Physics Chapter 4: Laws of Motion

Very Short Answer Questions

5.16. Bicycle and Stone Problem

Question: A girl riding a bicycle along a straight road with speed 5 m/s throws a stone of mass 0.5 kg which has speed 15 m/s with respect to ground along her direction of motion. The mass of girl and bicycle is 50 kg. Does the speed change? What is the change?

Answer: Yes, the speed decreases by 0.1 m/s.

Solution: Using conservation of momentum:

- Initial momentum: $(50 + 0.5) \times 5 = 252.5$ kg·m/s
- Final momentum: $50 \times v_1 + 0.5 \times 15 = 50v_1 + 7.5$

Conservation: $252.5 = 50v_1 + 7.5$ $v_1 = 245/50 = 4.9$ m/s

Change in speed = 5 - 4.9 = 0.1 m/s (decrease)

5.17. Person in Descending Lift

Question: A person of mass 50 kg stands on a weighing scale in a lift. If the lift is descending with downward acceleration 9 m/s², what would be the reading?

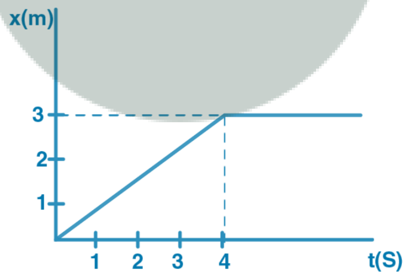
Answer: 5 kg

Solution:

- Apparent weight: $W' = m(g - a) = 50(10 - 9) = 50$ N
- Scale reading: $W'/g = 50/10 = 5$ kg

5.18. Position-Time Graph Impulse

Question: The position-time graph of a body of mass 2 kg shows motion from 0 to 3m in 4 seconds, then constant at 3m. What is the impulse at t = 0 sec and t = 4 sec?



Solution:

- For $0 \le t \le 4$: $x = (3/4)t$, so $v = 3/4 = 0.75$ m/s
- For $t > 4$: $v = 0$

Impulse at t = 0: $\Delta p = m(0.75 - 0) = 2 \times 0.75 = 1.5$ kg·m/s Impulse at t = 4: $\Delta p = m(0 - 0.75) = -1.5$ kg·m/s

5.19. Car Braking Without Seatbelt

Question: Why does a person fall forward when brakes are applied suddenly?

Answer: Due to inertia of motion. When the car stops suddenly, the person's upper body continues moving forward at the original velocity due to Newton's first law, causing them to hit the steering wheel.

5.20. Velocity Function Force Calculation

Question: The velocity of a body of mass 2 kg is given by **v**(t) = 2tî + t^2**ĵ**. Find momentum and force at t = 2 sec.

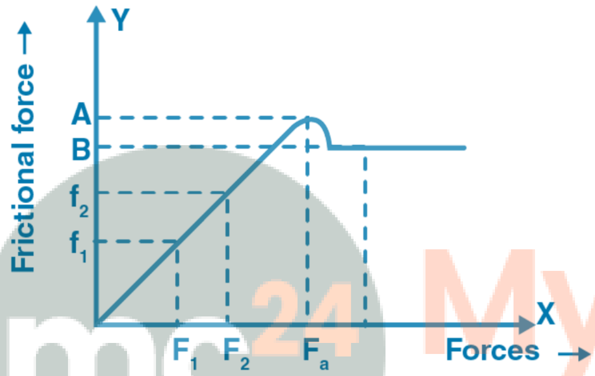
Solution:

- **v**(2) = 4î + 4ĵ m/s
- **p**(2) = m**v**(2) = 2(4î + 4ĵ) = (8î + 8ĵ) kg·m/s
- **a**(t) = d**v**/dt = 2î + 2tĵ
- **a**(2) = 2î + 4ĵ m/s^2
- **F**(2) = m**a**(2) = 2(2î + 4ĵ) = (4î + 8ĵ) N

5.21. Friction Force vs Applied Force Graph

Question: A block on rough horizontal surface is pulled by horizontal force F. Plot friction force f versus F.

Answer: The graph shows:



- Linear increase f = F for F ≤ f_s(max) = μ_s·N (static region)
- Constant f = f_k = μ_k·N for F > f_s(max) (kinetic region)
- Sharp drop from μ_s·N to μ_k·N when sliding begins

5.22. Porcelain Object Packing

Question: Why are porcelain objects wrapped in paper/straw before transportation?

Answer: To increase the time of impact during collisions, thereby reducing the force (F = Δp/Δt). The wrapping material increases Δt, which decreases F and prevents breaking.

5.23. Child Falling on Different Surfaces

Question: Why does a child feel more pain falling on hard cement than soft mud?

Answer: The stopping time is much shorter on hard cement than soft mud. Since F = Δp/Δt, shorter Δt means larger force and more pain.

5.24. Object Thrown and Rebounding

Question: A woman throws an object of mass 500 g with speed 25 m/s. a) What is the impulse imparted? b) If it rebounds with half the original speed, what is the change in momentum?

Solution: a) Impulse = Δp = m(v - u) = 0.5(25 - 0) = 12.5 N·s

b) m = 0.5 kg, u = +25 m/s, v = -12.5 m/s Δp = m(v - u) = 0.5(-12.5 - 25) = -18.75 kg·m/s

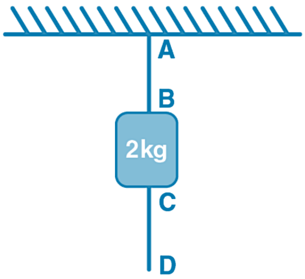
5.25. Mountain Roads Design

Question: Why are mountain roads made winding upwards rather than straight up?
Answer: Winding roads have smaller angle of inclination θ. The friction force available is $f_s = \mu N = \mu mg \cos\theta$, which decreases as θ increases. Smaller θ provides more friction to prevent skidding.

