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: $F/m - g = 12.1 - 9.8 \approx 2.3$ m/s² — 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

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

- **The units prove it:** $1\ \text{N} = (1\ \text{kg})(1\ \text{m/s}^2) = 1\ \text{kg·m/s}^2$
- Acceleration points the same direction as the net force
- The recipe, every time: FBD → choose axes → write $\Sigma F = ma$ 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: A

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

CALCULUS CORNER — WHAT ΣF = MA REALLY SAYS

Acceleration is a derivative, so Newton's Second Law is a statement about rates: **$\Sigma F = m \cdot dv/dt$**. A constant net force makes v(t) a straight ramp — that's why constant-force problems hand you constant-acceleration kinematics. Units audit: N/kg = m/s².

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 $\Sigma F = ma$ 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/s² and **(b)** downward at 2.0 m/s². Start from $\Sigma F = F_N - mg = ma$ 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 $a = +1.4\ m/s^2$.