CHAPTER 4

Turning Effect of Forces

Complete Solved Exercise — 9th Class Physics

Every Multiple Choice Question, Short Answer, Constructed Response, Comprehensive Question, and Numerical Problem from the Chapter 4 exercise has been solved and explained step by step in this document.

✓	Correct MCQ option
τ	Step-by-step explanation for every answer
■	Boxed final answer for every numerical problem

Contents

A Multiple Choice Questions — Solved

4.1

A particle is simultaneously acted upon by two forces of 4 N and 3 N. The net force on the particle is:

- (a) 1 N
- ✓ **(b) between 1 N and 7 N**
- (c) 5 N
- (d) 7 N

Explanation:

Two forces do not have to act along the same line, so the resultant depends on the angle between them. The two extreme cases are: when they act in exactly opposite directions the resultant is (4 – 3) = 1 N, and when they act in exactly the same direction the resultant is (4 + 3) = 7 N. For any other angle the resultant lies between these two extremes, so the net force must lie between 1 N and 7 N.

4.2

A force F makes an angle of 60° with the x-axis. Its y-component is equal to:

- (a) F
- ✓ **(b) F sin60°**
- (c) F cos60°
- (d) F tan60°

Explanation:

When a vector F is resolved into rectangular components, the component along the x-axis is F $\cos\theta$ and the component along the y-axis is F $\sin\theta$, where θ is the angle the vector makes with the x-axis. Here $\theta = 60°$, so the y-component is F $\sin 60°$.

4.3

Moment of force is also called:

- (a) moment arm
- (b) couple
- (c) couple arm

✓ **(d) torque**

Explanation:

The turning effect produced by a force about a pivot or axis is called the moment of the force, and this quantity is also known as torque ($\tau = rF \sin\theta$). A couple, by contrast, is a pair of equal and opposite parallel forces, not another name for a single moment.

4.4

If F1 and F2 are the forces acting on a body and τ is the torque produced, the body will be completely in equilibrium when:

✓ **(a) $\Sigma F = 0$ and $\Sigma\tau = 0$**

- (b) $\Sigma F = 0$ and $\Sigma\tau \neq 0$
- (c) $\Sigma F \neq 0$ and $\Sigma\tau = 0$
- (d) $\Sigma F \neq 0$ and $\Sigma\tau \neq 0$

Explanation:

Complete equilibrium requires both conditions of equilibrium to hold at the same time: the vector sum of all forces must be zero (translational/first condition, $\Sigma F = 0$), and the sum of all torques about any point must be zero (rotational/second condition, $\Sigma\tau = 0$). Only option (a) satisfies both conditions simultaneously.

4.5

A shopkeeper sells articles by a balance with unequal arms. If he puts the weights in the pan with the shorter arm, then the customer:

- (a) loses

✓ **(b) gains**

- (c) neither loses nor gains
- (d) not certain

Explanation:

At balance, the moments on both sides are equal: (weight of standard mass) × (longer arm) = (weight of article) × (shorter arm). Because the arm carrying the article is shorter, the actual weight of the article needed to balance the standard weight must be greater than the standard weight shown. So the customer actually receives more product than what was paid for — the customer gains, and it is the shopkeeper who loses.

4.6

A man walks on a tightrope. He balances himself by holding a bamboo stick horizontally. This is an application of:

- (a) law of conservation of momentum
- (b) Newton's second law of motion

✓ **(c) principle of moments**

- (d) Newton's third law of motion

Explanation:

Holding a long stick horizontally lets the rope-walker create small counter-torques by shifting the stick slightly whenever his body starts to tip to one side. This adjustment of moments to keep the net torque about the rope equal to zero is a direct application of the principle of moments (rotational equilibrium).

4.7

In stable equilibrium, the centre of gravity of the body lies:

- (a) at the highest position

✓ **(b) at the lowest position**

- (c) at any position

- (d) outside the body

Explanation:

A body is in stable equilibrium when a small displacement raises its centre of gravity and creates a restoring torque that brings it back to its original position. This condition is achieved when the centre of gravity is already at its lowest possible position, since it cannot be lowered further by the disturbance — any tilt only raises it.

