Mechanics & Relativity

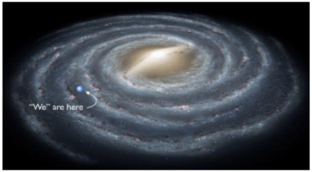
Dr Lily Asquith (Lily)

Week 4

Forces 1

This week's topics:

Frames of Reference



We live on the Earth, and so our natural frame of reference is to treat the Earth as stationary, and consider everything on the Earth to be moving around on its 'horizontal' surface.

In this fantasy, we are in an inertial (non-accelerating) frame of reference, so we can use Newton's laws.

The correct way to define a reference frame is to find the centre of mass position of the frame, and to treat the bodies within the frame as moving relative to the frame's centre of mass.

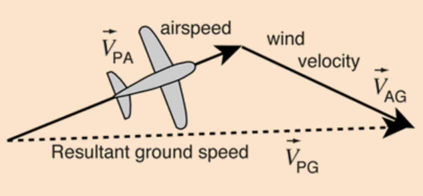
Relative Motion

To do calculations across different inertial reference frames, we need to consider their relative motion.

Example: plane-air-ground

An airplane has a speed of 135 mi/hr in still air. It is flying straight north so that it is always directly above a north-south highway. A ground observer tells the pilot by radio that a 70 mi/hr wind is blowing, but neglects to give the wind direction. The pilot observes that despite the wind, the plane can travel 135 miles along the highway in an hour. What is the direction of the wind?

- 15 W of N
- 30 E of N
- 20 S of W
- 30 N of E
- 15 N of W

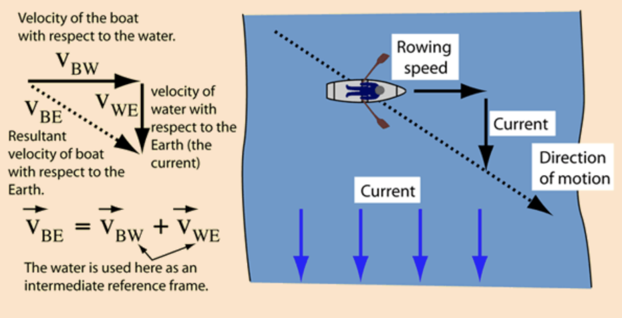


Example: ball-person-ground

A rugby player runs with the ball directly toward his opponent's goal, along the positive direction of an x axis. He can legally pass the ball to a teammate as long as the ball's velocity relative to the field does not have a positive x component. Suppose the player runs at speed 4.0 m/s relative to the field while he passes the ball with velocity $\underline{v}_{BP}$ relative to himself. If $\underline{v}_{BP}$ has magnitude 6.0 m/s, what is the smallest angle it can have for the pass to be legal?

Example: boat-river-ground

A 200-m-wide river has a uniform flow speed of 1.1 m/s through a jungle and toward the east. An explorer wishes to leave a small clearing on the south bank and cross the river in a powerboat that moves at a constant speed of 4.0 m/s with respect to the water. There is a clearing on the north bank 82 m upstream from a point directly opposite the clearing on the south bank.
(a) In what direction must the boat be pointed in order to travel in a straight line and land in the clearing on the north bank?
(b) How long will the boat take to cross the river and land in the clearing?



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Most hated problem from AP 4.2

Newton's First and Second Laws

N1: If there is no **net external force** acting on me, I will remain at my current velocity forever.

N2: $\underline{F} = m\underline{a}$

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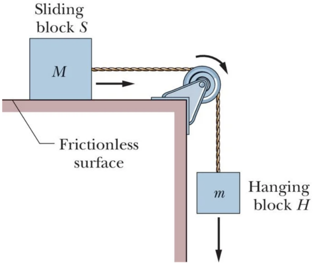
N1: Two forces acting on a particle

While two forces act on it, a particle is to move at the constant velocity $\underline{v} = (3ms^{-1})\hat{\boldsymbol{i}} - (4ms^{-1})\hat{\boldsymbol{j}}$.
One of the forces is $\underline{F} = (2N)\hat{\boldsymbol{i}} - (6N)\hat{\boldsymbol{j}}$. What is the other force?

