

GRADE 11 STUDY GUIDE | 2024

Newton's Laws of Motion

Physical Sciences

1. Newton's First Law (Law of Inertia)

An object will remain at rest or in uniform motion in a straight line UNLESS acted upon by a net (resultant) external force.

KEY: Inertia: the tendency of an object to resist changes in its state of motion. MASS is a measure of inertia -- heavier objects are harder to accelerate or stop.

2. Newton's Second Law

$$F_{\text{net}} = ma$$

$$\text{OR } a = F_{\text{net}} / m$$

Units: F in Newtons (N), m in kg, a in m/s^2

The net force on an object equals the product of its mass and acceleration. The acceleration is in the SAME DIRECTION as the net force.

Example: A 5 kg box is pushed with 30 N and experiences 10 N friction. Find acceleration.

$$F_{\text{net}} = 30 - 10 = 20 \text{ N}$$

$$a = F_{\text{net}}/m = 20/5 = 4 \text{ m/s}^2 \text{ (in direction of applied force)}$$

3. Newton's Third Law (Action-Reaction)

For every action there is an equal and opposite REACTION. Forces always occur in pairs. The action and reaction forces:

- Are equal in magnitude
- Are opposite in direction
- Act on DIFFERENT objects
- Are of the same type (both contact OR both gravitational, etc.)

KEY: Newton 3 pairs act on DIFFERENT objects so they NEVER cancel each other. Pairs that cancel (equilibrium) act on the SAME object.

4. Weight and Normal Force

$$\text{Weight: } F_g = mg \text{ (} g = 9.8 \text{ m/s}^2 \text{ downward)}$$

Normal force: N or F_N -- perpendicular to the surface, from the surface on the object

On a horizontal surface with no vertical acceleration: $N = F_g = mg$

On an inclined plane: $N = mg \cos(\theta)$ where θ is the angle of incline

5. Friction

Static friction: $f_s \leq \mu_s \times N$ (before object moves)

Kinetic friction: $f_k = \mu_k \times N$ (while object moves)

$\mu_k < \mu_s$ always

- Friction always opposes the direction of motion (or tendency of motion)
- μ (coefficient of friction) is dimensionless and depends on the surfaces in contact
- Normal force N changes when there is a vertical component of applied force

Example: 10 kg block on surface ($\mu_k=0.3$). 50 N horizontal force applied. Find a .

$$N = mg = 10 \times 9.8 = 98 \text{ N}$$

$$f_k = 0.3 \times 98 = 29.4 \text{ N}$$

$$F_{\text{net}} = 50 - 29.4 = 20.6 \text{ N}$$

$$a = 20.6/10 = 2.06 \text{ m/s}^2$$

6. Applications -- Connected Bodies and Pulley Systems

For two connected masses (e.g. hanging over a pulley), treat the SYSTEM as a whole to find acceleration:

$$a = F_{\text{net(system)}} / m_{\text{total}}$$

Then use individual object equations to find the tension (T) in the connecting string.

Example: 3 kg mass (m_1) on table, connected by string over pulley to 2 kg mass (m_2) hanging.

$$\text{System: } F_{\text{net}} = m_2 g = 2 \times 9.8 = 19.6 \text{ N}$$

$$a = 19.6/(3+2) = 3.92 \text{ m/s}^2$$

$$\text{Tension: use } m_1: T = m_1 a = 3 \times 3.92 = 11.76 \text{ N}$$

7. Free Body Diagrams

A free body diagram (FBD) shows ONE object with ALL forces acting ON it. Each force is represented by an arrow with label.

KEY: Steps: 1) Identify the object. 2) Draw the object. 3) Draw arrows for ALL forces (weight down, normal up, applied force, friction, tension). 4) Label each force with magnitude and direction. 5) DO NOT include forces the object exerts ON others.