Mechanics & Relativity

Dr Lily Asquith (Lily)

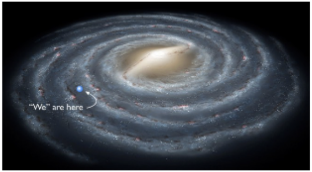
Week 4

Vectors

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.

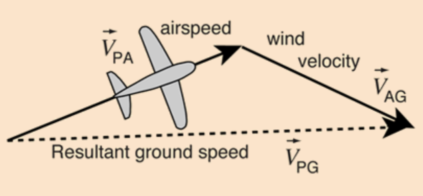
Relative Motion

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

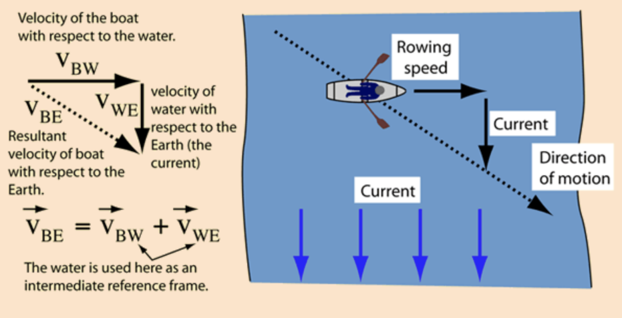


Example: ball-person-ground

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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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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A Problem

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?

Newton's Third Law

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

A problem

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?

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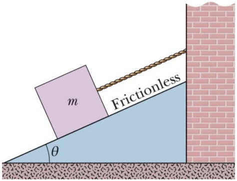
Work done by a constant Force

$W = \underline{\mathsf{F}} \cdot \underline{\mathsf{s}} =$

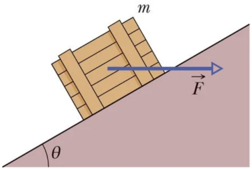
Crate on ramp problems

•**17** SSM WWW In Fig. 5-36, let the mass of the block be 8.5 kg and the angle θ be 30°. Find (a) the tension in the cord and (b) the normal force acting on the block. (c) If the cord is cut, find the magnitude of the resulting acceleration of the block.



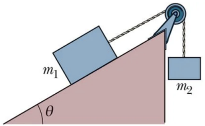
Crate on ramp problems

••34 In Fig. 5-40, a crate of mass m = 100 kg is pushed at constant speed up a frictionless ramp (θ = 30.0°) by a horizontal force $\vec{F}$. What are the magnitudes of (a) $\vec{F}$ and (b) the force on the crate from the ramp?



Crate on ramp problems

••57 ILW A block of mass $m_1 = 3.70$ kg on a frictionless plane inclined at angle $\theta = 30.0°$ is connected by a cord over a massless, frictionless pulley to a second block of mass $m_2 = 2.30$ kg (Fig. 5-52). What are (a) the magnitude of the acceleration of each block, (b) the direction of the acceleration of the hanging block, and (c) the tension in the cord?



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