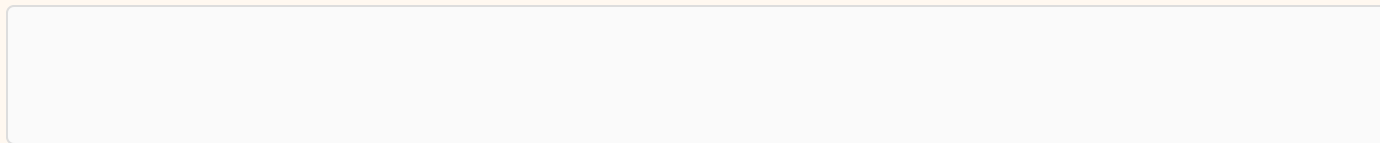


FORCES DAY 3: NEWTON'S SECOND LAW

WARMUP Day 2 Review

A 4.0 kg box on a level floor is pulled by 20 N at 30° above the horizontal. Draw the FBD and find the normal force.



Physics in the Wild — A Rocket vs. Your Bike: The Saturn V produced 35,000,000 N of thrust on 2,900,000 kg of rocket. Net upward acceleration at liftoff: $F/m - g = 12.1 - 9.8 \approx 2.3 \text{ m/s}^2$ — a kid on a bike can beat it off the line. Thrust means nothing by itself; only the ratio of *net force to mass* moves the needle. That ratio is today's law.

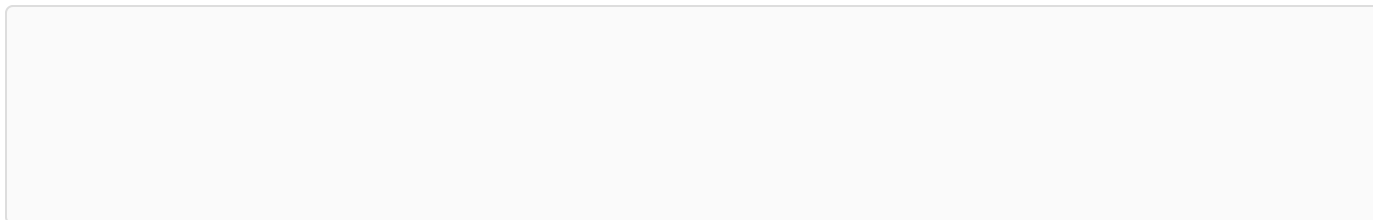
NEWTON'S SECOND LAW

$\Sigma \mathbf{F} = m\mathbf{a}$ — the *net* force (vector sum of every arrow on the FBD) equals mass times acceleration.

- **The units prove it:** $1 \text{ N} = (1 \text{ kg})(1 \text{ m/s}^2) = 1 \text{ kg}\cdot\text{m/s}^2$
- Acceleration points the same direction as the net force
- The recipe, every time: FBD $\rightarrow$ choose axes $\rightarrow$ write $\Sigma \mathbf{F} = m\mathbf{a}$ along each axis

WE DO Exercise 1: Net Force First

An 8.0 kg crate is pushed with 24 N while friction resists with 8.0 N. Draw the FBD, find the net force, then the acceleration — units in every line.



DYNAMICS MEETS KINEMATICS

THE BRIDGE VARIABLE: $\mathbf{a}$

Newton's Second Law gives you $\mathbf{a}$; Unit 1 kinematics turns $\mathbf{a}$ into distances, times, and speeds. Force problems and motion problems are now one subject, joined at the acceleration.

CALCULUS CORNER — WHAT $\Sigma \mathbf{F} = m\mathbf{a}$ REALLY SAYS

Acceleration is a derivative, so Newton's Second Law is a statement about rates: $\Sigma \mathbf{F} = m \cdot d\mathbf{v}/dt$. A constant net force makes $v(t)$ a straight ramp — that's why constant-force problems hand you constant-acceleration kinematics. Units audit: $\text{N/kg} = \text{m/s}^2$.

Day 6 preview: when the force CHANGES with time, $a(t) = F(t)/m$ changes too — the kinematic equations die, and you'll accumulate v from $a(t)$ exactly as in Unit 1.

YOU DO Exercise 2: Braking Force

A 1200 kg car moving at 24 m/s brakes to a stop in 60 m. **(a)** Use kinematics to find the acceleration. **(b)** Use $\Sigma \mathbf{F} = m\mathbf{a}$ to find the braking force.

WE DO Exercise 3: The Elevator Scale

A 70 kg student stands on a scale in an elevator. The scale reads the normal force. Find the reading when the elevator accelerates **(a)** upward at 2.0 m/s^2 and **(b)** downward at 2.0 m/s^2 . Start from $\Sigma \mathbf{F} = F_N - mg = m\mathbf{a}$ both times.

The scale never reads your weight in a moving-and-changing elevator. It reads F_N . Heavier-feeling = accelerating up; lighter-feeling = accelerating down — regardless of which way the elevator is *moving*.

TWO OBJECTS, ONE ACCELERATION

YOU DO Exercise 4: Connected Blocks

A 4.0 kg block and a 2.0 kg block sit on frictionless ice, connected by a string. The 4.0 kg block is pulled forward with 18 N. **(a)** Treat both blocks as one system to find the acceleration. **(b)** Draw the FBD of the 2.0 kg block alone and find the string tension.

CHALLENGE Exercise 5: Audit the Tension

For Exercise 4: verify your tension by writing $\Sigma F = ma$ for the 4.0 kg block alone (pull forward, tension backward). Show that both blocks' equations give the same acceleration — and explain why the tension must be *less* than the 18 N pull.

PAPER PRACTICE

PRACTICE PROBLEMS

P1 Net Force → Acceleration

A 6.0 kg box is pushed with 30 N against 6.0 N of friction. Find its acceleration.

P2 Elevator Cable

An 800 kg elevator accelerates upward at 1.5 m/s^2 . Find the cable tension.

P3 Find the Mass

A net force of 12 N gives an object an acceleration of 0.50 m/s^2 . Find its mass.

P4 Elevator, Full Ride

A 70 kg rider takes an elevator up: it speeds up, cruises, then slows to a stop at the top floor. **(a)** For each of the three phases, state whether the scale reads more than, equal to, or less than mg . **(b)** Compute the reading during the first phase if $a = +1.4 \text{ m/s}^2$.