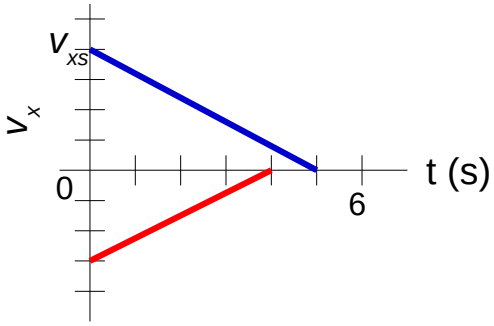
PHYSICS – problem solving exercises
2a. Kinematics: one-dimensional and two-dimensional motion

Notes: air friction is neglected in all cases, magnitude of free fall acceleration is 10 m/s^2

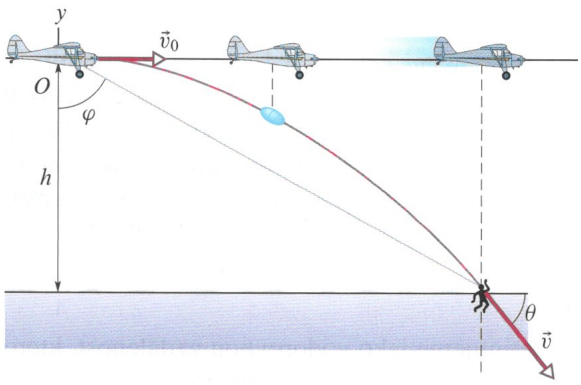
Problem 1:
As two trains move along a track, their conductors suddenly notice that they are headed toward each other. Attached figure gives their velocities v as functions of time t as the conductors slow the trains. The figure's vertical scaling is set by v_s = 40.0 m/s. The slowing processes begin when the trains are 200 m apart. What is their separations when both trains are stopped?



Problem 2:
A red train traveling at 72 km/h and a green train traveling at 144 km/h are headed toward each other along a straight, level track. When they are 950 m apart, each engineer sees the other's train and applies the brakes. The brakes slow each train at the rate of 1.0 m/s^2. Is there a collision?

Problem 3:
An electric vehicle starts from rest and accelerates at a rate of 2.0 m/s^2 in a straight line until it reaches a speed of 20 m/s. The vehicle then slows at a constant rate of 1.0 m/s^2 until it stops.
(a) How much time elapses from start to stop?
(b) How far does the vehicle travel from start to stop?

Problem 4:
A rescue plane flies at 198 km/h (= 55.0 m/s) and constant height h = 500 m toward a point directly over a victim, where a rescue capsule is to land. What should be the angle φ of the pilot's line of sight to the victim when the capsule release is made?

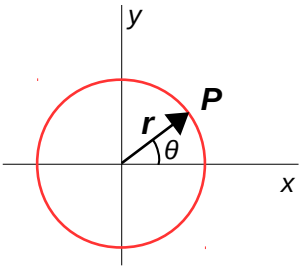


Problem 5:
A projectile is fired horizontally from a gun that is 45.0 m above flat ground, emerging from the gun with a speed of 250 m/s.
(a) How long does the projectile remain in the air?
(b) At what horizontal distance from the firing point does it strike the ground?
(c) What is the magnitude of the vertical component of its velocity as it strikes the ground?

Problem 6:
At a certain time a particle had a speed of 18 m/s in the positive x direction, and 2.4 s later its speed was 30 m/s in the opposite direction. What is the average acceleration of the particle during this 2.4 s interval?

2b. Kinematics: uniform circular motion + relative motion

Problem 7:
Particle P is in uniform circular motion, centered on the origin of an xy coordinate system.
(a) At what values of θ is the vertical component r_y of the position vector greatest in magnitude?
(b) At what values of θ is the vertical component v_y of the particle's velocity greatest in magnitude?
(c) At what values of θ is the vertical component a_y of the particle's acceleration greatest in magnitude?



Problem 8:
An Earth satellite moves in a circular orbit 640 km above Earth's surface with a period of 98.0 min. What are the (a) speed and (b) magnitude of the centripetal acceleration of the satellite? Earth's radius is 6371 km.

Problem 9:
A carnival merry-go-round rotates about a vertical axis at a constant rate. A man standing on the edge has a constant speed of 3.66 m/s and a centripetal acceleration ***a*** of magnitude 1.83 m/s^2. Position vector ***r*** locates him relative to the rotation axis.
(a) What is the magnitude of ***r***?
(b) What is the direction of ***r*** when ***a*** is directed due east?
(c) What is the direction of ***r*** when ***a*** is directed due south?

Problem 10:
When a large star becomes a supernova, its core may be compressed so tightly that becomes a neutron star, with a radius of about 20 km. If a neutron star rotates once every second:
(a) what is the speed of a particle on the star's equator?
(b) what is the magnitude of the particle's centripetal acceleration?
(c) if the neutron star rotates faster, do the answers to (a) and (b) increase, decrease, or remain the same?

Problem 11:
What is the magnitude of the acceleration of a sprinter running at 10 m/s when rounding a turn of radius 25 m?

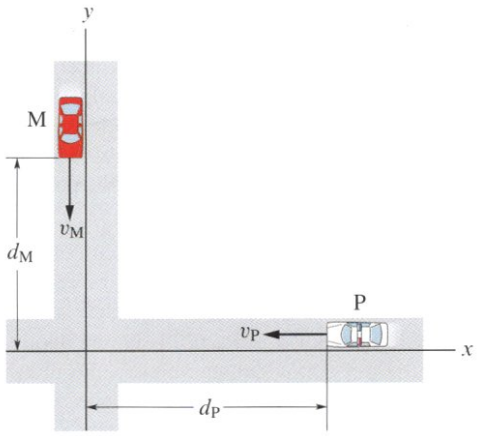
Problem 12:
A boat is traveling upstream in the positive direction of an x axis at 14 km/h with respect to the water of a river. The water is flowing at 9.0 km/h with respect to the ground.
(a) What are the magnitude and direction of the boat's velocity with respect to the ground?
(b) A child on the boat walks from front to rear at 6.0 km/h with respect to the boat. What are the magnitude and direction of the child's velocity with respect to the ground?

Problem 13:

Two highways intersect as shown in the figure. At the instant shown, a police car P is distance d_P = 800 m from the intersection and moving at speed v_P = 80 km/h. Motorist M is distance d_M = 600 m from the intersection and moving at speed v_M = 60 km/h.

(a) What is the velocity (x and y components) of the motorist with respect to the police car?

(b) For the instant shown in the figure, what is the angle between the velocity found in (a) and the line of sight between the two cars?



Problem 14:

A cameraman on a pickup truck is traveling westward at 20 km/h while he records a cheetah that is moving westward 30 km/h faster than the truck. Suddenly, the cheetah stops, turns, and then runs at 45 km/h eastward, as measured to the ground. The change in the animal's velocity takes 2.0 s.

(a) What are the magnitude and direction of the animal's acceleration according to the cameraman?

(b) What are the magnitude and direction of the animal's acceleration according to the ground?

Problem 15:
A train travels due south at 30 m/s (relative to the ground) in a rain that is blown toward the south by the wind. The path of each raindrop makes an angle of 70° with the vertical, as measured by an observer stationary on the ground. An observer on the train, however, sees the drops fall perfectly vertically. Determine the speed of the raindrops relative to the ground.

Problem 16:
Two ships, *A* and *B*, leave port at the same time. Ship*A* travels northwest at 24 knots, and ship *B* travels at 28 knots in a direction 40° west of south. What are the magnitude and direction of the velocity of ship *A* relative to *B*?