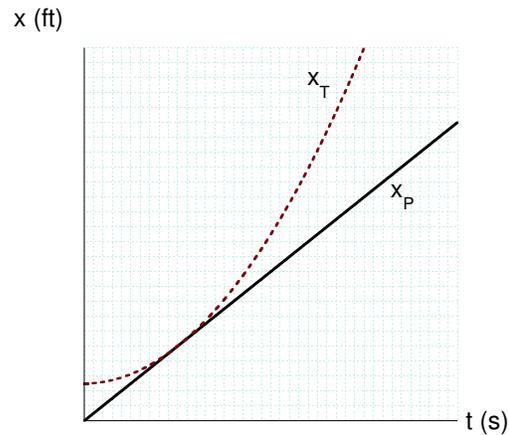


## Physics 101 Fall 2006: Test 1—Free Response #1 - Solution

1. (20 pts) A person is running at a maximum velocity of 10 ft/s to catch a train. When the person is a distance  $d$  from the nearest entry of the train, the train starts from rest with a constant acceleration of  $1 \text{ ft/s}^2$  away from the person. If the person just catches the train

(a) plot a graph of position vs time for the train and person on a common graph.



- (b) how long will it take the person to catch the train?

IF the person “just” catches the train, the train must have the same speed as the person at that instant in time. From the  $x$ -versus time graph, the slope of the train at the time the two meet is the same as the slope of the line governing the person’s position versus time.

$$v_{\text{person}} = v_{\text{train}} \quad (1)$$

$$v_0 = a t \quad (2)$$

$$t = \frac{v_0}{a} = 10 \text{ s} \quad (3)$$

- (c) what is the distance  $d$ ?

For the two objects to meet, we must equate the final  $x$  positions:

$$x_{\text{person}} = x_{\text{train}} \quad (4)$$

$$v_0 t = d + \frac{1}{2} a t^2 \quad (5)$$

$$d = \frac{1}{2} \frac{v_0^2}{a} = 50 \text{ ft} \quad (6)$$

## Physics 101 Fall 2006: Test 1—Free Response #2 - Solution

2. (25 pts) Three identical boxes of mass 10 kg are stacked vertically inside an elevator as shown in Fig.1 below. The elevator is pulled up the elevator shaft with a constant acceleration of  $2.5 \text{ m/s}^2$ .

- (a) Draw and label a free-body-diagram for each box inside the elevator. Label the bottom-most box as  $B_1$ , the middle box as  $B_2$ , and the top-most box as  $B_3$ .

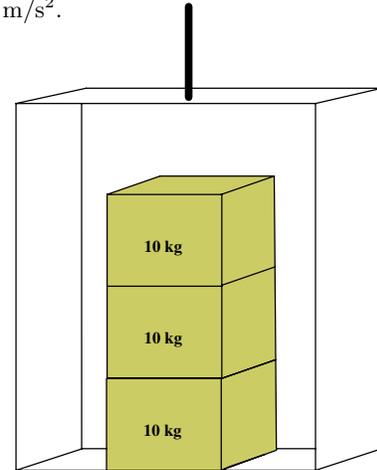
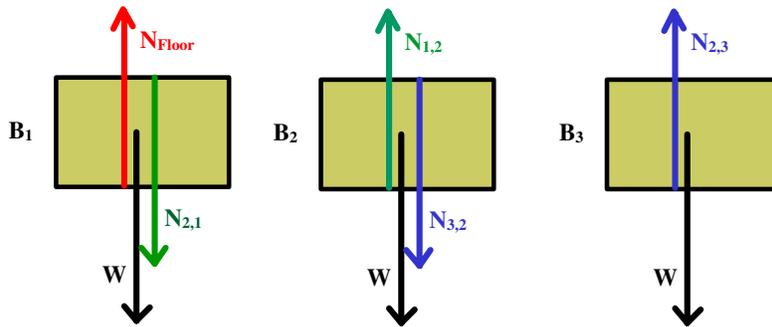