4.8

The centre of mass of a body:

- (a) lies always inside the body
- (b) lies always outside the body
- (c) lies always on the surface of the body
- ✓ **(d) may lie within, outside, or on the surface**

Explanation:

The centre of mass is simply the point where the entire mass of a body may be considered to act; its location depends on how the mass is distributed. For a solid, regularly shaped object it usually lies inside the body, but for a ring, a horseshoe, or an L-shaped object it can lie outside the material or right on its surface. So, in general, it may lie within, outside, or on the surface of the body.

4.9

A cylinder resting on its circular base is in:

- ✓ **(a) stable equilibrium**
- (b) unstable equilibrium
- (c) neutral equilibrium
- (d) none of these

Explanation:

When a cylinder stands upright on its flat circular end, tilting it slightly raises its centre of gravity and lengthens the vertical distance the centre of gravity has to fall back through. Gravity then produces a restoring torque that returns the cylinder to its upright position, which is the definition of stable equilibrium.

4.10

Centripetal force is given by:

- (a) rF
- (b) $rF\cos\theta$
- ✓ **(c) mv^2/r**
- (d) mv/r^2

Explanation:

Centripetal force is the net force directed towards the centre of a circular path that keeps a body moving in that circle. For a body of mass m moving with speed v on a circle of radius r, this force is given by $F_c = mv^2/r$.

B Short Answer Questions — Solved

4.1

Define like and unlike parallel forces.

Answer:

Like parallel forces are forces that act along parallel lines of action and point in the same direction (for example, two people pushing a table in the same direction). **Unlike parallel forces** are forces that act along parallel lines of action but point in opposite directions (for example, the two forces you apply when using a pair of scissors).

4.2

What are rectangular components of a vector and their values?

Answer:

When a single vector is split into two mutually perpendicular vectors that together have the same combined effect as the original vector, those two vectors are called its rectangular components. If a vector F makes an angle θ with the x-axis, its components are: horizontal component $F_x = F \cos\theta$, and vertical component $F_y = F \sin\theta$.

4.3

What is the line of action of a force?

Answer:

The line of action of a force is the straight line, extending infinitely in both directions, along which the force acts. It passes through the point where the force is applied and follows the direction of the force. It is important because the turning effect (torque) of a force depends on the perpendicular distance from the pivot to this line.

4.4

Define moment of a force. Prove that $\tau = rF\sin\theta$, where θ is the angle between r and F.

Answer:

The moment of a force (torque) is the turning effect produced by a force about a fixed point or axis. It is defined as the product of the force and the perpendicular distance from the axis of rotation to the line of action of the force.

Proof: Let a force F act at a point located at position vector r from the pivot O, making an angle θ with r. Resolve F into two rectangular components: one along r ($F\cos\theta$) and one perpendicular to r ($F\sin\theta$). The component along r passes through the pivot and produces no turning effect. Only the perpendicular component, $F\sin\theta$, contributes to rotation, acting at a distance r from the pivot. Therefore the moment is torque = (perpendicular force component) × (distance) =

$r \times F \sin\theta = rF\sin\theta$.

4.5

With the help of a diagram, show that the resultant force is zero but the resultant torque is not zero.

Answer:

Consider two equal and opposite forces, F and –F, acting along two different parallel lines separated by a perpendicular distance d (this arrangement is called a **couple**). Since the two forces are equal in magnitude and opposite in direction, their vector sum is zero: $F + (-F) = 0$, so the resultant force is zero.

However, both forces produce a turning effect in the *same* rotational sense about any point between them. The total torque of the couple is $\tau = F \times d$, which is not zero as long as F and d are non-zero. This is exactly why you can spin a steering wheel using two hands pushing in opposite directions without the wheel translating anywhere — the net force is zero, yet it turns.

4.6

Identify the state of equilibrium in each case shown in the figure: a cone resting on its flat base, a rounded (domed) object with a ball balanced on top, and a cylinder lying on its curved side.

