PHYSICS STUDY GUIDE

CHAPTER 03: DYNAMICS

Complete Solutions, Explanations & Step-by-Step Numerical Calculations

Comprehensive Academic Resource

Includes MCQs, Short Answers, Conceptual Response & Numerical Solutions

Published & Distributed by

scholareye.xyz

A. Multiple Choice Questions

3.1. When we kick a stone, we get hurt. This is due to:

(a) inertia (b) velocity (c) momentum (d) reaction

✅ Correct Answer: (d) reaction

Explanation: According to Newton's third law of motion, for every action, there is an equal and opposite reaction. When you kick the stone, you exert a force on it (action), and the stone exerts an equal and opposite force back on your foot (reaction), causing you pain.

3.2. An object will continue its motion with constant acceleration until:

(a) resultant force on it begins to decrease.
(b) resultant force on it is zero.
(c) resultant force on it begins to increase.
(d) resultant force is at right angle to its tangential velocity.

✅ Correct Answer: (b) the resultant force on it is zero.

Explanation: According to Newton's second law, $F_{net} = ma$. A constant acceleration requires a constant, non-zero net force. If the resultant force becomes zero, the acceleration becomes zero, and the object will continue moving at a constant velocity instead of accelerating.

3.3. Which of the following is a non-contact force?

(a) Friction (b) Air resistance (c) Electrostatic force (d) Tension in the string

✅ Correct Answer: (c) Electrostatic force

Explanation: Friction, air resistance, and tension require physical contact between objects to act. Electrostatic force acts at a distance between charged particles without any physical contact.

A. Multiple Choice Questions (Contd.)

3.4. A ball with initial momentum p hits a solid wall and bounces back with the same velocity. Its momentum p' after collision will be:

(a) $p' = p$ (b) $p' = -p$ (c) $p' = 2p$ (d) $p' = -2p$

✅ **Correct Answer: (b) $p' = -p$**

Explanation: Momentum is a vector quantity. If the ball bounces back with the same speed, its direction of motion is reversed. Since velocity becomes $-v$, the final momentum becomes $-p$. *(Note: The change in momentum $\Delta p = -p - p = -2p$, but the question specifically asks for final momentum p')*.

3.5. A particle of mass m moving with a velocity v collides with another particle of the same mass at rest. The velocity of the first particle after collision is:

(a) v (b) $-v$ (c) 0   (d) $-1/2$

✅ **Correct Answer: (c) 0**

Explanation: In a perfectly elastic collision between two objects of equal masses, the moving object transfers all its momentum and kinetic energy to the stationary object. The first particle comes to a complete stop ($v = 0$), and the second particle moves forward with velocity v.

3.6. Conservation of linear momentum is equivalent to:

(a) Newton's first law   (b) Newton's second law   (c) Newton's third law   (d) None

✅ **Correct Answer: (c) Newton's third law of motion**

Explanation: The principle of conservation of momentum is a direct consequence of Newton's third law. Action and reaction forces are equal and opposite ($F_1 = -F_2$). Since $F = \Delta p/\Delta t$, this implies $m_1\Delta v_1 = -m_2\Delta v_2$, meaning total momentum remains constant.

A. Multiple Choice Questions (Contd.)

3.7. An object with a mass of 5 kg moves at constant velocity of 10 m s^{-1}. A constant force then acts for 5 seconds on the object and gives it a velocity of 2 m s^{-1} in the opposite direction. The force acting on the object is:

(a) 5 N (b) -10 N (c) -12 N (d) -15 N

✅ **Correct Answer: (c) -12 N**

Explanation: Initial velocity u = 10 m/s. Final velocity v = -2 m/s (opposite direction). Time t = 5 s. Mass m = 5 kg.
Force F = m(v - u) / t = 5(-2 - 10) / 5 = 5(-12) / 5 = -12 N.

3.8. A large force acts on an object for a very short interval of time. In this case, it is easy to determine:

(a) magnitude of force (b) time interval (c) product of force and time (d) none

✅ **Correct Answer: (c) product of force and time**

Explanation: The product of a large force acting for a short time interval is known as impulse. Impulse equals the change in momentum ($F \times \Delta t = \Delta p$), which is easily measurable by finding the mass and the change in velocity of the object.

