Phys 230
Fall 2013

Intermediate Dynamics: Homework 5

Due: 23 September 2013

1 Relative velocities and accelerations

A freely falling object is observed by an observer which is at rest with respect to the Earth. Suppose that at $t = 0$ the object is thrown vertically up with speed v_0 from height y_0.

a) Determine an expression for the vertical position of the object y at any later time.

b) Determine an expression for the vertical component of velocity at any later time.

c) Determine an expression for the vertical component of acceleration at any later time.

The primed observer moves vertically upward with respect to the Earth and with a constant speed u. At $t = 0$ both frames are at the surface of the Earth.

d) Use the Galilean transformations to determine an expression for the vertical position of the object according to the primed observer, y', at any later time.

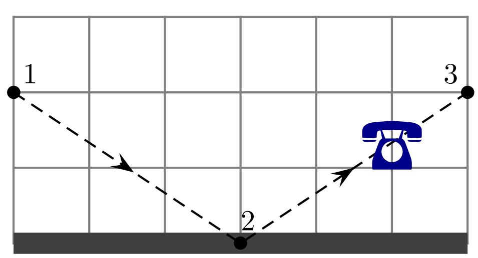
e) Use the previous result to determine an expression for the velocity of the object according to the primed observer at any later time.

f) Use the previous result to determine an expression for the acceleration of the object according to the primed observer at any later time.

g) Do the two observers agree on the velocity of the object. What about the acceleration of the object?

2 Bouncing phone

A rubber phone is thrown with constant velocity toward a wall. Its trajectory, as observed from the rest frame of the wall is as illustrated. The ball passes point 1, hits the wall at point 2 at time $t = 0\,\text{s}$, and bounces off reaching point 3. It's speed remains constant at $2.0\,\text{m/s}$ and the angle at which it rebounds from the wall is the same as that at which it hits the wall. A reference frame whose origin is at the point where the ball strikes the wall is provided.



a) Denote the horizontal axis by x and the vertical axis by y. List the coordinates and time for each of the three events as observed from the rest frame of the wall.

b) Determine the total distance traveled by the phone as observed from the rest frame of the wall.

c) Determine the velocity of the phone as observed from the rest frame of the wall.

Another observer travels in a car with speed 1 m/s vertically along the y axis as observed from the rest frame of the wall. The two observers' coordinates are related by Galilean transformations.

d) List the coordinates and time for each of the three events as observed from the rest frame of the car.

e) Determine the total distance traveled by the phone as observed from the rest frame of the car.

f) Determine the velocity of the phone as observed from the rest frame of the car.

g) Determine the speed of the phone as observed from the rest frame of the car.

3 Boat crossing river

A river is 150 m wide. Water flows long the river, perpendicular to the banks with a constant velocity of 15 m/s. A boat sets out from one side of the river attempting to reach the other side. A duck floating along with the water observes that the boat travels with velocity 12 m/s perpendicular to the bank (i.e. it always appears to point perpendicular to the river bank).

a) Determine the amount of time taken to cross the river.

The process is observed by someone at rest with respect to the bank. This person uses a reference frame in which the origin is at the point where the boat departs and he records that the boat departs at $t = 0\,\mathrm{s}$. At this instant the duck is at the same location.

b) Determine the coordinates of the two events (boat leaves one bank, boat reaches other bank) according to the duck and the person.

c) How far down the river does the boat arrive according to the observer at rest with respect to the bank?

d) Determine the velocity of the boat according to the duck and the person.

e) If the boat can only move with speed 12 m/s, is it possible for it to reach the point on the opposite bank directly across from where it started?

4 Helliwell, *Special Relativity*, 1-2, page 16.

5 Helliwell, *Special Relativity*, Problem 1-13, page 17.

6 Helliwell, *Special Relativity*, Problem 2-10, page 28.

7 Helliwell, *Special Relativity*, Problem 3-3, page 36.

8 Helliwell, *Special Relativity*, Problem 3-6, page 37. This requires care and is challenging. As an aid, label the actual times for the three situations t_1, t_2 and t_3. First relate these to the period T. The determine the time at which the light produced in each event reaches Earth. You should get three formulas involving t_1, t_2, t_3 and other quantities such as d, c, v. This will allow you to determine the time between the events as observed from Earth and to eventually answer the question.