Year 8 Science - Forces (Physics)

Page 1: Key Concepts and Calculations

Introduction to Forces

In physics, a force is any interaction that, when unopposed, will change the motion of an object. A force can cause an object with mass to change its velocity (which includes starting to move from rest), i.e., to accelerate. Force is a vector quantity, meaning it has both magnitude and direction. It is measured in the SI unit of Newtons (N).

Forces play a crucial role in our daily lives. From walking and throwing a ball to the movement of vehicles and the operation of complex machinery, forces are always at work. Understanding forces is fundamental to understanding how the world around us works.

Key Concepts

- Net Force: The combination of all forces acting on an object. If the forces are balanced, the net force is zero, and the object's motion remains unchanged. If the forces are unbalanced, the net force is not zero, and the object accelerates in the direction of the net force.
- Newton's Laws of Motion: These laws describe the relationship between a body and the forces acting upon it, and its motion in response to those forces.
  - Newton's First Law (Law of Inertia): An object at rest stays at rest, and an object in motion stays in motion with the same speed and in the same direction unless acted upon by an unbalanced force.
  - Newton's Second Law: The acceleration of an object is directly proportional to the net force acting on the object, is in the same direction as the net force, and is inversely proportional to the mass of the object. This is often represented by the equation: $F=ma$ (Force = mass x acceleration).
  - Newton's Third Law: For every action, there is an equal and opposite reaction.
- Gravity: A force that attracts any two objects with mass. The gravitational force between two objects is proportional to the product of their masses and inversely proportional to the square of the distance between their centers. On Earth, the acceleration due to gravity is approximately 9.8 m/s^2, often rounded to 10 m/s^2 for simpler calculations.
- Weight: The force of gravity acting on an object. Weight is calculated as: $W=mg$ (Weight = mass x acceleration due to gravity). Weight is a force, measured in

Newtons, while mass is the amount of matter in an object, measured in kilograms.

- Friction: A force that opposes motion between surfaces in contact. Friction can be static (preventing an object from starting to move) or kinetic (opposing the motion of a moving object).
- Normal Force: The force exerted by a surface on an object in contact with it. The normal force acts perpendicular to the surface.
- Tension: The pulling force transmitted through a string, rope, cable, or wire when it is pulled tight by forces acting from opposite ends.
- Air Resistance: The force that opposes the motion of an object through the air. It is a type of fluid friction.
- Momentum: A measure of an object's mass in motion. It is calculated as: p=mv (momentum = mass x velocity). Momentum is a vector quantity.
- Impulse: The change in momentum of an object. It is equal to the force applied to the object multiplied by the time interval during which the force acts: Impulse = .
- Energy: The ability to do work. There are different forms of energy, including:
  - Kinetic Energy: The energy of motion. It is calculated as: KE=21mv2.
  - Potential Energy: Stored energy. Gravitational potential energy is calculated as: GPE=mgh.
- Work: The energy transferred to or from an object by the application of a force along a displacement. It is calculated as: W=Fd (Work = Force x distance). Work is done only when the force and the displacement are in the same direction.
- Power: The rate at which work is done or energy is transferred. It is calculated as: P=tW (Power = Work / time).
- Pressure: The amount of force applied per unit area. It is calculated as: P=AF (Pressure = Force / Area).
- Centripetal Force: A force that makes a body follow a curved path. It is directed towards the center of the curve.

Sample Calculations

Here are some examples, similar to the questions you provided, showing how to apply the concepts and formulas:

- Example 1: Net Force
  - Question: What is the net force acting on a 5 kg object accelerating at 3 m/s^2?
  - Solution: Using Newton's Second Law (F=ma), we have:
    - F = (5 kg) x (3 m/s^2) = 15 N
  - Answer: The net force is 15 N.
- Example 2: Gravitational Potential Energy

- Question: A 10 kg object is lifted to a height of 5 meters. What is the gravitational potential energy gained? (Assume $g = 10 \text{ m/s}^2$)
- Solution: Using the formula for gravitational potential energy (GPE=mgh), we have:
  - GPE = (10 kg) x (10 m/s^2) x (5 m) = 500 J
- Answer: The gravitational potential energy gained is 500 J.

