Narayan Gurukul Academy

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

A · Force, FBD and Newton's Laws

1. State Newton's second law of motion in momentum form $\vec{F} = d\vec{p}/dt$ and hence define the unit newton. Also write the familiar form $\vec{F} = m\vec{a}$ for a constant mass. *[1]*

2. A pebble of mass 0.05 kg is thrown vertically upwards. (Ignore air resistance.) Find the magnitude and direction of the net force on the pebble (i) during its upward motion, (ii) at the highest point, and (iii) during its downward motion. Would the answers change if the pebble were thrown at 45° to the horizontal? *[3]*

3. A constant force acts on a body of mass 3.0 kg and changes its speed from $2.0\,\mathrm{m/s}$ to $3.5\,\mathrm{m/s}$ in 25 s without changing its direction. Find the magnitude and direction of the force. *[2]*

B · Third Law and Action–Reaction

4. Explain, using Newton's third law, how a horse is able to pull a cart on the ground, and why the horse cannot pull the cart if the ground were absent (empty space). *[3]*

5. Action and reaction are equal and opposite, yet they do not cancel each other. Explain why, giving the correct condition under which two forces do cancel. *[2]*

C · Impulse and the Impulse–Momentum Theorem

6. A 150 g cricket ball moving at $20\,\mathrm{m/s}$ is struck and returned along the same line at $15\,\mathrm{m/s}$. If the ball is in contact with the bat for 0.02 s, calculate the impulse on the ball and the average force exerted by the bat. *[3]*

7. A batsman deflects a cricket ball of mass 0.15 kg through an angle of 45° without changing its speed of $54\,\mathrm{km/h}$. Find the impulse imparted to the ball, using $J = 2mv\sin(\theta/2)$. *[2]*

8. Why do cricketers pull their hands backwards while catching a fast ball? Why are cars fitted with air bags and crumple zones? Answer in terms of the impulse–momentum theorem. *[2]*

D · Conservation of Momentum and Rocket Motion

9. A bullet of mass 20 g is fired horizontally from a gun of mass 2 kg with a muzzle speed of $80\,\mathrm{m/s}$. Find the recoil speed of the gun. *[2]*

10. A nucleus at rest disintegrates into two fragments. Show that the fragments must fly apart in opposite directions with momenta equal in magnitude. *[3]*

11. Explain why a rocket works even in empty space. State the principle on which its motion is based and identify the two quantities whose rate controls its acceleration. *[2]*

E · Connected Bodies, Lift, Equilibrium and Pseudo Force

12. Two masses of 8 kg and 12 kg are connected by a light inextensible string passing over a frictionless pulley. Take $10\,\mathrm{m/s^2}$. Find the acceleration of the system and the tension in the string. *[3]*

13. A man of mass 70 kg stands on a weighing machine placed inside a lift. Take $10\,\mathrm{m/s^2}$. Find the reading shown by the machine when the lift moves (i) up with uniform velocity, (ii) up with acceleration $5\,\mathrm{m/s^2}$, (iii) down with acceleration $5\,\mathrm{m/s^2}$, and (iv) falls freely under gravity. Express each answer in kgf. *[3]*

14. Two blocks of masses 5 kg and 10 kg are kept in contact on a frictionless horizontal table. A horizontal force of 60 N pushes the 5 kg block, pushing both. Find the acceleration of the system and the contact force between the blocks. *[2]*

F · Friction

15. A block of mass $5\,\mathrm{kg}$ rests on a horizontal floor for which $\mu_s = 0.4$. Take $10\,\mathrm{m/s}^2$. Find the minimum horizontal force needed to just move the block. Describe how static friction adjusts as the applied force increases from zero to this value. *[2]*

16. A block just begins to slide down a rough inclined plane when the plane is tilted through angle θ. Show that $\tan\theta = \mu$. Hence find the angle of repose for $\mu = 1/\sqrt{3}$. *[3]*

G · Circular Dynamics and Banking

17. A stone of mass $0.25\,\mathrm{kg}$ is whirled in a horizontal circle of radius $1.5\,\mathrm{m}$ at a uniform speed of $40\,\mathrm{rev/min}$. Find the tension in the string. *[2]*

18. A car of mass $1500\,\mathrm{kg}$ takes a circular turn of radius $100\,\mathrm{m}$ on a level road at $36\,\mathrm{km/h}$. Take $10\,\mathrm{m/s}^2$. Calculate (i) the centripetal force required and (ii) the minimum coefficient of friction needed between the tyres and the road to prevent skidding. *[3]*

Answer Key — Assignment 1 (with solution pointers)

1. $\vec{F} = d\vec{p}/dt$ and for constant mass $\vec{F} = m\vec{a}$. Result: one newton is the force that accelerates a $1\,\text{kg}$ mass at $1\,\text{m/s}^2$.

