Physics 121 Fall 2003
Exam #1 Solutions

1. A Southwest Airlines 737 took off at 9:15 AM from Sky Harbor Airport in Phoenix and flew, in a straight line, the 172 km to Tucson International Airport, arriving there at 9:45 AM.

(a) (2 points) What was the airplanes average speed (in m/s)?

\[
\bar{v} = \frac{d}{t} = \frac{172000 \text{ m}}{1800 \text{ sec}} = 95.6 \text{ m/sec.}
\]

(b) (3 points) Tucson lies 140 km south of Phoenix and 100 km east. What was the airplanes average velocity? (Give the answer in m/s and be sure to define your coordinate system.)

The coordinate system used has positive y pointing north and positive x pointing east.

\[
v_{avg} = \frac{\Delta r}{\Delta t} = \frac{(100\hat{x} - 140\hat{y}) \times 10^3 \text{ m}}{1800 \text{ sec}} = (55.5\hat{x} - 77.8\hat{y}) \text{ m/sec.}
\]

(c) (3 points) If, during the flight, a monsoon wind blew directly from the south with a speed of 12 m/s. What was the airplanes average air velocity? To arrive in Tucson at the same time, the plane must compensate for the wind by increasing the y component of its velocity. The plane flys at \((55.5\hat{x} - 89.8\hat{y})\) m/sec.

(d) (2 points) What was the planes average air speed?

Using the x and y components from above \(v_{air} = 105 \text{ m/sec.}\)

2. A place kicker must kick a football from a point 36 meters from the goal, and the ball must clear the crossbar, which is 3.05 meters high. When kicked, the ball leaves the ground with a speed of 20 m/s at an angle of 53° to the horizontal.

(a) (4 points) By what distance does the ball clear the crossbar?

The y coordinate of the ball as a function of its x coordinate is \(y(x) = -\frac{1}{2}g\left(\frac{x}{v_0 \cos \theta}\right)^2 + x \tan \theta\). This gives \(y(x = 36 \text{ m}) = 3.93 \text{ m.}\) The ball clears the goalpost by 0.89 m.

(b) (2 points) How much time does it take for the ball to clear the crossbar?

The ball travels the 36 m in \(t = \frac{x}{v_0 \cos \theta} = 3.00 \text{ sec.}\)

(c) (2 points) What is the total time of flight?

The total time of flight is determined by finding the roots of \(y(t) = 0\) and keeping the root where \(t > 0\). This yields 3.26 sec.
(d) (2 points) How far beyond the goalpost does the ball land?

The time of flight is known from part d, so the total distance is just \( d = v_0 \cos \theta t = 39.2 \) m. The ball lands 3.2 meters beyond the goalpost.

3. A car traveling at a constant speed of 30 m/sec passes a trooper hidden behind a billboard. One second after the speeding car passes the billboard, the trooper sets off in chase with a constant acceleration of 3.0 m/sec\(^2\).

(a) (4 points) How long does it take the trooper to overtake the speeding car?

The car is overtaken when the \( x \) coordinates of the two vehicles are the same. For the car \( x_c(t) = 30t + 30 \), the car has a 30 m lead when the trooper begins to move. \( x_T(t) = \frac{1}{2}at^2 = 1.5t^2 \). The time coordinate is zero when the trooper begins to move. The two vehicles meet when \( t = 21 \) sec.

(b) (3 points) How far does the trooper travel before overtaking the speeding car?

The trooper travels \( x = 1.5t^2 = 661 \) m in the first 21 seconds.

(c) (3 points) What is the trooper’s speed when he overtakes the speeding car?

The speed of the trooper is \( v = at = 3t = 63 \) m/sec.

4. Multiple Choice. Write the letter corresponding to the most correct response in the blank at the right of the page.

1. A hungry student attempts to knock an orange out of the tree with a slingshot. They aim the shot directly at the fruit, but at the instant it is released the orange falls out of the tree of its own accord. (Assume the shot travels fast enough to reach the trees position.)
   c. The shot will hit the orange anyway.

2. The coordinate of a particle in meters is given by \( x(t) = 12t - 3.0t^2 \), where the time \( t \) is in seconds. The particle is momentarily at rest at \( t = \)
   a. 2.0 s

3. A ball is thrown straight upwards. Regardless of its initial velocity, the ball experiences an acceleration of 9.8 m/s\(^2\) downwards
   d. Throughout its trajectory.

4. A pellet is fired with an initial speed of \( v_0 \) at an angle of 60° above the horizontal. Another pellet is fired at the same angle but with an initial speed of 2\( v_0 \). If the net distance traveled by the first pellet is \( D \) then the net distance traveled by the second pellet is
   d. 4\( D \)

5. An object is shot from the back of a truck moving at 30 mph on a straight horizontal road. The launcher is aimed upward, perpendicular to the bed of the truck. The object
falls:
c. on the truck

6. In the absence of appreciable air resistance, the path followed by an object thrown near the surface of the Earth
   a. is parabolic
   
7. A car rounds a 20-m radius curve at 10 m/s. The magnitude of its acceleration in m/s² is:
   c. 5.0

8. A bicyclist starts at 6:00 AM on a Monday morning in Marseilles, France and travels 640 kilometers through France, Switzerland, and Italy before returning to his starting point at 4:00 PM Friday.
   a. His average speed is 1.68 m/sec.

9. A plane traveling north at 200 m/s turns and then travels south at 200 m/s. The change in its velocity is:
   e. 400 m/s south

10. The acceleration of an object whose velocity is zero may be:
    d. any of the above