N2: Blocks & Pulleys

A block S with mass $M_s = 3.3$ kg is free to move along a horizontal frictionless surface and is connected, by a cord that wraps over a frictionless pulley, to a second block H with mass $M_h = 2.1$ kg. The cord and pulley have negligible masses.
Find (a) the acceleration of block S, (b) the acceleration of block H, and (c) the tension in the cord.



N2: Boxes & Ramps

A cord pulls a box of biscuits up along a frictionless plane inclined at angle $\theta = 30.0^\circ$. The box has mass m = 5.00 kg, and the force from the cord has magnitude T = 25.0 N. What is the box's acceleration along the inclined plane?

N2: Inside a lift

A passenger of mass m = 72.2 kg stands on a weighing scale in a lift. We are concerned with the scale readings when the cab is stationary and when it is moving up or down. Find a general solution for the scale reading, whatever the vertical motion of the cab.

N2: Block pushing Block

A constant horizontal force of magnitude 20 N is applied to block A of mass mA = 4.0 kg, which pushes against block B of mass mB = 6.0 kg. The blocks slide over a frictionless surface, along an x axis. (a) What is the acceleration of the blocks? (b) What is the force on block B from block A?

Newton's Third Law

N3: $\underline{F}_{AB} = -\underline{F}_{BA}$

N3: Equal and opposite forces

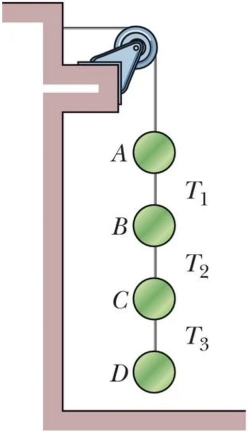
The earth has mass $M_E = 6 \times 10^{24}$ kg. A large, sleepy dog has mass $M_D = 6 \times 10^{1}$ kg.

What is the acceleration of the Earth due to the Dog?

Most hated problem from AP 4.3

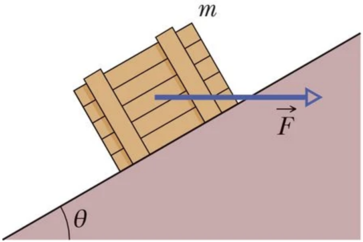
Hanging disks in series

Four disks are suspended by cords. The longer, top cord loops over a frictionless pulley and pulls with a force of magnitude 98 N on the wall to which it is attached. The tensions in the three shorter cords are T1 = 58.8 N, T2 = 49.0 N, and T3 = 9.8 N. What are the masses of each of the disks?



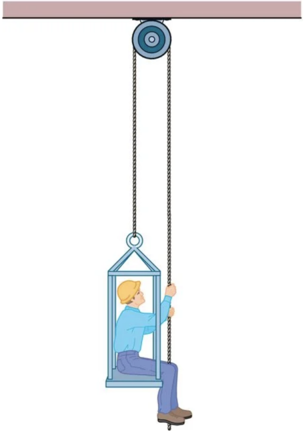
Crate problem

A crate of mass m $= 100$ kg is pushed at constant speed up a frictionless ramp ($\theta = 30.0^\circ$) by a horizontal force $\underline{F}$. What are the magnitudes of (a) $\underline{F}$ and (b) the force on the crate from the ramp?



Pulley Problem that messes with Lily's brain

A man sitting in a bosun's chair that dangles from a massless rope, which runs over a massless, frictionless pulley and back down to the man?s hand. The combined mass of man and chair is 95.0 kg. With what force magnitude must the man pull on the rope if he is to rise (a) with a constant velocity and (b) with an upward acceleration of 1.30 ms^{-2}?



Another Menacing Pulley Problem

•••67 Figure 5-58 shows three blocks attached by cords that loop over frictionless pulleys. Block *B* lies on a frictionless table; the masses are $m_A = 6.00$ kg, $m_B = 8.00$ kg, and $m_C = 10.0$ kg. When the blocks are released, what is the tension in the cord at the right?