3.9. A lubricant is usually introduced between two surfaces to decrease friction. The lubricant:

(a) decreases temperature (b) acts as ball bearings
(c) prevents direct contact of the surfaces (d) provides rolling friction

✅ **Correct Answer: (c) prevents direct contact of the surfaces**

Explanation: Lubricants form a thin layer between the two surfaces, preventing the microscopic irregularities (asperities) of the surfaces from interlocking. This reduces sliding friction significantly.

B. Short Answer Questions

3.1. What kind of changes in motion may be produced by a force?

Answer: A force can produce the following changes in motion:
1. Change the speed (magnitude of velocity) of an object (e.g., accelerating a car).
2. Change the direction of motion of an object (e.g., turning a steering wheel).
3. Change both speed and direction simultaneously.
4. Bring a moving object to rest or set a stationary object in motion.

3.2. Give 5 examples of contact forces.

Answer: 1. Friction 2. Tension 3. Normal force 4. Air resistance/Drag 5. Applied force.

3.3. An object moves with constant velocity in free space. How long will the object continue to move with this velocity?

Answer: The object will continue to move with this constant velocity indefinitely (forever) until and unless an external net force acts upon it. This is a direct application of Newton's First Law of Motion (Law of Inertia), as free space implies no friction or air resistance.

3.4. Define impulse of force.

Answer: Impulse is defined as the product of a force and the time interval for which it acts. Mathematically, $Impulse = F \times \Delta t$. It is a vector quantity and is equal to the total change in momentum of the object (Δp).

3.5. Why has not Newton's first law been proved on the Earth?

Answer: Newton's first law states that an object remains at rest or in uniform motion unless acted upon by a net external force. On Earth, it is practically impossible to eliminate all external forces like friction, air resistance, and gravity entirely. Because we cannot create a perfectly frictionless environment, we cannot experimentally prove the first law perfectly on Earth.

B. Short Answer Questions (Contd.)

3.6. When sitting in a car which suddenly accelerates from rest, you are pushed back into the seat, why?

Answer: This happens due to inertia. When the car accelerates forward, your body tends to remain at rest because of its inertia. The seat moves forward with the car, but your upper body lags behind, creating the sensation of being pushed back into the seat.

3.7. The force expressed in Newton's second law is a net force. Why is it so?

Answer: Newton's second law is expressed as $F_{net} = ma$. It is a net force because acceleration is directly proportional to the vector sum of *all* forces acting on the object. If multiple forces act on a body, they must be resolved into a single resultant (net) force to accurately determine the resulting acceleration.

3.8. How can you show that rolling friction is less than the sliding friction?

Answer: Place a heavy block on a surface and attach a spring balance to it. Pull it horizontally and note the force required to just keep it sliding (sliding friction). Now, place cylindrical rollers under the same block and pull it again. The spring balance will show a much smaller force (rolling friction). This demonstrates that rolling friction is significantly less than sliding friction.

3.9. Define terminal velocity of an object.

Answer: Terminal velocity is the constant maximum velocity attained by a falling object when the downward force of gravity is exactly balanced by the upward force of air resistance (drag). At this point, the net force on the object is zero, and it falls with zero acceleration.

3.10. An astronaut walking in space wants to return to his spaceship by firing a hand rocket. In what direction does he fire the rocket?

Answer: He must fire the hand rocket in the direction opposite to the spaceship (away from the spaceship). By Newton's Third Law, the exhaust gases pushing backward will create an equal and opposite forward reaction force, propelling the astronaut towards the spaceship.

C. Constructed Response Questions

3.1. Two ice skaters weighing 60kg and 80 kg push off against each other on a frictionless ice track. The 60 kg skater gains a velocity of 4 m s^{-1}. Considering all the relevant calculations involved, explain how Newton's third law applies to this situation.

