# CHAPTER-5: LAWS OF MOTION

# QUESTIONS :

1. What is Aristotle's fallacy?
2. State Aristotlean law of motion
3. Why uniformly moving body comes to rest?
4. What is uniform motion?
5. Who discovered Aristotlean law of motion?
6. What is the measure of inertia?
7. Give an example for inertia of rest.
8. Give an example for inertia of motion
9. State Newton's first law of motion.
10. State the law of inertia.
11. What is the acceleration of a body having uniform linear motion?
12. What is the force on a body moving with uniform speed?
13. Whose ideas did Newton make use of while framing his famous laws of motion?
14. A space ship out in an interstellar space, far from all other objects and with all its rockets turned off, has zero acceleration but still in motion, Why?
15. State Newton's second law of motion
16. Define linear momentum of a body.
17. Is linear momentum of a body is scalar or a vector?
18. Write the S.I unit of linear momentum
19. Write the dimensional formula for linear momentum.
20. Why athletes run a few steps before taking a jump?
21. Why a passenger standing in a bus fall backwards, when the bus suddenly starts moving?
22. Why a passenger getting down from a moving bus must run a few steps in the direction of the motion of the bus?
23. It is more difficult to catch a cricket ball than a tennis ball thrown with same velocity. Why?
24. The rate of change of momentum of a body is 5 $Kgms^{-1}$. What is the force acting on the body?

25. Why a cricketer does lower his hand soon after/while catching a cricket ball?
26. Give an example for an object having magnitude of momentum fixed but change in direction.
27. Define impulse of a force.
28. What is an impulsive force?
29. State Newton's third law of motion.
30. State the law of conservation of linear momentum.
31. What is meant by equilibrium of a particle?
32. What is frictional force?
33. What is meant by static friction?
34. What is meant by normal reaction force?
35. What is meant by the limiting force of friction?
36. What is meant by kinetic friction?
37. What is frictional force?
38. Define co-efficient of static friction.
39. What is kinetic (sliding) friction?
40. What is rolling friction?
41. What is centripetal force?
42. Is Aristotelian law correct? Justify you answer.
43. What is inertia? Who gave this concept?
44. A net external force of 5 N is acting on a body of mass 10 Kg. What is the acceleration produced?
45. Compare the linear momenta of two bodies one of mass 5 g moving with a speed of 50 $ms^{-1}$ and another body of mass 0.5 Kg moving with a speed of 0.5 $ms^{-1}$.
46. Mention any two advantages of friction.
47. State Newton's second law of motion and hence derive F=ma
48. Write the S.I unit and dimensional formula for force.
49. Define newton the S.I unit of force.
50. What is the force acting on a body of mass 0.05 Kg if it accelerates the body by $3ms^{-2}$.?
51. What is impulse?
52. What is impulsive force?
53. Write the S.I unit and dimensional formula of impulse.

54. State Newton's third law of motion.
55. State the law of conservation of linear momentum.
56. Prove the law of conservation of momentum.
57. Mention the common forces in mechanics.
58. What is the change in momentum of a particle in uniform circular motion at diametrically opposite points?
59. Write the expression for the spring force and explain the terms.
60. In mechanics we come across so many contact forces, their origin is electrical force though the particles are neutral. Explain.
61. Write the important points to be noted about the Newton's third law of motion with regard to the usage of the terms 'action & reaction'.
62. When do we say that the particle is in equilibrium under the action of 'n' number of forces say $F_1$, $F_2$, $F_3$ ------- $F_n$
63. Derive the expression for maximum speed of circular motion of a car on (i) a level road (ii) on a banked road.
64. Write the steps to be followed to solve problems in mechanics.

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# ANSWERS :

1. An external force is required to keep the body in motion.
2. An external force is required to keep the body in motion.
3. Due to opposing force /frictional force.
4. If a body covers equal distance in equal intervals of time, however small these intervals be.
5. Galileo galilei
6. Gravitational mass
7. A book kept on the stationary table
8. An object moving with uniform speed
9. Everybody continues to be in the state of rest or of uniform motion in a straight line unless compelled by an external force to act otherwise.
10. Everybody continues to be in the state of rest or of uniform motion in a straight line unless compelled by an external force to act otherwise
11. zero
12. zero
13. Galileo Galilee's ideas
14. Due to inertia of motion
15. The rate of change of momentum of a body is directly proportional to the applied force and takes place in the direction in which the force acts
16. Linear momentum of a body is defined as the product of the mass of the body and its velocity.
17. Vector
18. Kg m $s^{-1}$
19. $M^1L^1T^{-1}$
20. To gain the linear momentum, this enables the athlete to jump a longer distance.
21. Due to inertia of rest
22. Due to inertia of motion
23. Since the mass of a cricket ball is more than the tennis ball, the momentum of the cricket ball is more than the momentum of the tennis ball.
24. Force = rate of change of momentum = 5 N

