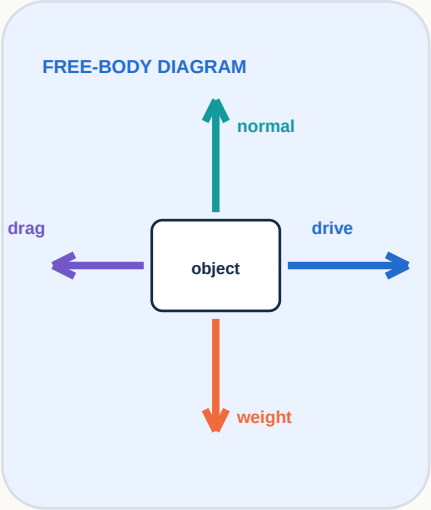
PEARSON EDEXCEL IAL PHYSICS | UNIT 1

# LESSON 1.1.3

## Forces, Free-Body Diagrams and Newton's Laws

Start with one chosen object, identify every external interaction, then combine the forces before predicting the motion.




### FORCE BASICS

**CONTACT FORCES**

Normal contact force, friction, tension, drag and thrust require direct physical interaction.

**NON-CONTACT FORCES**

Gravitational, electric and magnetic forces act without direct contact.

**RESULTANT FORCE = VECTOR SUM**

$$\Sigma F_x = +12 - 5 = +7 \text{ N}$$

### FIVE FREE-BODY DIAGRAM RULES

1. Choose one object or system.
2. Show external forces only.
3. Use arrow direction and relative length.
4. Label each force by physical type.
5. Do not add velocity, acceleration, or an extra resultant arrow.

**CORE HABIT**

Draw the forces first. Choose a positive direction, calculate the resultant, then apply Newton's second law.

# 1 Newton's laws connect force and motion

The resultant force controls acceleration. Equal and opposite interaction forces must be assigned to the correct objects.

## THE THREE LAWS

**1 FIRST LAW**

If the resultant force is zero, an object remains at rest or moves with constant velocity.

**2 SECOND LAW**

For constant mass, acceleration is proportional to the resultant force and points in its direction.

**3 THIRD LAW**

Every interaction produces equal-magnitude, opposite-direction forces on different objects.

## NEWTON'S SECOND LAW

$$\Sigma F = ma$$

SI definition: 1 N = 1 kg m $s^{-2}$

## WORKED RESULTANT-FORCE CALCULATION

**A 12 kg trolley has 50 N driving force and 14 N resistance.**

$\Sigma F = 50 - 14 = 36$ N to the right

$$a = \frac{\Sigma F}{m} = 36 / 12 = 3 \text{ m s}^{-2} \text{ to the right}$$

## BALANCED FORCES OR THIRD-LAW PAIR?

**BALANCED FORCES**

Act on the same object. Their vector sum may be zero. Example: weight and normal force on a resting book.

**THIRD-LAW PAIR**

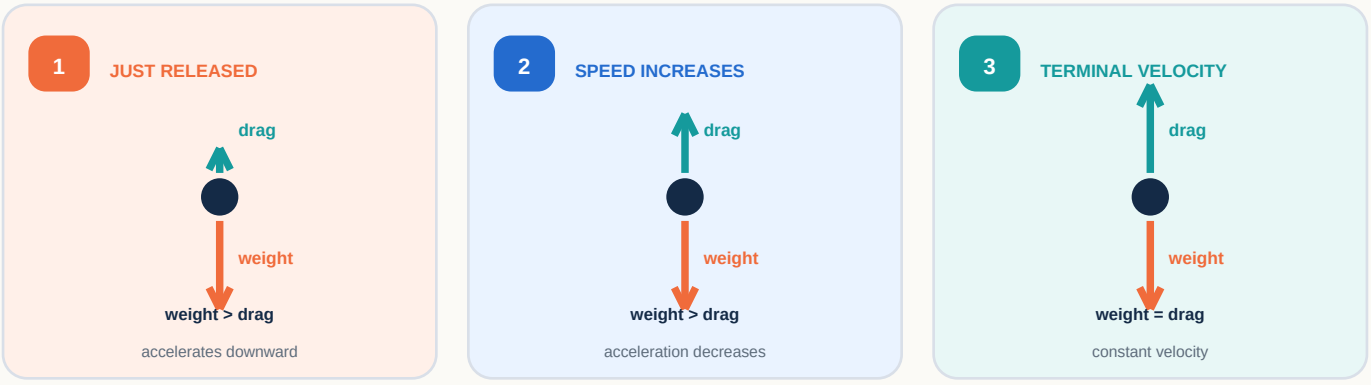
Act on different objects, arise from one interaction, and are equal and opposite. They never cancel on one free-body diagram.

**Zero resultant force means zero acceleration - not necessarily zero velocity.**

# 2 Terminal velocity and force balance

Drag changes with speed. Compare drag with weight to find the resultant force and therefore the acceleration.

## A FALLING OBJECT




**At terminal velocity: ΣF = 0, so a = 0, but v is not zero.**

## EXAM-STYLE CHECK

A 1200 kg car has 3000 N driving force and 600 N resistance.

**ΣF = +3000 - 600 = +2400 N**

$$a = \frac{\Sigma F}{m} = 2400 / 1200 = 2.0 \text{ m s}^{-2} \text{ forward}$$

## FINAL DISTINCTIONS

### FORCE VS MOTION

A force arrow shows an interaction, not velocity. An object can move right while a leftward resultant makes it slow down.

### MASS VS WEIGHT

Mass is measured in kilograms. Weight is a force measured in newtons: W = mg. Near Earth, g is about 9.81 N/kg.

**Exam method: isolate the system -> draw forces -> resolve signs -> find ΣF -> apply ΣF = ma.**