Figure 1: Problem 1

- (b) Apply Newton's 2<sup>nd</sup> law to each box.

$$\sum_{B_1} F_y = N_{\text{floor}} - N_{2,1} - W = m_1 a \quad (1)$$

$$\sum_{B_2} F_y = N_{1,2} - N_{3,2} - W = m_2 a \quad (2)$$

$$\sum_{B_3} F_y = N_{2,3} - W = m_3 a \quad (3)$$

- (c) Find the net resultant force on each box.

$$F_{\text{net } B_1} = m_1 a = 25 \text{ N.} \quad (4)$$

$$F_{\text{net } B_2} = m_2 a = 25 \text{ N.} \quad (5)$$

$$F_{\text{net } B_3} = m_3 a = 25 \text{ N.} \quad (6)$$

- (d) If the elevator cable breaks and it descends in free-fall, what are now the forces acting on the individual boxes? IF the cable breaks, then everything is in free fall. The only force acting on the individual boxes is the force of gravity (i.e., the weight).

## Physics 101 Fall 2006: Test 1—Free Response #3 - Solution

3. (25 pts) Darth Vader of the Empire (otherwise known as the “Dark Side”) is testing the personnel of a new defense station on Earth. A test aircraft traveling horizontally a few feet above sea-level is cruising at a constant speed of 200 m/s. The aircraft passes directly over the cannon of the new defense station. The surprised operator of the cannon takes 5 seconds to react to the overflight of the test aircraft at which point she fires a cannonball at  $30^\circ$  with respect to the horizontal. To her surprise, she hits the test aircraft. Assuming that the test aircraft continues to fly in a straight line and remains at the same altitude

- (a) What was the initial speed of the cannonball?

After 5 s have elapsed, the test plane has moved a horizontal distance of  $(200 \text{ m/s}) 5\text{s} = 1000 \text{ m}$ .

In order for the cannon ball to hit the test plane, we require that  $x_{\text{fplane}} = x_{\text{fcball}}$  and  $y_{\text{fplane}} = y_{\text{fcball}}$ . We know that the initial  $y$  value of the plane is the same as the initial  $y$  value of the cannon “passes directly over the cannon”.

$$x_{\text{fplane}} = x_{\text{fcball}} \quad (1)$$

$$x_{0\text{plane}} + v_{0x\text{plane}} t = x_{0\text{cball}} + v_{0xc} t \quad (2)$$

$$1000 + 200 t = 0 + (v_c \cos 30^\circ) t \quad (3)$$

$$y_{\text{fplane}} = y_{\text{fcball}} \quad (4)$$

$$y_{0\text{plane}} + v_{0y\text{plane}} t = y_{0\text{cball}} + v_{0yc} t - \frac{1}{2} g t^2 \quad (5)$$

$$0 = v_c \sin 30^\circ t - \frac{1}{2} g t^2 \quad (6)$$

$$\Rightarrow t = \frac{2 v_c \sin 30^\circ}{g} \quad (7)$$

$$\Rightarrow t = \frac{v_c}{g} \quad (8)$$

$$\Rightarrow v_c^2 \left( \frac{\sqrt{3}}{2g} \right) - v_c \left( \frac{200}{g} \right) - 1000 = 0 \quad (9)$$

$$v_c = 272.5 \text{ m/s} \approx 273 \text{ m/s} \quad (10)$$

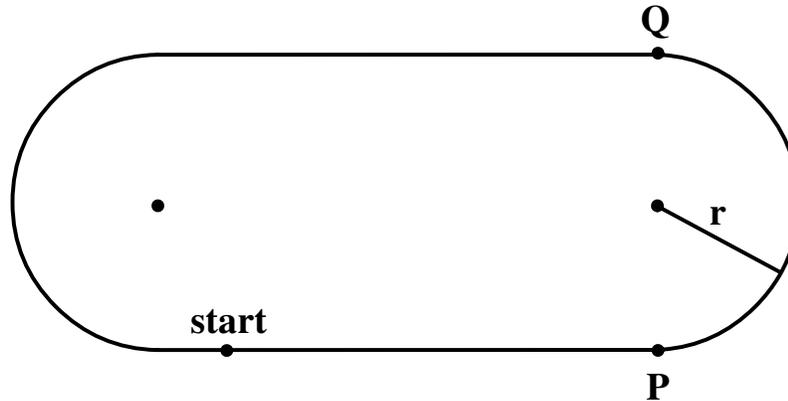
- (b) How long was the cannonball in the air?