Answer:
• **Initial State:** Both skaters are initially at rest, so total initial momentum = 0.
• **Calculation:** According to the law of conservation of momentum (a consequence of Newton's 3rd law), total momentum after pushing off must also be 0:
$m_1v_1 + m_2v_2 = 0 \Rightarrow 60(4) + 80(v_2) = 0 \Rightarrow 240 + 80v_2 = 0 \Rightarrow v_2 = -3\ m\ s^{-1}$.
• **Explanation:** The 80 kg skater moves backwards at 3 m s^{-1}. Newton's third law states that when the first skater pushes the second, the second pushes back with an equal and opposite force. Because they act on different masses for the same amount of time, impulses are equal and opposite ($F \times t = -F \times t$), resulting in equal and opposite changes in momentum.

3.2. Inflatable airbags are installed in the vehicles as safety equipment. In terms of momentum, what is the advantage of airbags over seatbelts?

Answer: The primary advantage is the increase in the time interval (Δt) of the impact. The change in momentum (Δp) required to stop a passenger is fixed based on their mass and velocity. Since Impulse ($F \times \Delta t = \Delta p$), if time ($\Delta t$) is increased by airbag crumpling, the average force (F) experienced by the passenger is significantly reduced. Additionally, airbags distribute force over a larger area, reducing localized injuries.

3.3. A horse refuses to pull a cart. The horse argues, "according to Newton's third law, whatever force I exert on the cart, the cart will exert an equal and opposite force on me. Since the net force will be zero, therefore, I have no chance of accelerating (pulling) the cart." What is wrong with this reasoning?

Answer: The horse's reasoning is flawed because it applies action-reaction forces to the same body. Action-reaction forces act on *different* bodies. To determine motion of the cart, we look only at forces on the *cart*. The horse pushes the ground backward, and the ground pushes the horse forward (friction). If this forward force on the horse exceeds the backward reaction force from the cart, the horse accelerates forward.

C. Constructed Response (Contd.)

3.4. When a cricket ball hits high, a fielder tries to catch it. While holding the ball he/she draws hands backward. Why?

Answer: Drawing hands backward increases the time interval (Δt) during which the ball's momentum reduces to zero. According to the impulse-momentum theorem, $F = \Delta p / \Delta t$. By increasing Δt, the impulsive force (F) exerted by the ball on the fielder's hands is greatly reduced, preventing injury and making the catch easier.

3.5. When someone jumps from a small boat onto the river bank, why does the jumper often fall into the water? Explain.

Answer: Before jumping, total momentum of the boat and jumper system is zero. When the jumper pushes off to leap forward, they acquire forward momentum. By conservation of momentum, the boat must acquire equal and opposite backward momentum. Because the boat has much less resistance on water, it moves backward away from the bank, causing the jumper to miss the bank and fall in.

3.6. Imagine that if friction vanishes suddenly from everything, then what could be the scenario of daily life activities?

Answer: If friction vanished:
1. We could not walk, run, or stand (feet would slip).
2. Vehicles could not start moving, turn corners, or brake to stop.
3. We couldn't hold objects like pens or cups; they would slip out.
4. Nails and screws would slide out of walls.
5. Matches couldn't be struck, and brakes would fail entirely.

D. Comprehensive Questions

3.1. Explain the concept of force by practical examples.

Answer: Force is an external agent that changes or tends to change the state of rest or uniform motion, direction of motion, or shape and size of an object. It is a vector quantity measured in Newtons (N).
Examples: Kicking a football changes its state from rest to motion. Applying brakes changes state of motion to rest. Pulling a rubber band changes its shape. Gravity keeps us grounded on Earth.

3.2. Describe Newton's laws of motion.

Answer:
• **Newton's First Law (Law of Inertia):** A body remains at rest or continues to move with uniform velocity in a straight line unless acted upon by a net external force.
• **Newton's Second Law:** The acceleration of an object is directly proportional to net force and inversely proportional to its mass ($F_{net} = ma$).
• **Newton's Third Law:** For every action, there is an equal and opposite reaction acting on two different bodies simultaneously.

3.3. Define momentum and express Newton's 2nd law of motion in terms of change in momentum.

Answer: Momentum (p) is the product of mass (m) and velocity (v): $p = mv$. It is a vector quantity. Newton's Second Law in momentum terms states: The rate of change of momentum of a body equals the applied force: $F = \Delta p / \Delta t = m(v_f - v_i) / \Delta t$. When mass is constant, this simplifies to $F = ma$.