25. To increase the time interval to stop the ball and hence require a smaller force.
26. A stone tied to a string and whirled with uniform speed in a horizontal plane.
27. It is defined as the product of force and time. It is also equal to the change in momentum of the body
28. Large force acting for a short interval of time to produce a finite change in momentum is called an impulsive force
29. To every action, there is always an equal and opposite reaction.
30. The total momentum of an isolated system of interacting particles is conserved.
31. A body is said to be in equilibrium if the net external force acting on it is zero.
32. The opposing force arising between the two surfaces in contact due to applied force
33. The force of friction which opposes the applied force during the stationary state of a body is called static friction
34. Normal reaction force is a contact force exerted by one body on the other body in a direction perpendicular to the surface of contact.
35. The maximum value of static frictional force which comes into play when a body just starts moving over the surface of another body is called as limiting force of friction
36. The force of friction which comes into play when one body moves over the surface of another body is called kinetic friction.
37. The opposing force arising between the two surfaces in contact due to applied force.
38. The co-efficient of static friction is defined as the ratio pf applied force to the normal force. $\mu_s = \frac{f_s}{N}$
39. Frictional force that opposes the relative motion between the surfaces in contact is called kinetic friction.
40. The force of friction that comes into play when one body roles over the other body is called rolling friction.
41. The force experienced by a body moving along a circular path and always directed towards the centre.

42. No. When the body is moving uniformly no external force is required to maintain the motion.
43. An object continuing in the same state of rest or of uniform motion is called inertia .Galileo Galilee gave the concept of inertia.
44. F=ma => a = F/m = 5/10 = 0.5N
45. we know that momentum p = mv

$P_1 = m_1v_1 = 5 \times 10^{-3} \times 50 = 0.25$

$P_2 = m_2v_2 = 0.5 \times 0.5 = 0.25$ Kg

Therefore $p_1 = p_2$

Both the bodies have the same momenta.

46. frictional force helps us to walk on the surface of earth

Frictional force helps us to hold any object with hands. It helps to apply the brakes, vehicles to move without sliding etc.,

47. The rate of change of momentum of a body is directly proportional to the applied force and takes place in the direction in which the force acts.

Let us consider a body of mass 'm' moving with velocity 'v' under the action of force 'F' changes to v+Δv in a time 'Δt'.

From II law of motion $F \propto \frac{\Delta p}{\Delta t}$ or $F = K\frac{\Delta p}{\Delta t}$ where k=constant

$\lim_{\Delta p \to 0}\left(\frac{\Delta p}{\Delta t}\right) = \frac{dp}{dt}$ Therefore $F = K\frac{dp}{dt}$

For a body of constant mass $\frac{dp}{dt} = \frac{d(mv)}{dt} = m\frac{dv}{dt} = ma$

Therefore F=K ma, If K=1, $F = \frac{dp}{dt} = ma$

$$\boldsymbol{F = ma}$$

48. newton---S.I unit

$M^1L^1T^{-2}$ ---- dimensional formula

49. Force is said to be 0ne newton if it causes an acceleration of $1ms^{-2}$ to a mass of 1 Kg.
50. We know that F=ma = 0.05 X 3 = 0.15N
51. Impulse is product of force and time I= F X t

52. A large force acting for a short time to produce a finite change in momentum is called an impulsive force.
53. S.I unit---- N-s

    Dimensional formula-----$MLT^{-1}$
54. To every action, there is always an equal and opposite reaction.
55. The total momentum of an isolated system of interacting particles is conserved.
56. Let us consider two bodies A & B with initial momenta $p_A$ & $p_B$ collide, get apart with final momenta $p_A^1$ & $p_B^1$ respectively.

    From Newton's second law of motion

    $F_{AB}\,\Delta t = p_A^1 - p_A$ & $F_{BA}\,\Delta t = p_B^1 - p_B$

    Where $\Delta t$ = time for which the bodies are in contact.

    From Newton's III law of motion

    $$F_{AB} = -F_{BA} \rightarrow p_A^1 - p_A = -(p_B^1 - p_B)$$

    $$\mathbf{p_A^1 + p_B^1 = p_A + p_B}$$

    **Total final momentum = total initial momentum**

57. a) frictional force b) viscous force c) spring force d)gravitational force.
58. p-(-p) = p + p= 2p
59. F = -K x where k=spring constant, x= displacement
60. At the microscopic level, all bodies are made of charged constituents (nuclei and electrons). Various contact forces are arising due to elasticity of bodies, molecular collisions and impacts, etc., These forces are due to electrical forces of charged constituents of different bodies.
61. 1. Action and reaction are nothing but force.

