15.

Determine the maximum acceleration of the train in which a box lying on its floor will remain stationary, given that the co-efficient of static friction between the box and the train's floor is 0.2.

Answer:

Since the acceleration of the box is due to the static friction,
$ma = f_s \leq \mu_s N = \mu_s mg$
i.e., $a \leq \mu_s g$
So, $a_{max} = \mu_s g = 0.2 \times 10 = 2.0\ m/s^2$.

Question 16.

What is the unit and dimension of "Impulse"?

Answer:

Units: kg-m/s or N-s.
Dimension: $[MLT^{-1}]$.

Question 17.

Give the magnitude and direction of the net force acting on a stone of mass 0.5 kg.
(a) Just after it is dropped from the window of a stationary car.
(b) Just after it is dropped from the window of a car accelerating with 2 m/s^2.

Answer:

(a) Mass of stone = 0.5 kg.
Acceleration = 10 m/s^2.
Net force, $F = mg = 0.5 \times 10 = 5.0\ N$
The force acts vertically downwards.

(b) When the train accelerates at 2 m/s^2, the stone experiences an additional force of F' = ma = 0.5 × 2 = 1.0 N in horizontal direction.
But as the stone is dropped, the force F' no longer acts and the net force acting on the stone,
F = mg = 0.5 × 10 = 5.0 N (vertically downwards).

Question 18.

Two billiard balls each of mass 0.08 kg moving in opposite directions with speed 5 m/s collide and rebound with the same speed. What is the impulse imparted to each ball due to the other?

Answer:

Mass of each ball = 0.08 kg.
Initial velocity of each ball = 5 m/s.
Magnitude of the initial momentum of each ball, p_i = 0.4 kg-m/s.
After collision, the balls change their directions of motion without changing the magnitudes of their velocity.
Final momentum of each ball, p_f = -0.4 kg-m/s.
Impulse imparted to each ball = change in the momentum of the system.
So, $(p_f - p_i)$ = (-0.4 – 0.4) = -0.8 kg-m/s.
Here, negative sign indicates that the impulses imparted to the balls are opposite in direction.

Question 19.

A stream of water flowing horizontally with a speed of 12 m/s gushes out of a tube of cross-sectional area 2×10^{-2} m^2 and hits a vertical wall nearby. What is the force exerted on the wall by the impart of water, assuming it does not rebound?

Answer:

Speed of water flowing, v = 12 m/s.
Cross- sectional area of the tube, A = 2×10^{-2} m^2.
So, in one second, the distance travelled = velocity(v)
Density of water, ρ = 1000 kg-m^{-3}.

Mass of water hitting the wall per second = ρ×A×v = $1000 \times 2 \times 10^{-2} \times 12$ kg/s. = 240 kg/s.
Hence, the force exerted on the wall by the impart of water = momentum loss of water per second = mass × velocity = 240 × 12 = 2880 N.

Question 20.

A bob of mass 0.2 kg hung from the ceiling of a room by a string 4 m long is set into oscillation. The speed of the bob at its mean position is 1.5 m/s. What is the trajectory of the bob if the string is cut, when the bob is (a) at one of its extreme positions, and (b) at its mean position?

Answer:

(a) At each extreme position, the velocity of bob is zero because it is only under the influence of gravity at the extreme position. Hence, the bob will fall vertically on the ground.
(b) At each mean position, the velocity of the bob is 1.5 m/s along the tangent to the arc, which is in horizontal direction. So, if the string is cut at the mean position, the bob will behave as horizontal projectile and will follow a parabolic path.

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