$$t = \frac{v_c}{g} \approx 27.82 \text{ s} \quad (11)$$

## Physics 101 Fall 2006: Test 1—Multiple-Choice Questions

Refer to the figure below for questions 1 and 2.

A cyclist follows the track shown below. While moving between the starting point and point  $P$ , the cyclist acquires a maximum speed  $v$  which she maintains constant around the circular path defined by points  $P$  and  $Q$ .



1. Which vector best represents the average velocity between points  $P$  and  $Q$ ?

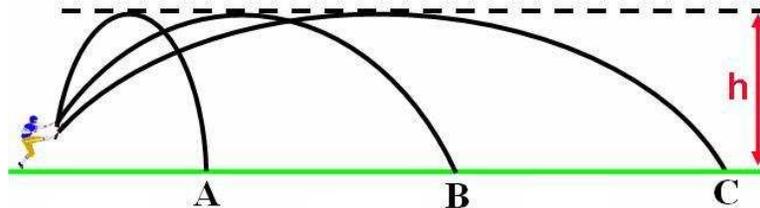
- (a) ↓
- (b) ↑
- (c) →
- (d) ←
- (e) 0

2. Which vector best represents the average acceleration between points  $P$  and  $Q$ ?

- (a) ↓
- (b) ↑
- (c) →
- (d) ←
- (e) 0

Refer to the figure below for questions 3 and 4.

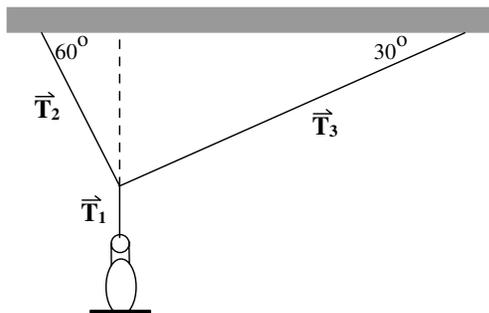
Three trajectories labeled A, B, and C are shown below.



3. For which trajectory is the vertical velocity component at launch the greatest.
  - a. A.
  - b. B.
  - c. C.
  - d. All three trajectories have the same initial vertical velocity component at launch.
  - e. More information is needed to answer the question.
4. For which trajectory is the horizontal velocity component at launch the greatest.
  - a. A.
  - b. B.
  - c. C.
  - d. All three trajectories have the same initial horizontal velocity component at launch.
  - e. More information is needed to answer the question.
5. You are standing on a spring scale inside of an elevator. Of the following scenarios, the scale shows the highest reading when the elevator:
  - (a) moves downward with increasing speed.
  - (b) moves downward with decreasing speed.
  - (c) remains stationary.
  - (d) moves upward with decreasing speed.
  - (e) moves upward with constant speed.

6. A lamp of mass  $m$  is suspended from the ceiling by two cords as indicated below. Which of the following relationships between the  $y$ -components of tensions  $\vec{T}_2$  and  $\vec{T}_3$  (i.e.,  $T_{2y}$  and  $T_{3y}$ ) is correct?

