

## Classical Mechanics

### Newton's Laws and Energy Quiz – Answer Key

1. (C) **10 N.** Using Newton's Second Law:  $F = ma = 5 \text{ kg} \times 2 \text{ m/s}^2 = 10 \text{ N.}$
2. (C) **Centripetal acceleration toward the center.** Even at constant speed, direction changes continuously, requiring acceleration toward the center:  $a_c = v^2/r.$
3. (C) **Quadruples.** Kinetic energy  $KE = \frac{1}{2}mv^2.$  If  $v \rightarrow 2v,$  then  $KE \rightarrow \frac{1}{2}m(2v)^2 = 4 \times \frac{1}{2}mv^2.$
4. (C) **For every action, there is an equal and opposite reaction.** Newton's Third Law states forces always occur in pairs of equal magnitude and opposite direction acting on different objects.
5. (B) **Velocity is zero but acceleration is  $g$  downward.** At the apex, instantaneous velocity is zero, but gravitational acceleration ( $g = 9.8 \text{ m/s}^2$ ) acts continuously throughout the motion.
6. **True.** Work  $W = F \cdot d \cdot \cos \theta.$  When  $\theta = 90^\circ, \cos 90^\circ = 0,$  so  $W = 0.$  Example: centripetal force does no work on circular motion.
7. **False.** Momentum is conserved in all collisions (elastic and inelastic) when no external forces act. Kinetic energy is conserved only in elastic collisions.
8. **False.** In free fall (neglecting air resistance), an object experiences constant acceleration ( $g$ ), not constant velocity. Velocity continuously increases.

#### 9. Derivation:

Starting with Newton's Second Law:  $F = ma$

For displacement  $d$  in the direction of force:

$$W = F \cdot d = ma \cdot d$$

Using kinematic equation  $v^2 = v_0^2 + 2ad:$

$$ad = \frac{v^2 - v_0^2}{2}$$

Substituting:

$$W = m \cdot \frac{v^2 - v_0^2}{2} = \frac{1}{2}mv^2 - \frac{1}{2}mv_0^2 = \Delta KE$$

**Work-Energy Theorem:**  $W_{net} = \Delta KE = KE_f - KE_i$

**Physical significance:**

- Net work done on an object equals change in kinetic energy
- Positive work increases kinetic energy (speeds up object)

- Negative work decreases kinetic energy (slows down object)
- Provides energy-based alternative to force analysis
- Useful when forces vary with position

**10. Principle:** In an isolated system with only conservative forces, the total mechanical energy (kinetic + potential) remains constant:

$$E_{total} = KE + PE = \text{constant}$$

#### Conditions for conservation:

- Only conservative forces do work (gravity, spring force)
- No non-conservative forces (friction, air resistance, applied forces)
- System is isolated (no external work)

#### Pendulum example:

- At maximum height:  $KE = 0, PE = mgh_{max}$  (all potential)
- At lowest point:  $KE = \frac{1}{2}mv_{max}^2, PE = 0$  (all kinetic)
- Energy transforms between KE and PE:  $mgh = \frac{1}{2}mv^2$
- Maximum speed:  $v_{max} = \sqrt{2gh}$

#### Roller coaster example:

- At top of first hill (height  $h_1$ ):  $E = mgh_1$  (starting from rest)
- At any other point (height  $h_2$ ):  $mgh_1 = \frac{1}{2}mv^2 + mgh_2$
- Speed at height  $h_2$ :  $v = \sqrt{2g(h_1 - h_2)}$
- Coaster cannot rise higher than starting height without external work