FORCES DAY 2: FREE-BODY DIAGRAMS

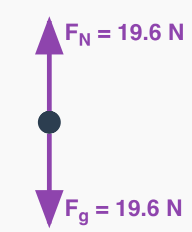
WARMUP Day 1 Review

A 2.0 kg mass sits at x = 0 and a 6.0 kg mass sits at x = 4.0 m. Find the center of mass — units carried through the fraction.

Physics in the Wild — The X-Ray of Forces: Before a single beam of a bridge is ordered, engineers draw a free-body diagram of every joint — each one a dot with arrows. If the arrows don't balance, the joint accelerates, and bridges aren't supposed to accelerate. The FBD is the single most important diagram in this course: every problem for the rest of the year starts with one.

THE RULES OF THE FBD

- The object becomes a **dot**; arrows point *away* from it
- Only forces **ON** the object — never forces it exerts on other things
- Label by type and agent: F_g (Earth), F_N (surface), F_T (rope), F_f (surface), F_{push} (person)
- Longer arrow = bigger force
- At rest or constant velocity → arrows balance (Newton's 1st Law)



2.0 kg book resting on a table

WE DO Exercise 1: Book on a Table

For the 2.0 kg book in the diagram: compute F_g = mg with units, and explain how the FBD tells you the size of F_N without any new formula.

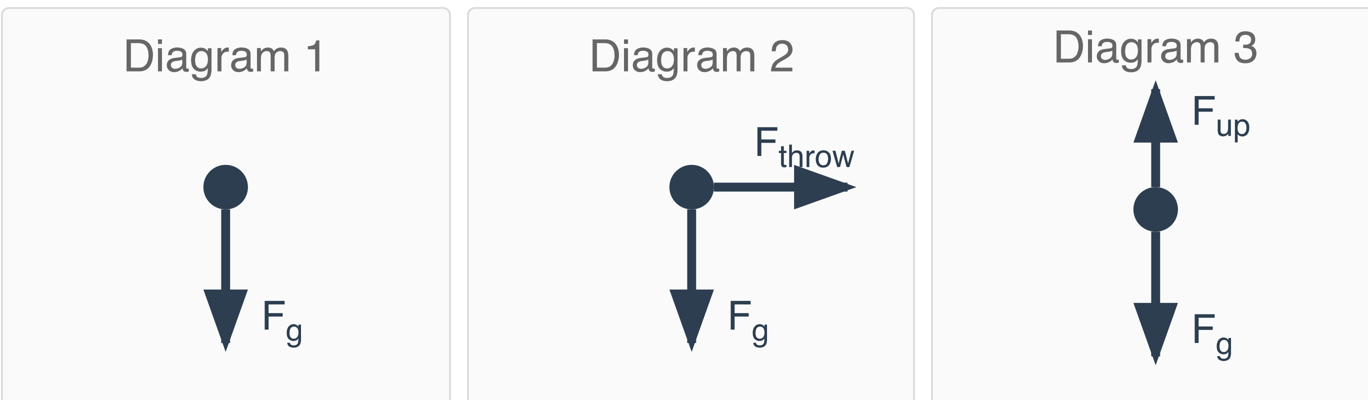
AP FREE-RESPONSE PRACTICE

FRQ Type — Translation Between Representations: the AP exam loves FBDs because they sit between the words and the math. Your diagram, the written situation, and the equations must all tell one consistent story.

AP FRQ · REPRESENTATIONS **Words ↔ Diagrams**

(a) A sled is pulled across rough, level snow at *constant velocity* by a rope angled above the horizontal. Draw the sled's FBD (four forces). Make the lengths consistent with constant velocity.

(b) A ball has been thrown straight up and is now at the very top of its flight. Circle the correct FBD and, in one sentence, explain what is wrong with each of the other two.



(c) Write a one-sentence scenario that matches this FBD: a dot with F_N up, F_g down (equal lengths), and F_f pointing left as the only horizontal force.

WHEN THE NORMAL FORCE ISN'T MG

F_N = mg is a special case, not a law. The normal force is whatever the surface must supply to balance the *vertical* force tally. An angled pull upward reduces it; an angled push downward increases it. Always find F_N from the FBD's vertical equation.

WE DO **Exercise 2: Angled Pull**

A 10 kg crate on a level floor is pulled by a rope with 40 N at 30° above the horizontal. The crate stays on the floor. Draw the FBD, then find the normal force from the vertical equation: $F_N + F \sin \theta = mg$.

YOU DO **Exercise 3: Constant-Speed Lift**

A crane raises a 50 kg crate straight up at constant speed. Draw the FBD and find the cable tension. Would the tension change if the crate moved up at a different constant speed? Explain in one sentence.

YOU DO **Exercise 4: Cable Components**

A guy-wire pulls on a pole with 60 N at 37° above the horizontal. Find the horizontal and vertical components of the pull.

PAPER PRACTICE

PRACTICE PROBLEMS

P1 Resting Object

A 6.0 kg lamp sits at rest on a desk. Draw its FBD and give the size of each force.

P2 Braking Car

A car skids to a stop on a level road. Draw the car's FBD while it is skidding. Which arrow is unbalanced, and what does that unbalanced arrow do to the car's motion?

P3 Angled Pull, Normal Force

An 8.0 kg sled on level ground is pulled by 30 N at 30° above the horizontal. Find the normal force.

P4 The Angled Rope

A 5.0 kg sign hangs at rest from a single vertical rope. **(a)** Find the rope's tension. **(b)** If the rope instead ran at an angle from the vertical (sign still at rest, held by that one rope plus a horizontal wire), would the rope's tension be larger or smaller than in part (a)? Justify using the vertical component.