Answer:

(a) Cone on its base: stable equilibrium — tilting it raises the centre of gravity, so it returns to its original position.

(b) Ball balanced on top of a dome: unstable equilibrium — the slightest displacement lowers the centre of gravity of the system and the ball rolls away, never returning.

(c) Cylinder lying on its curved side: neutral equilibrium — rolling it to a new position keeps the centre of gravity at the same height, so it neither returns nor moves further away; it simply stays in its new position.

4.7

Give an example of a body which is moving yet in equilibrium.

Answer:

A car moving on a straight road at a constant speed is a body in equilibrium even though it is moving. Equilibrium requires zero net force and zero net torque, not zero velocity — the car's driving force exactly balances friction and air resistance, so its velocity stays constant (zero acceleration), which satisfies the condition for equilibrium.

4.8

Define centre of mass and centre of gravity of a body.

Answer:

Centre of mass is the point in a body (or system of bodies) where the entire mass may be considered to be concentrated for the purpose of studying its translational motion.

Centre of gravity is the point where the entire weight of the body can be considered to act, regardless of how the body is oriented. For ordinary-sized objects near the Earth's surface, the centre of mass and the centre of gravity coincide.

4.9

What are the two basic principles of stability in physics that are applied in designing balancing toys and racing cars?

Answer:

1. Lowering the centre of gravity: a lower centre of gravity means a body has to be tilted through a larger angle before its centre of gravity moves outside its base, making it harder to topple.

2. Increasing the area of the base of support: a wider base means the vertical line through the centre of gravity stays within the base for a much larger range of tilt, again making the object harder to overturn. Balancing toys use a heavy, low, rounded base, while racing cars are built low and wide for exactly the same reason.

4.10

How can you prove that the centripetal force always acts perpendicular to the velocity?

Answer:

In circular motion, the velocity of a body is always directed along the tangent to the circular path at that point, while the centripetal force is always directed along the radius, towards the centre of the circle. Since a radius of a circle is always perpendicular to the tangent drawn at the same point, the centripetal force is always perpendicular to the velocity. This can also be shown mathematically: the dot product of the velocity vector and the centripetal force vector is $F \cdot v = Fv \cos 90° = 0$, which is only possible if the angle between them is exactly 90°.

C Constructed Response Questions — Solved

4.1

A car travels at the same speed around two curves with different radii. For which radius does the car experience more centripetal force? Prove your answer.

Answer:

The centripetal force is given by $F_c = mv^2/r$. For a fixed mass m and a fixed speed v, Fc is inversely proportional to the radius r ($F_c \propto 1/r$).

Proof: Compare a smaller radius r_1 and a larger radius r_2, with $r_1 < r_2$. Since $F_{c1}/F_{c2} = r_2/r_1$, and $r_2/r_1 > 1$, it follows that $F_{c1} > F_{c2}$.

So the car experiences a **greater centripetal force on the curve with the smaller radius**. This is exactly why sharp, tight turns feel more forceful than gentle, sweeping curves taken at the same speed.

4.2

A ripe mango does not normally fall from the tree. But when the branch of the tree is shaken, the mango falls down easily. Can you tell the reason?

Answer:

While hanging quietly, the mango is in equilibrium: its weight acting downward is exactly balanced by the force of attachment of the stem, so the net force on it is zero and it stays in place.

When the branch is shaken, it moves rapidly back and forth, which gives the mango a sudden acceleration. By Newton's second law, this requires an additional force on the mango, over and above its weight. Because of the mango's own inertia, it tends to lag behind the branch's motion, and this extra force adds to (or briefly exceeds) the maximum force the stem can withstand. Once the force needed exceeds the strength of the stem, the stem snaps and the mango falls, whereas gently hanging weight alone was never enough to break it.

4.3

Discuss the concepts of stability and centre of gravity in relation to objects toppling over. Provide an example where an object's centre of gravity affects its stability, and explain how altering its base of support can influence stability.

Answer:

An object topples over when the vertical line drawn downward from its centre of gravity falls outside its base of support; as long as this line stays within the base, the object's own weight produces a restoring torque that keeps it upright.