- Example 3: Force and Acceleration
  - Question: If a 20 N force is applied to a 4 kg object, what will be its acceleration?
  - Solution: Using Newton's Second Law (F=ma), we can rearrange it to solve for acceleration: a=mF
    - a = 20 N / 4 kg = 5 m/s^2
  - Answer: The acceleration will be 5 m/s^2.
- Example 4: Momentum
  - Question: What is the momentum of a 500 kg car moving at 30 m/s?
  - Solution: Using the formula for momentum (p=mv):
    - p = 500 kg * 30 m/s = 15000 kg m/s
  - Answer: The momentum is 15000 kg m/s.
- Example 5: Kinetic Energy
  - Question: What is the kinetic energy of a 4 kg object moving at 10 m/s?
  - Solution: Using the formula for kinetic energy (KE=21mv2):
    - KE = 0.5 * 4 kg * $(10 \text{ m/s})^2$ = 200 J
  - Answer: The kinetic energy is 200 J.

Page 2: Applying Forces Concepts

More Worked Examples from Provided Questions

Here are the answers and explanations to the questions you provided, formatted for clarity:

- What is the net force acting on a 10 kg object accelerating at 2 m/s^2 on a frictionless surface?
  - Answer: 20 N
  - Explanation: Using F=ma, F = (10 kg) * (2 m/s^2) = 20 N.
- A 5 kg object is lifted to a height of 3 meters. What is the gravitational potential energy gained? (Assume $g = 10 \text{ m/s}^2$)
  - Answer: 150 J
  - Explanation: Using GPE=mgh, GPE = (5 kg) * (10 m/s^2) * (3 m) = 150 J.

- What is the force required to accelerate a 1000 kg car from rest to 20 m/s in 10 seconds?
  - Answer: 2000 N
  - Explanation: First, find the acceleration: a=tvf−vi=10s20m/s−0m/s=2m/s2. Then, use F=ma: F = (1000 kg) * (2 m/s^2) = 2000 N.
- If a 10 N force is applied to a 2 kg object, what will be its acceleration?
  - Answer: 5 m/s^2
  - Explanation: Using a=mF, a = 10 N / 2 kg = 5 m/s^2.
- What is the normal force acting on a 50 kg object on a horizontal surface?
  - Answer: 500 N
  - Explanation: On a horizontal surface, the normal force equals the weight of the object. W=mg = (50 kg) * (10 m/s^2) = 500 N.
- A car moving at 30 m/s comes to a stop in 10 seconds. What is the average deceleration?
  - Answer: 3 m/s^2
  - Explanation: Deceleration is negative acceleration. a=tvf−vi=10s0m/s−30m/s=−3m/s2. The magnitude is 3 m/s^2.
- What is the momentum of a 1000 kg car moving at 20 m/s?
  - Answer: 20,000 kg m/s
  - Explanation: Using p=mv, p = (1000 kg) * (20 m/s) = 20,000 kg m/s.
- A spring stretches 0.5 meters under a 10 N force. What is the spring constant?
  - Answer: 20 N/m
  - Explanation: Using Hooke's Law F=kx, where k is the spring constant. k = F/x = 10N / 0.5m = 20 N/m
- A 60 kg astronaut pushes off a 500 kg satellite. If the astronaut accelerates at 0.2 m/s^2, what is the satellite's acceleration?
  - Answer: 0.024 m/s^2
  - Explanation: By conservation of momentum, the momentum gained by the astronaut is equal and opposite to the momentum gained by the satellite.
  - ma∗va=ms∗vs
  - We know va can be found using va=aa∗t and vs=as∗t Substituting these into the momentum equation:
  - ma∗aa∗t=ms∗as∗t
  - ma∗aa=ms∗as
  - (60kg)∗(0.2m/s2)=(500kg)∗as
  - as=500kg(60kg)∗(0.2m/s2)=0.024m/s2
- What is the gravitational force between two 10 kg masses separated by 2 meters? (G = 6.67×10^{-11} N m^2/kg^2)
  - Answer: 1.67×10^{-9} N

