Narayan Gurukul Academy

Shining minds, building character, transforming lives

CBSE · Physics · Class 11 **Chapter 4 · Laws of Motion**

Section A · Mixed Numericals on Newton's Laws

1. Two forces of $8\,\mathrm{N}$ and $6\,\mathrm{N}$ act at right angles on a body of mass $5\,\mathrm{kg}$. Find the magnitude of the acceleration and its direction measured from the $8\,\mathrm{N}$ force. *[2]*

2. A body of mass $0.40\,\mathrm{kg}$ moving with a constant speed of $10\,\mathrm{m/s}$ to the north is subjected to a constant force of $8.0\,\mathrm{N}$ directed towards the south for $30\,\mathrm{s}$. Taking the origin at the point where the force is first applied, predict the position of the body at $t = -5\,\mathrm{s}$, $t = 25\,\mathrm{s}$ and $t = 100\,\mathrm{s}$. *[3]*

3. A constant retarding force of $50\,\mathrm{N}$ acts on a body of mass $20\,\mathrm{kg}$ moving with a speed of $15\,\mathrm{m/s}$. How long does the body take to come to rest? *[2]*

4. A $400\,\mathrm{kg}$ three-wheeler together with its driver of mass $65\,\mathrm{kg}$ is moving with a speed of $36\,\mathrm{km/h}$. The vehicle is braked and comes to rest in $4.0\,\mathrm{s}$. Find the average retarding force. *[2]*

5. A block of mass $2\,\mathrm{kg}$ moving on a rough horizontal surface at $4\,\mathrm{m/s}$ is brought to rest purely by friction over a distance of $4\,\mathrm{m}$. Find the constant frictional force acting on it. *[2]*

6. Two blocks of masses $2\,\mathrm{kg}$ and $3\,\mathrm{kg}$ connected by a light string are pulled along a smooth horizontal surface by a horizontal force of $15\,\mathrm{N}$ applied to the $3\,\mathrm{kg}$ block. Find the common acceleration and the tension in the string. *[2]*

Section B · Impulse and Momentum

7. A ball of mass $0.15\,\mathrm{kg}$ moving at $10\,\mathrm{m/s}$ is struck so that it rebounds along its original path at $8\,\mathrm{m/s}$. If the contact time is $0.05\,\mathrm{s}$, find the impulse on the ball and the average force exerted on it. *[2]*

8. A varying force rising linearly from zero to $20\,\mathrm{N}$ in $2\,\mathrm{s}$ is applied to a body and then ceases. Find the impulse delivered. *[2]*

9. A ball of mass $100\,\mathrm{g}$ hits a wall normally at $5\,\mathrm{m/s}$ and rebounds elastically (same speed). Find the impulse imparted to the ball by the wall. *[2]*

Section C · Variable Mass and Rockets

10. A rocket of initial mass $4000\,\mathrm{kg}$ (of which $3000\,\mathrm{kg}$ is fuel) is launched vertically. It ejects gas at the constant rate of $60\,\mathrm{kg/s}$ with exhaust velocity $800\,\mathrm{m/s}$. Take $10\,\mathrm{m/s^2}$. (i) Find the initial thrust. (ii) Neglecting air resistance, find the maximum velocity the rocket attains. *[5]*

Section D · Two-Body and Connected-Body Dynamics

11. A man of mass m stands on a weighing machine in a lift. Derive the expression for the machine reading when the lift moves (i) up with acceleration a and (ii) down with acceleration a. Evaluate for $m = 70\,\mathrm{kg}$, $a = 5\,\mathrm{m/s^2}$ and $10\,\mathrm{m/s^2}$. *[3]*

12. Two bodies of masses $10\,\mathrm{kg}$ and $20\,\mathrm{kg}$ are tied to the ends of a light inextensible string resting on a smooth horizontal table. A horizontal force of $600\,\mathrm{N}$ pulls the $20\,\mathrm{kg}$ body, the string dragging the $10\,\mathrm{kg}$ body behind it. Find the common acceleration and the tension in the string. *[3]*

13. A block of mass $2\,\mathrm{kg}$ is placed on the floor of a lift that accelerates vertically upwards at $2\,\mathrm{m/s^2}$. Take $10\,\mathrm{m/s^2}$. Find the normal reaction exerted by the floor on the block. *[2]*

14. Explain what is meant by a pseudo force and in which frame it is introduced. Hence calculate the horizontal pseudo force experienced by a $60\,\mathrm{kg}$ passenger when a bus accelerates at $3\,\mathrm{m/s^2}$. *[2]*

Section E · Friction on Inclined Planes

15. A block of mass $2\,\mathrm{kg}$ slides down a rough inclined plane of inclination 30° with coefficient of friction $\mu = 0.2$. Take $10\,\mathrm{m/s}^2$. *[2]*
Find the acceleration of the block.

16. A block is projected up a rough inclined plane of inclination 30° with an initial speed of $10\,\mathrm{m/s}$. If $\mu = 0.2$ and $10\,\mathrm{m/s}^2 = 10\,\mathrm{m/s}^2$, find the distance the block travels along the plane before it comes momentarily to rest. *[2]*

17. Show that a body just begins to slide down an inclined plane when the tangent of the angle of inclination equals the coefficient of static friction. Define the angle of repose using this result. *[3]*

Section F · Circular Dynamics and Banking

18. Derive the expression $v = \sqrt{rg\tan\theta}$ for the optimum safe speed of a vehicle on a banked road when friction is neglected. A road is banked with $\tan\theta = 0.4$ and radius of curvature $r = 250\,\mathrm{m}$; take $10\,\mathrm{m/s}^2$. Find the optimum safe speed. *[3]*