Stability therefore depends on two things: (i) the **height of the centre of gravity** — the lower it is, the further the object must be tilted before the vertical line through it leaves the base, and (ii) the **size of the base of support** — a wider base allows a much greater tilt before the same thing happens.

Example: A loaded double-decker bus is far more likely to tip over if heavy passengers or luggage are on the upper deck (raising the centre of gravity) than if the same load is kept on the lower deck. Similarly, widening a vehicle's wheelbase (a larger base of support), as is done in racing cars, makes it much more resistant to toppling during sharp turns, even though its centre of gravity height stays the same.

4.4

Why can an accelerated body not be considered in equilibrium?

Answer:

By Newton's second law, $F = ma$. If a body is accelerating, its acceleration a is not zero, which means the net force F acting on it cannot be zero either (since mass m is never zero for a real object).

But the first condition of equilibrium specifically requires the net (resultant) force on a body to be zero, $\Sigma F = 0$. Since an accelerating body has $\Sigma F \neq 0$ by definition, it fails the first condition of equilibrium and therefore cannot be considered to be in equilibrium.

4.5

Two boxes of the same weight but different heights are lying on the floor of a truck. If the truck makes a sudden stop, which box is more likely to tumble over? Why?

Answer:

The **taller box is more likely to tumble over**.

When the truck stops suddenly, inertia makes the contents of the truck (including the boxes) tend to keep moving forward. This effectively produces a backward-acting inertial force on each box, acting through its centre of gravity, which creates a torque about the box's forward bottom edge and tends to tip it forward.

Since both boxes have the same weight and presumably a similar base, the taller box has its centre of gravity higher above the floor. A higher centre of gravity means the same inertial force produces a larger torque about the tipping edge (torque = force × perpendicular height), and it also means a smaller forward tilt is enough to push the vertical line through the centre of gravity outside the base. Both effects make the taller box far more prone to tumbling than the shorter one.

D Comprehensive Questions — Solved

4.1

Explain the principle of moments with an example.

Answer:

The **principle of moments** states that a body is in rotational equilibrium when the sum of the clockwise moments about any point is equal to the sum of the anticlockwise moments about the same point.

Example: Consider a see-saw balanced on a central pivot. A child of weight W1 sits at distance d1 on one side, and a child of weight W2 sits at distance d2 on the other side. The see-saw remains balanced (in equilibrium) only when the clockwise moment equals the anticlockwise moment: $W1 \times d1 = W2 \times d2$. If a heavier child sits closer to the pivot, the see-saw can still balance a lighter child sitting further away, which is the principle of moments in action.

4.2

Describe how you could determine the centre of gravity of an irregular-shaped lamina experimentally.

Answer:

This is done using the **plumb line method**:

1. Make a small hole near the edge of the irregular lamina and suspend it freely so it can swing, using a pin passed through the hole.

2. Hang a plumb line (a small weight tied to a thread) from the same pin, and let both the lamina and plumb line come to rest.

3. Mark the straight line traced by the plumb line on the lamina (or note two points along it) — the centre of gravity must lie somewhere on this vertical line.

4. Repeat the process by suspending the lamina from a different hole near another edge, and again mark the line traced by the plumb line.

5. The point where the two marked lines intersect is the **centre of gravity** of the lamina. As a check, the lamina should balance horizontally when supported exactly at this point.

4.3

State and explain the two conditions of equilibrium.

Answer:

First condition of equilibrium (translational equilibrium): The vector sum of all the forces acting on a body must be zero, $\Sigma F = 0$. This means the sums of forces along any two perpendicular directions (usually x and y) must independently be zero: $\Sigma F_x = 0$ and $\Sigma F_y = 0$. When this condition holds, the body has no linear acceleration — it is either at rest or moving with constant velocity.

Second condition of equilibrium (rotational equilibrium): The sum of all the torques (moments) acting on a body about any point must be zero, $\Sigma\tau = 0$. This means the sum of clockwise moments equals the sum of anticlockwise moments about that point. When this condition holds, the body has no angular acceleration — it is either not rotating or rotating at a constant angular velocity.