    2. Forces always occur in pairs. $F_{AB} = -F_{BA}$ that is force on A by B is equal to negative force on B by A.

    3. There is no cause and effect relation implied in third law.

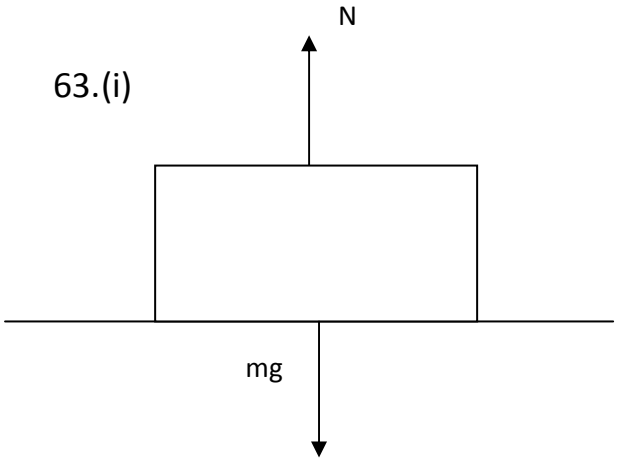
    4. The force on A by B and the force on B by A act at the same instant.

    5. Action and reaction forces act on different bodies and not on the same body.

    6. By considering system of two bodies as a whole $F_{AB}$ & $F_{BA}$ are internal forces of the system (A+B). They add up to give a null force.

62. A particle is said to be in equilibrium under the action of 'n' number of forces say $F_1$, $F_2$, $F_3$ ------- $F_n$ if they can be represented by the sides of a closed n-sided polygon with arrows taken in order.

63.(i)




In order to have circular motion centripetal force should be balanced by static frictional force between car tyres and road.

Centripetal force $=\frac{mv^2}{R}$ where R= radius of the circle

frictional force $f_s \leq \mu_s N$ But N=mg

$$f_s \leq \mu_s mg$$

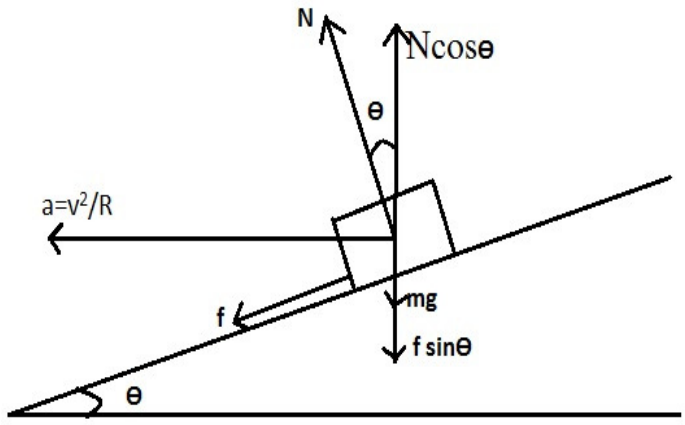
$$\frac{mv^2}{R} \leq \mu_s mg$$

$$v^2 \leq \mu_s Rg$$

From the above equation we know that the velocity is independent of mass of the car.

Therefore for a given value of $\mu_s$ and R maximum speed of circular motion $\boldsymbol{v_{max} = \sqrt{\mu_s Rg}}$

ii)




From figure we have N cos⍰ = mg + f sin⍰ ----------(1)

Nsin⍰ + f cos⍰ = $mv^2/R$ ----------(2)

Centripetal force is provided by the horizontal components of 'f' & 'N' and velocity is maximum when $f = \mu_s N$

$$N\cos\Theta = mg + \mu_s N \sin\Theta$$

$$N\cos\Theta - \mu_s N \sin\Theta = mg$$

$$N(\cos\Theta - \mu_s \sin\Theta) = mg$$

$$N = \frac{mg}{\cos\Theta - \mu_s \sin\Theta}$$

Substituting the value of N and 'f' in equation (2) we get

$$\frac{mg}{(\cos\Theta - \mu_s \sin\Theta)}(\sin\Theta + \mu_s \cos\Theta) = \frac{mv^2}{R}$$

$$v^2 = \frac{(\sin\Theta + \mu_s \cos\Theta)}{(\cos\Theta - \mu_s \sin\Theta)} Rg$$

Dividing the numerator and denominator by cos⍰ we get

$$v^2 = \frac{(\tan\Theta + \mu_s)}{(1 - \mu_s \tan\Theta)} Rg$$

$$\mathbf{v = \sqrt{\frac{(\tan\Theta + \mu_s)}{(1 - \mu_s \tan\Theta)} Rg}}$$ If $\mu_s = 0$ , then $\boldsymbol{v = \sqrt{\tan\theta\, Rg}}$

64.a) Using the given data a free body diagram should be drawn.

b) One of the convenient part should be chosen as one system
c) A separate diagram which shows this system and the forces acting on it is written
d) The magnitude and the directions of all the forces are represented.
e) The rest should be treated as unknown to be determined using Newton's laws of motion
f) The remaining part of the problem can be solved by considering another part of the diagram and Newton's third law of motion.

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