FORCES DAY 9: PULLEYS & CONNECTED OBJECTS

WARMUP **Day 8 Review**

Find the acceleration of a block sliding down a frictionless 37° incline. Does the answer change for a block of twice the mass?

Physics in the Wild — Every Elevator Is an Atwood Machine: Look up an elevator shaft and you'll find a counterweight riding the other side of the cable, sized to balance the car plus about half a load of passengers. The motor doesn't lift the elevator — it only supplies the small *difference*. That's today's machine: two masses, one cable, one shared acceleration.

THE SYSTEM METHOD

Step 1 — whole system: objects tied together share one acceleration. Internal forces (tension, contact) cancel in pairs, so:

a = (net external force along the motion) / (total mass)

Step 2 — one object alone: to find an internal force (tension or contact force), draw the FBD of a single object and apply ΣF = ma with the a from Step 1.

WE DO **Exercise 1: Blocks in Contact**

A 6.0 kg block and a 2.0 kg block sit touching on frictionless ice. You push the 6.0 kg block with 24 N, driving both forward. **(a)** Find the system's acceleration. **(b)** FBD of the 2.0 kg block alone: find the contact force on it.

YOU DO **Exercise 2: Modified Atwood**

A 3.0 kg cart on a frictionless table is tied to a 1.0 kg mass hanging over a pulley at the table's edge. **(a)** What single external force drives the whole 4.0 kg system? **(b)** Find the acceleration. **(c)** Find the string tension from the cart's FBD, then verify it with the hanger's FBD.

Tension is not the hanging weight. If the string pulled with the full 9.8 N, the 1.0 kg hanger would have zero net force and couldn't accelerate — but it does. So the tension must be less than the hanging weight: $T < m_h g$. Check each body separately: the cart alone gives $T = m_{cart} a$, and the hanger alone gives $m_h g - T = m_h a$ — one string, one tension, and the same value must satisfy both equations.

AP FREE-RESPONSE PRACTICE

FRQ Type — Mathematical Routines: a multi-step quantitative problem. Write each equation in symbols first, substitute with units, and cross-check where the problem allows it — graders award the setup, not just the number.

AP FRQ · MATHEMATICAL ROUTINES

The Atwood Machine

A 3.0 kg mass and a 5.0 kg mass hang from opposite ends of a string over a frictionless, massless pulley. The system is released from rest.

(a) Draw an FBD for each mass (two forces each).

(b) Find the system's acceleration: $a = (m_2 - m_1)g / (m_1 + m_2)$.

(c) Find the string tension from the 3.0 kg mass's FBD, then *verify* it from the 5.0 kg mass's FBD — both must agree.

(d) How fast is each mass moving after the heavy side falls 0.80 m? (Unit 1 closes the deal.)

PAPER PRACTICE

PRACTICE PROBLEMS

P1 Contact Force

A 4.0 kg block and a 1.0 kg block sit touching on a frictionless floor. A 20 N push on the 4.0 kg block drives both. Find the acceleration and the contact force on the 1.0 kg block.

P2 Atwood Numbers

An Atwood machine carries 6.0 kg and 4.0 kg. Find **(a)** the acceleration and **(b)** the string tension.

P3 Distance in Time

A system accelerates from rest at 2.45 m/s². How far does it move in 1.2 s?

P4 Bracket the Tension

For your Atwood machine in P2: without re-deriving anything, explain in two sentences why the tension had to come out between 39.2 N (the light side's weight) and 58.8 N (the heavy side's weight).