

# Multiple forces can be applied to an object (for AP Physics 1 and 2)

## First principles

A **force** is a push or a pull exerted on an object by another object.

$$[F] = \text{N}$$

### Newton I

(special case of Newton II)

So long as the sum of all external forces acting on an object equals zero, the object's velocity is constant.

$$\sum \vec{F} = \vec{0} \Leftrightarrow \text{constant } \vec{v}$$

### Newton II

The velocity of an object changes at a rate proportional to the sum of all external forces and inversely proportional to the object's mass (tendency to not accelerate).

$$[m] = \text{kg}$$

$$\vec{a} = \frac{\sum \vec{F}}{m}$$

### Newton III

Each force has a partner force of equal magnitude and opposite direction, with the roles of the object doing the pushing and the object being pushed exchanged.

$$\text{There exists } \vec{F}_{\_, 2 \text{ ON } 1} \\ \Rightarrow$$

there also exists

$$\vec{F}_{\_, 1 \text{ ON } 2} = -\vec{F}_{\_, 2 \text{ ON } 1}$$

## Common forces

Origin	Force	Label	Magnitude formula	Direction relative to object being acted on		
Peripheral proximity to Earth	Gravitational (Newtonian)	$F_G$	$mg$	From object toward Earth		
			$\frac{Gm_1m_2}{r^2}$	From object to other mass		
Contact with stretched string	Tension	$T$	No defining formula	From object back into string		
Contact with surface	Normal	$N$	No defining formula	$\perp$ to contact plane, pushes back into object		
			Static friction	$f_s$	Less than greatest sustainable (for a given $N$ ) $f_s < \mu_s N$	$\parallel$ to contact plane, opposes interfacial slippage
					Greatest sustainable ( <sup>usu</sup> ) $f_s = \mu_s N$	
Unsustainable ( <sup>usu</sup> ) $f_s > \mu_s N$						
Kinetic friction	$f_k$	$\mu_k N$				
Contact with spring	Spring (Hookean)	$F_{\text{SPR}}$	$k \Delta x $	Opposes spring deformation		
Contact with fluid medium	Drag	$F_{\text{DRAG}}$	$\uparrow v_{\text{OBJ,FL}} \Rightarrow \uparrow F_{\text{DRAG}}$	Opposes motion of object through fluid		
	Buoyant	$F_{\text{BUOY}}$	$\rho_{\text{FLUID}} V_{\text{REPL}} g$	Opposes weight		
Proximity to other charge	Electric (Coulomb)	$F_E$	$\frac{k q_1  q_2 }{r^2}$	Opposites attract; like repel		
			$ q E$	$\vec{F}_E \parallel \vec{E}$ for (+) test charge		
Proximity to other moving charge(s)	Magnetic (Lorentz)	$F_B$	$ q v \sin\theta B$	RHR		
			$I\ell \sin\theta B$			

There is **no such force as "the net" force**. The phrase "the net force" refers to the sum of all *actual* forces acting on a system.

## Problem-solving algorithm

- Carefully **read** problem three times.
- Sketch system(s)** of interest enclosed in **dashed bubble(s)** and sketch relevant aspects of the **environment**.
- List any **givens** not already sketched. List requested **unknowns**.
- For each system** of interest, draw a **dot diagram** with **signed Cartesian axes**.
  - Include all actual forces. Ask the following questions and obtain, as needed, *labels* from the table of common forces.
    - Is the **Earth nearby**?
    - Is **anything touching** the system?
    - Other than the Earth, are any **massive objects nearby**?
    - Any **charges nearby**?
    - Any **moving charges nearby**?
  - Do not include extraneous forces. All forces on a dot diagram must act **on** the object represented by the dot.
  - Populate a spreadsheet of force components (e.g.  $F_x$  and  $F_y$ )
  - If dot diagrams for multiple systems are drawn, recognize each **interaction force pair** (equal magnitudes).
  - Sum up forces** in each column of spreadsheet ( $\sum F_x = ma_x$  etc.)
- Solve** resulting system of equations for unknowns (or determine unknowns directly in cells of spreadsheet). Sometimes, substituting *formulas* for magnitudes might be necessary.
- Remember: **Base your reasoning on Newtonian principles**, not on "what it feels should be the case."