- Explanation: Using Newton's Law of Universal Gravitation: F=Gr2m1m2
    - F = (6.67 × 10^{-11} N m^2/kg^2) * (10 kg * 10 kg) / (2 $m)^2$
    - F = 1.67 × 10^{-9} N
- A 1000 kg car moving at 15 m/s crashes into a stationary 1000 kg car. What is their combined speed after the collision if they stick together?
  - Answer: 7.5 m/s
  - Explanation: Using conservation of momentum:
    - m1v1+m2v2=(m1+m2)vf
    - (1000 kg * 15 m/s) + (1000 kg * 0 m/s) = (1000 kg + 1000 kg) * v_f$
    - 15000 kg m/s = 2000 kg * v_f
    - vf = 7.5 m/s
- What is the power required to lift a 50 kg object 5 meters high in 10 seconds?
  - Answer: 250 W
  - Explanation: First, find the work done: W=Fd=mgh=(50kg)∗(10m/s2)∗(5m)=2500J. Then, use P=tW: P = 2500 J / 10 s = 250 W.
- If the mass of an object is doubled, what happens to its kinetic energy if the speed remains the same?
  - Answer: It doubles.
  - Explanation: Since KE=21mv2, if mass (m) is doubled, KE is also doubled, assuming velocity (v) is constant.
- What is the work done when a 20 N force moves an object 5 meters in the direction of the force?
  - Answer: 100 J
  - Explanation: Using W=Fd, W = (20 N) * (5 m) = 100 J.
- What is the pressure exerted by a 500 N object on a 0.5 m^2 surface?
  - Answer: 1000 Pa
  - Explanation: Using P=AF, P = 500 N / 0.5 m^2 = 1000 Pa.
- A 60 kg skydiver reaches terminal velocity. What is the net force acting on them?
  - Answer: 0 N
  - Explanation: At terminal velocity, the force of gravity is balanced by the force of air resistance, so the net force is zero.
- What is the resultant force if two 10 N forces act on an object at right angles to each other?
  - Answer: 14.1 N
  - Explanation: Use the Pythagorean theorem: R2=102+102=200. R = √200 ≈ 14.1 N.
- What is the acceleration due to gravity on a planet where a 60 kg object weighs 300 N?

    - Answer: 5 m/s^2
    - Explanation: Using W=mg, we can solve for g: g = W / m = 300 N / 60 kg = 5 m/s^2.
- If the kinetic energy of a moving object is 500 J and its mass is 20 kg, what is its speed?
    - Answer: 7.1 m/s
    - Explanation: Using KE=21mv2, we solve for v:
        - 500J=21∗20kg∗v2
        - 500J=10kg∗v2
        - v2=50m2/s2
        - v = $\sqrt{50}$ m^2/s^2 ≈ 7.1 m/s
- A car with a mass of 800 kg accelerates from 0 to 20 m/s in 4 seconds. What is the average force exerted?
    - Answer: 4000 N
    - Explanation: First find acceleration: a = (20 m/s - 0 m/s) / 4 s = 5 m/s^2. Then use F = ma: F = 800 kg * 5 m/s^2 = 4000 N.
- What is the potential energy of a 10 kg object raised 10 meters above the ground? (g = 10 m/s^2)
    - Answer: 1000 J
    - Explanation: Using GPE = mgh: GPE = 10 kg * 10 m/s^2 * 10 m = 1000 J
- What is the impulse exerted when a 5 N force acts on an object for 10 seconds?
    - Answer: 50 Ns
    - Explanation: Impulse = FΔt = 5 N * 10 s = 50 Ns
- What is the centripetal force acting on a 2 kg object moving at 10 m/s in a circle with a radius of 5 m?
    - Answer: 40 N
    - Explanation: Centripetal Force Fc=rmv2=5m2kg∗(10m/s)2=40N
- What is the speed of a 2 kg mass that has 400 J of kinetic energy?
    - Answer: 20 m/s
    - Explanation: KE=21mv2

        - 400J=21∗2kg∗v2
        - v2=400
        - v = 20 m/s
- What is the weight of a 2 kg mass on the Moon where g = 1.6 m/s^2?
    - Answer: 3.2 N
    - Explanation: W = mg = 2 kg * 1.6 m/s^2 = 3.2 N
- If a 500 N force is applied at an angle of 60 degrees to the horizontal, what is the horizontal component?
    - Answer: 250 N

- Explanation: The horizontal component of a force is given by $Fx=F*\cos(\theta)$
    - $Fx=500N*\cos(60°)=500N*0.5=250N$
- What is the gravitational potential energy of a 10 kg object 10 m above the ground?
    - Answer: 1000 J
    - Explanation: GPE = mgh = 10 kg * 9.8 m/s^2 * 10 m = 980 J. If we use g = 10 m/s^2, then GPE = 10 kg * 10 m/s^2 * 10 m = 1000 J
- A 10 kg object moving at 10 m/s collides with a 5 kg object at rest. What is their combined speed if they stick together?
    - Answer: 6.7 m/s
    - Explanation: Using conservation of momentum:
        - m1v1+m2v2=(m1+m2)vf
        - (10 kg * 10 m/s) + (5 kg * 0 m/s) = (10 kg + 5 kg) * vf
        - 100 kg m/s = 15 kg * vf
        - vf = 6.666... m/s ≈ 6.7 m/s
- If the radius of a rotating object is halved while keeping the speed constant, what happens to the centripetal acceleration?
    - Answer: It doubles
    - Explanation: Centripetal acceleration is given by ac=rv2. If r is halved, the denominator becomes r/2.
    - ac=r/2v2=2*rv2. Therefore, the acceleration doubles.