Multiple forces can be applied to an object (for AP Physics C)

First principles

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

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

Newton I

The sum of all external forces acting on a material object equals zero only for all times when the object's velocity is staying constant.

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

Newton II

The velocity of a material object changes at a rate proportional to the sum of all external forces and inversely proportional to the object's inertial mass.

$$[m_\mathrm{I}] = \mathrm{kg}$$

$$\vec{\mathbf{a}} := \frac{\mathrm{d}\vec{\mathbf{v}}}{\mathrm{d}t} = \frac{\sum \vec{\mathbf{F}}}{m_\mathrm{I}}$$

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.

There exists $\vec{\mathbf{F}}_{\_\_,2\to1}$

$\Rightarrow$

there also exists

$$\vec{\mathbf{F}}_{\_\_,1\to2} = -\vec{\mathbf{F}}_{\_\_,2\to1}$$

Common forces

Origin	Force	Label	Magnitude formula	Direction relative to object being acted on
Peripheral proximity to **Earth**	**Gravitational** (Newtonian)	F_G	$m_\mathrm{G} g$	From object toward Earth
Proximity to **massive object**			$\frac{G m_{\mathrm{G},1} m_{\mathrm{G},2}}{r^2}$	From object to other mass
Contact with stretched **string**	**Tension**	T	No memorized formula	From object back into string
Contact with **surface**	**Normal**	N	No memorized formula	⊥ to contact plane, pushes back into object
	Static **friction**	f_S	Less than greatest sustainable (for a given N) $f_\mathrm{S} < \mu_\mathrm{S} N$	∥ to contact plane, opposes interfacial slippage
			Greatest sustainable (“”) $f_\mathrm{S} = \mu_\mathrm{S} N$	
			Unsustainable (“”) $f_\mathrm{S} > \mu_\mathrm{S} N$	
	Kinetic **friction**	f_K	$\mu_\mathrm{K} N$	
Contact with **fluid medium**	Viscous **drag** (laminar)	D	$b\lvert v\rvert$	Opposes motion of object through fluid
	Ballistic **drag**		$\frac{1}{2} C\rho A v^2$	
Contact with **spring**	**Spring** (Hookean)	F_SPR	$k\lvert\Delta x\rvert$	Opposes spring deformation
Proximity to **other charge**	**Electric** (Coulomb)	F_E	$\frac{k\lvert q_1\rvert\lvert q_2\rvert}{r^2}$	Opposites attract; like repel
			$\lvert q\rvert E$	$\vec{\mathbf{F}}_\mathrm{E} \parallel \vec{\mathbf{E}}$ for (+) test charge
Proximity to **other moving charge(s)**	**Magnetic** (Lorentz)	F_B	$\lvert q\rvert\ v\ \lvert\sin\theta\rvert\ B$	RHR
			$I\ell\lvert\sin\theta\rvert B$	

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

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