Short Answer Questions

5.26. Thread Breaking Problem

Question: A 2 kg mass is suspended by thread AB. Thread CD is attached below. Lower thread is pulled gradually. Which thread breaks?



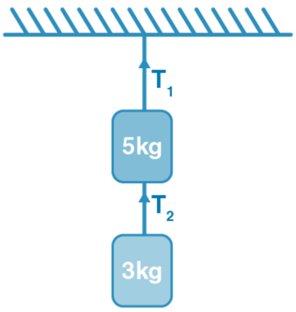
Answer: Thread AB breaks.
Explanation: Thread AB must support both the 2 kg weight (20 N) plus the applied force F. Thread CD only experiences force F. Therefore AB experiences greater tension and breaks first.

5.27. Thread with Sudden Jerk

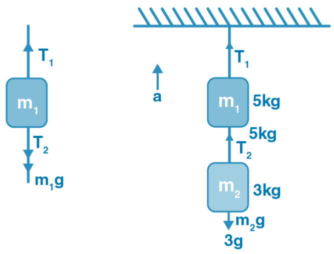
Question: In the above problem, what happens if lower thread is pulled with a jerk?
Answer: Thread CD breaks.
Explanation: When jerked suddenly, the 2 kg mass cannot respond immediately due to inertia. The applied force is transmitted directly to thread CD, which breaks before the system can respond.

5.28. Two Masses with Upward Acceleration

Question: Two masses 5 kg and 3 kg are suspended by strings. The system accelerates upward at 2 m/s². Calculate T_1 and T_2.

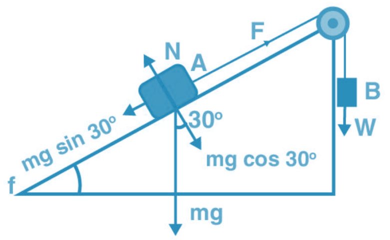


Solution: For 3 kg mass: $T_2 - 3g = 3a$ $T_2 = 3(g + a) = 3(10 + 2) = 36$ N
For 5 kg mass: $T_1 - T_2 - 5g = 5a$
$T_1 = T_2 + 5g + 5a = 36 + 50 + 10 = 96$ N



5.29. Equilibrium on Inclined Plane

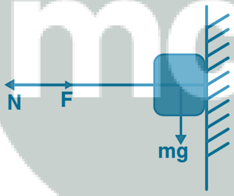
Question: Block A (weight 100 N) rests on frictionless inclined plane (slope 30°). Connected by cord over pulley to block B (weight W). Find W for equilibrium.



Solution: For equilibrium: W = component of A's weight along incline W = 100 sin 30° = 100 × (1/2) = 50 N

5.30. Block Against Vertical Wall

Question: A block of mass M is held against rough vertical wall by horizontal force. If coefficient of friction is μ, find minimum force required.



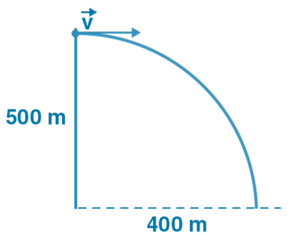
Solution: For equilibrium:

- Horizontal: F = N (normal force from wall)
- Vertical: f = Mg (friction balances weight)
- Maximum friction: f ≤ μN = μF

Therefore: Mg ≤ μF Minimum force: F = Mg/μ

5.31. Gun Firing from Cliff

Question: A 100 kg gun fires a 1 kg ball horizontally from 500 m high cliff. Ball lands 400 m from cliff base. Find gun's recoil velocity.



Solution: Step 1: Find time of flight h = ½gt² → 500 = 5t² → t = 10 s

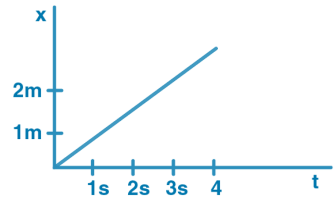
Step 2: Find ball's horizontal velocity

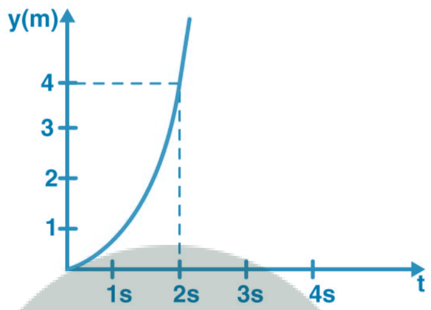
v_{ball} = horizontal distance/time = 400/10 = 40 m/s

Step 3: Apply conservation of momentum Initial momentum = 0 Final momentum: $1 \times 40 + 100 \times v_{gun} = 0$ $v_{gun} = -40/100 = -0.4$ m/s (opposite to ball's direction)

5.32. Force from 2D Motion Graphs

Question: From (x,t) and (y,t) graphs of a 500 g particle, find the force.





Solution: From x-t graph: x increases linearly, so v_x = constant = 1 m/s, $a_x = 0$

From y-t graph: $y = t^2$, so $v_y = 2t$, $a_y = 2$ m/s²

F = ma = $0.5(0\hat{i} + 2\hat{j}) = \hat{j}$ N

5.33. Coin in Accelerating Elevator

Question: Person in elevator accelerating upward at 2 m/s² tosses coin vertically upward at 20 m/s. When does it return?

Solution: In elevator's reference frame:

- Effective acceleration: $a' = g + a_{elevator} = 10 + 2 = 12$ m/s² (downward)
- Using $v = u - a't$ for upward motion to maximum height: $0 = 20 - 12t \rightarrow t = 20/12 = 5/3$ s
- Total time for return: $2t = 10/3 = 3.33$ s