D. Comprehensive Questions (Contd.)

3.4. State and explain the principle of conservation of momentum.

Answer:
• **Statement:** In the absence of an external net force, the total linear momentum of an isolated system remains constant.
• **Explanation:** Consider two colliding objects with masses m_1, m_2 and initial velocities u_1, u_2. During collision, by Newton's 3rd Law, $F_1 = -F_2$. Thus $m_1 a_1 = -m_2 a_2$. Substituting a = (v-u)/t gives $m_1 u_1 + m_2 u_2 = m_1 v_1 + m_2 v_2$, proving momentum before collision equals momentum after.

3.5. Describe the motion of a block on a table taking into account the friction between the two surfaces. What is static friction and kinetic friction?

Answer: When a small horizontal force is applied to a block on a table, static friction self-adjusts to match the applied force up to a maximum limit ($f_{s,max}$). Once the applied force exceeds $f_{s,max}$, the block slides, and kinetic friction takes over. Kinetic friction is constant and slightly less than maximum static friction.

3.6. Explain the effect of friction on the motion of vehicles in context of tyre surface and braking force.

Answer: Engine rotates wheels, and tires grip the road using static friction to push the vehicle forward. For braking, brake pads slow wheel rotation, and tires rely on static friction with the road to stop the car. Slippery roads or worn/bald tires reduce friction, increasing stopping distance and risk of skidding.

E. Numerical Problems

3.1. A 10 kg block is placed on a smooth horizontal surface. A horizontal force of 5 N is applied to the block. Find: (a) acceleration produced (b) velocity after 5 seconds.

Given: $m = 10$ kg, $F = 5$ N, $u = 0$ m/s, $t = 5$ s.
(a) Acceleration (a):
$a = F / m = 5 / 10 =$ **0.5 m s⁻²**
(b) Velocity after 5s (v):
$v = u + at = 0 + (0.5)(5) =$ **2.5 m s⁻¹**

3.2. Mass of a person is 80 kg. What will be his weight on Earth? What will be his weight on Moon? ($g_{moon} = 1.6$ m s⁻², $g_{earth} = 10$ m s⁻²).

Given: $m = 80$ kg.
Weight on Earth (W_e): $W_e = m \times g_{earth} = 80 \times 10 =$ **800 N**
Weight on Moon (W_m): $W_m = m \times g_{moon} = 80 \times 1.6 =$ **128 N**

3.3. What force is required to increase the velocity of an 800 kg car from 10 m s⁻¹ to 30 m s⁻¹ in 10 seconds?

Given: $m = 800$ kg, $u = 10$ m/s, $v = 30$ m/s, $t = 10$ s.
Acceleration (a): $a = (v - u) / t = (30 - 10) / 10 = 2$ m s⁻²
Force (F): $F = m \times a = 800 \times 2 =$ **1600 N**

E. Numerical Problems (Contd.)

3.4. A 5 g bullet is fired by a gun. The bullet moves with a velocity of 300 m s^{-1}. If the mass of the gun is 10 kg, find the recoil speed of the gun.

Given: $m_b = 5$ g $= 0.005$ kg, $v_b = 300$ m/s, $m_g = 10$ kg.

By Conservation of Momentum:

Total Initial Momentum = Total Final Momentum

$0 = m_b v_b + m_g v_g \Rightarrow 0 = (0.005)(300) + 10(v_g)$

$0 = 1.5 + 10\ v_g \Rightarrow 10\ v_g = -1.5$

$v_g =$ **-0.15 m s^{-1}** (Negative sign indicates recoil opposite to bullet).

3.5. An astronaut weighs 70 kg. He throws a wrench of mass 300 g at a speed of 3.5 m s^{-1}. Determine: (a) speed of astronaut as he recoils (b) distance covered in 30 minutes.

Given: $m_a = 70$ kg, $m_w = 0.3$ kg, $v_w = 3.5$ m/s, $t = 30$ min $= 1800$ s.