19. Derive $v_{\max} = \sqrt{\frac{rg(\mu+\tan\theta)}{1-\mu\tan\theta}}$ for the maximum safe speed of a vehicle on a banked curve when friction is present. Evaluate for radius $r = 100\,\mathrm{m}$, banking angle $\theta = 15^\circ$ and $\mu = 0.2$. *[5]*

20. A conical-pendulum bob of mass $0.5\,\mathrm{kg}$ rotates in a horizontal circle of radius $0.4\,\mathrm{m}$, the string making 30° with the vertical. Take $10\,\mathrm{m/s}^2$. Find (i) the tension in the string and (ii) the speed of the bob. *[3]*

Answer Key — Assignment 2 (detailed solutions)

1. $F = \sqrt{8^2 + 6^2} = 10\,\mathrm{N}$; $a = 10/5 = 2\,\mathrm{m/s^2}$ at $\theta = \tan^{-1}(6/8) = 36.9^\circ$ to the 8 N force.

2. $a = -8/0.4 = -20\,\mathrm{m/s^2}$ (south). For $t < 0$: $x = 10t = -50\,\mathrm{m}$. For $0 < t < 30$: $x = 10t - 10t^2$, giving $x(25) = 250 - 6250 = -6000\,\mathrm{m}$. After 30 s: $v = 10 - 600 = -590\,\mathrm{m/s}$ and $x = 300 - 9000 - 590(t - 30)$, giving $x(100) = -8700 - 41300 = -50000\,\mathrm{m}$.

3. $a = 50/20 = 2.5\,\mathrm{m/s^2}$; $t = v/a = 15/2.5 = 6\,\mathrm{s}$.

4. $v_0 = 10\,\mathrm{m/s}$; $a = 10/4 = 2.5\,\mathrm{m/s^2}$; $F = 465 \times 2.5 = 1162.5\,\mathrm{N}$.

5. $v^2 = 2as \Rightarrow a = v^2/(2s) = 16/8 = 2\,\mathrm{m/s^2}$; $f = ma = 2 \times 2 = 4\,\mathrm{N}$.

6. $a = 15/5 = 3\,\mathrm{m/s^2}$; tension accelerates the 2 kg block: $T = 2 \times 3 = 6\,\mathrm{N}$.

7. $J = m(v - u) = 0.15 \times (8 - (-10)) = 2.7\,\mathrm{N\,s}$; $F = 2.7/0.05 = 54\,\mathrm{N}$.

8. Impulse = area under the $F - t$ graph = $\frac{1}{2} \times 2 \times 20 = 20\,\mathrm{N\,s}$.

9. $J = m(v - u) = 0.1 \times (5 - (-5)) = 1\,\mathrm{N\,s}$ (normal to the wall).

10. (i) Thrust $F = (dm/dt)v_{rel} = 60 \times 800 = 48000\,\mathrm{N}$. (ii) Burn time $t = 3000/60 = 50\,\mathrm{s}$, final mass 1000 kg: $v = v_{rel}\ln(m_0/m_f) - gt = 800\ln 4 - 500 \approx 1109 - 500 = 609\,\mathrm{m/s}$. *[Hint: rocket equation with gravity]*

11. $N = m(g + a)$ upward, $N = m(g - a)$ downward. Values: $70 \times 15 = 1050\,\mathrm{N}$ and $70 \times 5 = 350\,\mathrm{N}$.

12. $a = F/(m_1 + m_2) = 600/30 = 20\,\mathrm{m/s^2}$; $T = m_1 a = 10 \times 20 = 200\,\mathrm{N}$.

13. $N = m(g + a) = 2 \times 12 = 24\,\mathrm{N}$.

14. Pseudo force $F = -ma$ is invented in a non-inertial (accelerating) frame so that Newton's laws hold there. Magnitude for the passenger: $F = 60 \times 3 = 180\,\mathrm{N}$, opposite to the bus's acceleration.

15. $a = g(\sin 30^\circ - \mu\cos 30^\circ) = 10(0.5 - 0.2 \times 0.866) = 10 \times 0.3268 = 3.27\,\mathrm{m/s^2}$.

16. Going up, retardation $a = g(\sin 30^\circ + \mu\cos 30^\circ) = 10 \times 0.6732 = 6.73\,\mathrm{m/s^2}$; $s = v^2/(2a) = 100/13.46 = 7.43\,\mathrm{m}$.

17. At the verge of slipping $mg\sin\theta = \mu mg\cos\theta$, so $\tan\theta = \mu$. The angle of repose is that inclination; the angle of friction satisfies $\tan\lambda = \mu$, hence equal.

18. $v = \sqrt{rg\,\tan\theta}$; with $\tan\theta = 0.4$, $r = 250\,\mathrm{m}$: $v = \sqrt{250 \times 10 \times 0.4} = \sqrt{1000} = 31.6\,\mathrm{m/s}$.

19. $v_{\max} = \sqrt{\frac{rg(\mu + \tan\theta)}{1 - \mu\tan\theta}}$. With $r = 100$, $\tan 15^\circ = 0.268$, $\mu = 0.2$: $v^2 = 1000 \times (0.2 + 0.268)/(1 - 0.2 \times 0.268) = 494\,\mathrm{m^2/s^2}$, so $v \approx 22.2\,\mathrm{m/s}$.

20. (i) $T\cos 30^\circ = mg \Rightarrow T = 0.5 \times 10/0.866 = 5.77\,\mathrm{N}$. (ii) $v = \sqrt{rg\tan\theta}$; $\tan 30^\circ = 0.577$: $v = \sqrt{0.4 \times 10 \times 0.577} = \sqrt{2.31} = 1.52\,\mathrm{m/s}$.