2. Net force is always $mg = 0.05 \times 10 = 0.5\,\text{N}$ downward — upward trip, highest point and downward trip alike. No change at 45°, because the weight acts vertically and air resistance is neglected.

3. $a = (3.5 - 2.0)/25 = 0.06\,\text{m/s}^2$; $F = 3.0 \times 0.06 = 0.18\,\text{N}$ in the direction of motion.

4. The horse pushes the ground backwards; the ground's reaction pushes the horse (and hence the cart) forward. With no ground to push, there is nothing to supply the forward reaction — the horse cannot move the system.

5. The pair acts on two different bodies, so they appear in different FBDs and never cancel. Two forces cancel only when they act on the same body (e.g. N and mg).

6. $J = m(v-u) = 0.15 \times (15 - (-20)) = 5.25\,\text{N s}$; $F_{avg} = J/\Delta t = 5.25/0.02 = 262.5\,\text{N}$.

7. $v = 54/3.6 = 15\,\text{m/s}$; $J = 2mv\sin(\theta/2) = 2 \times 0.15 \times 15 \times \sin 22.5^\circ \approx 1.7\,\text{N s}$.

8. Impulse $J = F\Delta t$ is fixed by the change in momentum; pulling the hands back (or inflating a bag) lengthens Δt and so lowers the force F on the hand/occupant.

9. $V = mv/M = (0.02 \times 80)/2 = 0.8\,\text{m/s}$ opposite to the bullet.

10. Initial total momentum zero; with no external force $\vec{p}_1 + \vec{p}_2 = 0$, so the fragments have momenta equal in magnitude and opposite in direction.

11. Conservation of linear momentum: the ejected gases carry backward momentum, so the rocket gains equal forward momentum. Acceleration is controlled by the exhaust velocity v_{rel} and the rate of ejection of fuel dm/dt.

12. $a = (m_2 - m_1)g/(m_1 + m_2) = (4/20) \times 10 = 2\,\text{m/s}^2$; $T = 2m_1m_2g/(m_1+m_2) = (2 \times 8 \times 12/20) \times 10 = 96\,\text{N}$.

13. Reading $= N/g$ kgf: (i) $70\,\text{kgf}$; (ii) $m(g+a)/g = 70 \times 15/10 = 105\,\text{kgf}$; (iii) $70 \times 5/10 = 35\,\text{kgf}$; (iv) 0 (free fall, apparent weightlessness).

14. $a = F/(m_1 + m_2) = 60/15 = 4\,\text{m/s}^2$; contact force accelerates the $10\,\text{kg}$ block: $N = m_2 a = 10 \times 4 = 40\,\text{N}$.

15. $f_{s,\text{max}} = \mu_s N = 0.4 \times 50 = 20\,\text{N}$. Static friction is self-adjusting: it equals the applied force up to $20\,\text{N}$, above which the block starts moving.

16. At the verge of slipping the limiting friction balances the down-plane weight component: $f_{s,\text{max}} = \mu mg\cos\theta$ and $mg\sin\theta = \mu mg\cos\theta$ give $\tan\theta = \mu$. For $\mu = 1/\sqrt{3}$, $\theta = \tan^{-1}(1/\sqrt{3}) = 30^\circ$.

17. $\omega = 2\pi(40/60) = 4\pi/3\,\text{rad/s}$; $T = m\omega^2 r = 0.25 \times (4\pi/3)^2 \times 1.5 \approx 6.6\,\text{N}$.

18. $v = 10\,\text{m/s}$; $F_c = mv^2/r = 1500 \times 100/100 = 1500\,\text{N}$; $\mu_{\text{min}} = F_c/(mg) = 1500/15000 = 0.10$.