(a) Recoil speed (v_a):

$0 = m_a v_a + m_w v_w \Rightarrow 0 = 70(v_a) + 0.3(3.5)$

$70\ v_a = -1.05 \Rightarrow v_a =$ **-0.015 m s^{-1}** (or -1.5×10^{-2} m s^{-1})

(b) Distance covered (d):

$d = \text{speed} \times \text{time} = 0.015 \times 1800 =$ **27 m**

E. Numerical Problems (Contd.)

3.6. A 6.5×10^4 kg bogie of a goods train moves with velocity 0.8 m s^{-1}. Another bogie of mass 9.2×10^4 kg coming from behind at 1.2 m s^{-1} collides and couples to it. Find common velocity.

Given: $m_1 = 65000$ kg, $u_1 = 0.8$ m/s, $m_2 = 92000$ kg, $u_2 = 1.2$ m/s.

By Conservation of Momentum:

$m_1u_1 + m_2u_2 = (m_1 + m_2)v$

$(65000)(0.8) + (92000)(1.2) = (65000 + 92000)v$

$52000 + 110400 = 157000\ v$

$162400 = 157000\ v \Rightarrow v = 162400 / 157000 = \mathbf{1.03\ m\ s^{-1}}$

3.7. A cyclist weighing 55 kg rides a 5 kg bicycle from rest. Applies force of 90 N for 8 seconds, then continues at constant speed for another 8 seconds. Calculate total distance.

Given: Total mass $m = 55 + 5 = 60$ kg, $F = 90$ N, $t_1 = 8$ s, $t_2 = 8$ s.

Phase 1 (Accelerating):

$a = F / m = 90 / 60 = 1.5$ m s^{-2}

Final speed $v = u + at_1 = 0 + 1.5(8) = 12$ m s^{-1}

Distance $s_1 = ut_1 + 0.5\ a\ t_1^2 = 0 + 0.5(1.5)(64) = 48$ m

Phase 2 (Constant Speed):

Distance $s_2 = v \times t_2 = 12 \times 8 = 96$ m

Total Distance: $s_{total} = 48 + 96 = \mathbf{144\ m}$

E. Numerical Problems (Contd.)

3.8. A ball of mass 0.4 kg is dropped on the floor from a height of 1.8 m. It rebounds straight upward to a height of 0.8 m. What is magnitude and direction of impulse applied by floor?

Given: $m = 0.4$ kg, $h_1 = 1.8$ m, $h_2 = 0.8$ m, $g = 10$ m s^{-2}.

Velocity before hitting (v_1): $v_1 = -\sqrt{(2gh_1)} = -\sqrt{(2 \times 10 \times 1.8)} = -6$ m s^{-1}

Velocity after rebound (v_2): $v_2 = +\sqrt{(2gh_2)} = +\sqrt{(2 \times 10 \times 0.8)} = +4$ m s^{-1}

Impulse (J): $J = m(v_2 - v_1) = 0.4(4 - (-6)) = 0.4(10) =$ **4 N s**

Direction: Upward

3.9. Two balls of masses 0.2 kg and 0.4 kg move towards each other at 20 m s⁻¹ and 5 m s⁻¹. After collision, velocity of 0.2 kg ball becomes 6 m s⁻¹. Find velocity of 0.4 kg ball.

Given: $m_1 = 0.2$ kg, $u_1 = 20$ m/s, $m_2 = 0.4$ kg, $u_2 = -5$ m/s, $v_1 = 6$ m/s.

By Conservation of Momentum:

$m_1u_1 + m_2u_2 = m_1v_1 + m_2v_2$

$(0.2)(20) + (0.4)(-5) = (0.2)(6) + (0.4)(v_2)$

$4 - 2 = 1.2 + 0.4\, v_2 \Rightarrow 2 = 1.2 + 0.4\, v_2$

$0.8 = 0.4\, v_2 \Rightarrow v_2 = 0.8 / 0.4 =$ **2 m s^{-1}**

END OF CHAPTER 03

Dynamics — Solutions & Calculations Complete

Document Summary:

✔ 9 Multiple Choice Questions
✔ 10 Short Answer Questions
✔ 6 Constructed Response Questions
✔ 6 Comprehensive Theoretical Questions
✔ 9 Step-by-Step Numerical Problems