A body is said to be in **complete equilibrium** only when both conditions are satisfied simultaneously.

4.4

How can the stability of an object be improved? Give a few examples to support your answer.

Answer:

The stability of an object can be improved mainly by two methods:

1. Lowering the centre of gravity: the lower the centre of gravity, the larger the tilt an object can withstand before it topples, since it takes a greater angle for the vertical line through the centre of gravity to move outside the base. Example: racing cars are built with a very low chassis and a heavy engine mounted close to the ground.

2. Increasing the area of the base of support: a wider base allows the vertical line through the centre of gravity to remain within the base over a much greater range of tilt. Example: tripod stands, wide-based table lamps, and buses with a wide wheelbase are all more resistant to tipping over.

Combining both methods gives maximum stability — this is why objects such as double-decker buses are loaded with heavier items on the lower deck (lowering the centre of gravity) and built with a wide wheelbase (increasing the base of support), and why racing cars are both low and wide.

E Numerical Problems — Solved

4.1

A force of 200 N is acting on a cart at an angle of 30° with the horizontal direction. Find the x and y-components of the force.

Given:

Force, $F = 200$ N

Angle with horizontal, $\theta = 30°$

Solution:

The x-component (horizontal) of the force is: $F_x = F \cos\theta = 200 \times \cos 30° = 200 \times 0.866 =$ **173.2 N**

The y-component (vertical) of the force is: $F_y = F \sin\theta = 200 \times \sin 30° = 200 \times 0.5 =$ **100 N**

✓ Final Answer: $F_x = 173.2$ N, $F_y = 100$ N

4.2

A force of 300 N is applied perpendicularly at the knob of a door to open it. If the knob is 1.2 m away from the hinge, what is the torque applied? Is it positive or negative torque?

Given:

Force, $F = 300$ N (applied perpendicular to the door)

Perpendicular distance, $r = 1.2$ m

Solution:

Since the force is applied perpendicular to the door, $\theta = 90°$ and $\sin 90° = 1$, so torque is simply: $\tau = rF = 1.2 \times 300 =$ **360 N·m**

Opening the door by pushing the knob turns it in the counter-clockwise sense (the conventional positive rotational direction), so the torque is **positive**.

✓ Final Answer: τ = 360 N·m, positive

4.3

Two weights are hanging from a metre rule at the positions shown, with one weight w at 40 cm from the centre of gravity (C.G.) on one side and a 4 N weight at 30 cm from the C.G. on the other side. If the metre rule is balanced at its C.G., find the unknown weight w.

Given:

Known weight = 4 N at distance 30 cm from the pivot (C.G.)

Unknown weight = w at distance 40 cm from the pivot (C.G.)

Solution:

Since the rule is balanced, by the principle of moments: clockwise moment = anticlockwise moment

$w \times 40 = 4 \times 30$

$w = 120 / 40 =$ **3 N**

✓ Final Answer: w = 3 N

4.4

A see-saw is balanced with two children sitting near either end. Child A weighs 30 kg and sits 2 metres away from the pivot, while child B weighs 40 kg and sits 1.5 metres from the pivot. Calculate the total moment on each side and determine if the see-saw is in equilibrium.

Given:

Child A: mass = 30 kg, distance from pivot = 2 m

Child B: mass = 40 kg, distance from pivot = 1.5 m

Solution:

Moment on side A = mass × distance = 30 × 2 = 60 kg·m

Moment on side B = mass × distance = 40 × 1.5 = 60 kg·m

Since both children experience the same gravitational acceleration g, this g cancels out when the two moments are compared, so comparing (mass × distance) directly is valid here.

Because the moment on side A equals the moment on side B (60 = 60), the clockwise and anticlockwise moments are equal, so the **see-saw is in equilibrium**.

✓ Final Answer: Moment on each side = 60 (kg·m); the see-saw is balanced

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4.5

A crowbar is used to lift a box. If a downward force of 250 N is applied at the end of the bar, 30 cm from the pivot, and the box rests 5 cm from the pivot on the other side, how much weight does the other end (the box) bear? The crowbar itself has negligible weight.