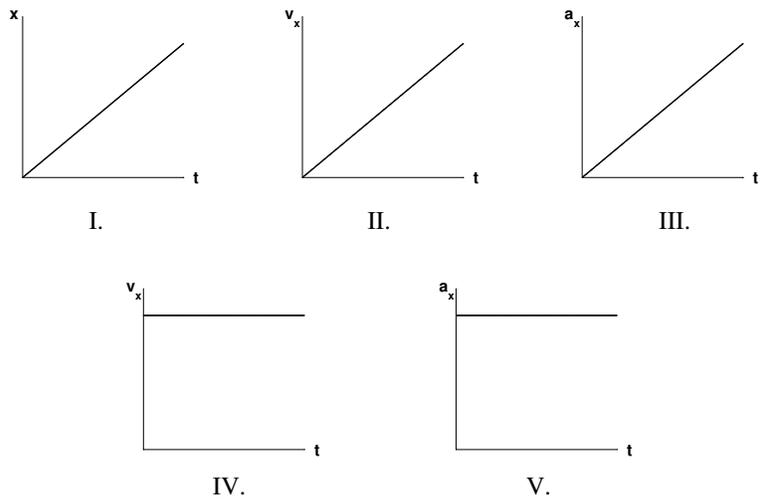
- (a)  $T_{2y} = T_{3y}$ .  
 (b)  $T_{2y} = 2 T_{3y}$ .  
 (c)  $T_{2y} = \frac{\sqrt{3}}{3} T_{3y}$ .  
 (d)  $T_{2y} = \frac{3}{2} T_{3y}$ .  
 (e)  $T_{2y} = 3 T_{3y}$ .



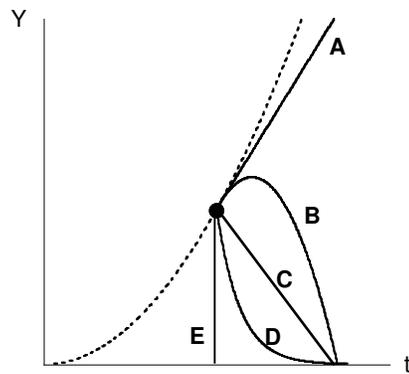
7. Two objects are traveling around different circular orbits with constant speed. They both have the same acceleration, but object A is traveling twice as fast as object B. The orbit radius for object A is
- (a) one-fourth the orbit for object B.  
 (b) one-half the orbit for object B.  
 (c) the same as the orbit for object B.  
 (d) twice the orbit for object B.  
 (e) four times the orbit for object B.
8. Identical guns fire identical bullets horizontally at the same speed from the same height above level planes, one on the Earth and one on the Moon. Which of the following statement(s) is (are) true? **Note: the acceleration due to gravity on the Moon is substantially less than that on Earth.**
- I. The horizontal distance traveled by the bullet is greater on the Moon.  
 II. The flight time is less for the bullet on the Earth.  
 III. The flight time is less for the bullet on the Moon.  
 IV. The speed of the bullets at impact are the same.
- (a) I only.  
 (b) II only.  
 (c) I and IV only.  
 (d) I and II only.  
 (e) I, II and III only.

9. Consider the following five graphs (*note the axes carefully*). Which of these represent(s) one-dimensional motion at constant speed?

- (a) I only.
- (b) I, II and III only.
- (c) I and II only.
- (d) I and IV only.
- (e) IV only.



10. An elevator is moving upward with constant acceleration. The dashed curve shows the position  $y$  of the ceiling of the elevator as a function of time  $t$ . At the instant indicated by the dot, a bolt breaks loose and drops from the ceiling. Which curve labeled A thru D best represents the position of the bolt as function of time?



- (a) A.
- (b) B.
- (c) C.
- (d) D.
- (e) E.

## Physics 101 Fall 2006: Test 1—Multiple-Choice Answers

|    | A | B | C | D | E |
|----|---|---|---|---|---|
| 1  |   | X |   |   |   |
| 2  |   |   |   | X |   |
| 3  |   |   |   | X |   |
| 4  |   |   | X |   |   |
| 5  |   | X |   |   |   |
| 6  |   |   |   |   | X |
| 7  |   |   |   |   | X |
| 8  |   |   |   | X |   |
| 9  |   |   |   | X |   |
| 10 |   | X |   |   |   |