Welcome! Today, we hope to introduce you to Newtons Laws, as well as provide some practice problems to solve. There is a total of **32** points. Points indicate relative difficulty.

Idea 1: Newton's First Law

Newton's 1st Law, also known as the law of inertia, states the following: **A body moves with constant velocity (which may be zero) unless acted on by a force.** Essentially, this law states that an object will not change velocity unless acted on by a force.

[1] **Problem 1.** Use Newton's First Law to explain why you lean to the side when a car turns.

Idea 2: Newton's Second Law

Newton's 2nd Law, also known as $F = ma$, states: **The rate of change of the momentum of a body equals the force acting on the body.** This is commonly referred to as the equation

$$F_{\text{net}} = ma$$

where F_{net} denotes the net force, and m and a denote mass and acceleration, respectively.

[1] **Problem 2.** A 2 kg toy car is pushed with a net force of 10 N. What is the acceleration of the car?

Idea 3: Newton's Third Law

Newton's 3rd Law states that **Given two bodies A and B, if A exerts a force on B, then B exerts an equal and opposite force on A.** We can call these action-reaction pairs, and it essentially says that things dont happen in isolation; if an object feels a force, then there must be another object somewhere feeling the opposite force.

[1] **Problem 3.** Describe the action-reaction pairs at play when you are walking along the floor.

Important Idea 1:

Be sure you understand how to draw and interpret a free body diagram! We aren't covering them today, but they are extremely important in physics so make sure you are comfortable with them.

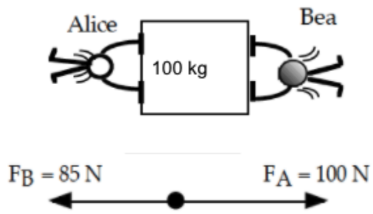
1 Practice Problems

[3] **Problem 4.** Two people, Alice and Bea, are trying to push a 100 kg crate across the floor, but they are doing so very clumsily. The forces they exert are shown as viewed from above. The vertical forces (F_g and F_N) cancel and are not shown. Find

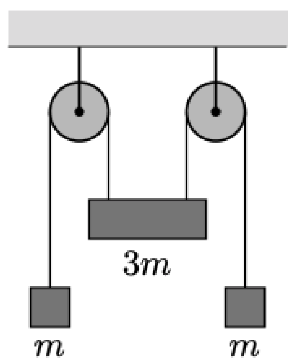
(a) The net force and acceleration of the crate.

(b) Alice and Bea stop after pushing the crate for 100 seconds. How far, in meters, did they push the crate?

(c) Alice, instead of pushing towards eastward against Bea, starts pushing northbound with 100 N of force. Find the new net force and acceleration of the crate, including their directions.

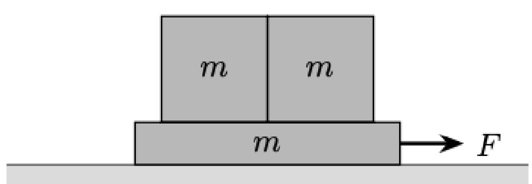


[4] **Problem 5.** (2023 F=ma Problem 5) Two blocks of mass m and a block of mass $3m$ are attached to a system of massless fixed pulleys are massless string, as shown.



Assume all surfaces are frictionless. In terms of g, find the acceleration of each mass m.

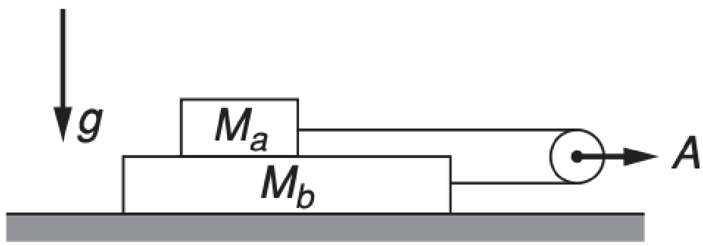
[4] **Problem 6.** (2023 F=ma Problem 7) Two boxes are stacked side-by-side on top of a larger box as shown.



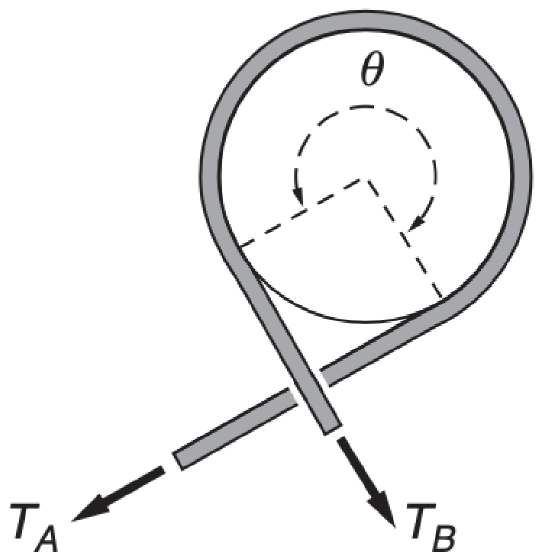
All three boxes have mass m, the coefficient of static friction between the left box and the bottom box is μ_s, and all other surfaces are frictionless. A rightward force F is applied to the bottom box. In terms of F, m, and g, find the minimum value of μ_s so that the upper boxes don't slide.

2 Challenge Problems

[5] **Problem 7.** Mass M_a lies on top of mass M_b, as shown. Assume $M_b > M_a$. The two blocks are pulled from rest by a massless rope passing over a pulley. The pulley is accelerated at rate A. Block M_b slides on the table without friction, but there is a constant friction force f between M_a and M_b due to their relative motion. Find the tension in the rope.



[6] **Problem 8.** A device called a capstan is used aboard ships in order to control a rope which is under great tension. The rope is wrapped around a fixed drum, usually for several turns (the drawing shows about a three-quarter turn). The load on the rope pulls it with a force T_A, and the sailor holds it with a much smaller force T_B. Show that $T_B = T_A e^{-\mu\theta}$, where μ is the coefficient of friction and θ is the total angle subtended by the rope on the drum.



[7] **Problem 9.** Find the shortest possible period of revolution of two identical gravitating solid spheres that are in circular orbit in free space about a point midway between them. The spheres have uniform density ρ. (Note that the two spheres cannot overlap!)