Given:

Applied force, F = 250 N at distance = 30 cm from the pivot

Box (load) at distance = 5 cm from the pivot

Solution:

By the principle of moments, taking moments about the pivot: moment of applied force = moment of load

$F \times 30 = W \times 5$

$250 \times 30 = W \times 5$

$W = 7500 / 5 =$ **1500 N**

✓ Final Answer: W = 1500 N

4.6

A 30 cm long spanner is used to open the nut of a car. If the torque required for it is 150 N·m, how much force F should be applied on the spanner?

Given:

Length of spanner (perpendicular distance), $r = 30\ \text{cm} = 0.30\ \text{m}$

Required torque, $\tau = 150\ \text{N·m}$

Solution:

Using $\tau = rF$, and assuming the force is applied perpendicular to the spanner ($\theta = 90°$):

$F = \tau / r = 150 / 0.30 =$ **500 N**

✓ Final Answer: F = 500 N

4.7

A 5 N ball hanging from a rope is pulled to the right by a horizontal force F. The rope makes an angle of 60° with the ceiling. Determine the magnitude of force F and tension T in the string.

Given:

Weight of ball, $W = 5\ \text{N}$ (acting vertically downward)

Angle between rope and ceiling (horizontal), $\theta = 60°$

Solution:

The ball is in equilibrium under three forces: its weight W (down), the horizontal pulling force F, and the tension T along the rope.

Vertical equilibrium (component of T balances the weight): $T \sin 60° = W$

$T = W / \sin 60° = 5 / 0.866 =$ **5.8 N**

Horizontal equilibrium (component of T balances the applied force): $F = T \cos 60°$

$F = 5.8 \times 0.5 =$ **2.9 N**

✓ Final Answer: F = 2.9 N, T = 5.8 N

4.8

A signboard weighing 200 N is suspended by means of two steel wires attached symmetrically, 2 m on either side of the centre. What is the tension in each of the two wires?

Given:

Weight of signboard, W = 200 N

Each wire attached at equal distance (2 m) from the centre — symmetric arrangement, wires assumed vertical

Solution:

Since the two wires are attached symmetrically, equal distances on either side of the centre of gravity of the signboard, each wire carries exactly half of the total weight.

$T1 = T2 = W / 2 = 200 / 2 =$ **100 N** each

This can also be confirmed using the principle of moments about either wire: the moment of the weight about that wire equals the moment of the tension in the other wire, which gives the same equal split because the distances are equal.

✓ Final Answer: T■ = 100 N, T■ = 100 N

4.9

One girl of 30 kg mass sits 1.6 m from the axis of a see-saw. Another girl of mass 40 kg wants to sit on the other side, so that the see-saw remains in equilibrium. How far from the axis should the other girl sit?

Given:

Girl 1: mass = 30 kg, distance from axis = 1.6 m

Girl 2: mass = 40 kg, distance from axis = d (unknown)

Solution:

For the see-saw to be in equilibrium, by the principle of moments (mass × distance is the same on both sides, since g cancels): $30 \times 1.6 = 40 \times d$

$d = 48 / 40 =$ **1.2 m**

✓ Final Answer: d = 1.2 m

4.10

Find the tension in each string in the given arrangement, if the block weighs 150 N and one string makes an angle of 60° with the horizontal ceiling while the other string is horizontal.

Given:

Weight of block, W = 150 N

One string (T) makes an angle θ = 60° with the horizontal

Other string (T1) is horizontal

Solution:

At the point where the strings meet, three forces act in equilibrium: the weight W (down), the horizontal string tension T1, and the inclined string tension T along the 60° string.

Vertical equilibrium: the vertical component of T balances the weight: $T \sin 60° = W$

$T = W / \sin 60° = 150 / 0.866 =$ **173.2 N**

Horizontal equilibrium: the horizontal component of T balances the horizontal string: $T1 = T \cos 60°$

$T1 = 173.2 \times 0.5 =$ **86.6 N**

✓ Final Answer: T = 173.2 N, T■ = 86.6 N