Name Key Instructor ____________________

Physics 1210 Exam 1

September 26, 2013

Please write directly on the exam and attach other sheets of work if necessary. Calculators are allowed. No notes or books may be used. Multiple-choice problems have only one correct answer. You may choose to circle two answers on a multiple-choice problem and, if one of them is correct, receive half credit. Circle three and if one is correct, 1/3 credit, etc. For worked problems, be complete and show all work, beginning with diagrams and fundamental, general equations used.

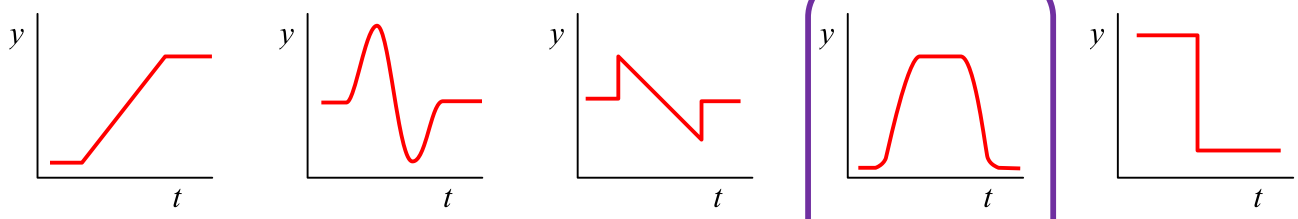
Kinematics $v_{\text{avg}} = \frac{x_2 - x_1}{t_2 - t_1} = \frac{\Delta x}{\Delta t}$ $\quad \vec{\boldsymbol{v}} = \frac{d\vec{\boldsymbol{r}}}{dt}$ $\quad a_{\text{avg}} = \frac{v_2 - v_1}{t_2 - t_1} = \frac{\Delta v}{\Delta t}$ $\quad \vec{\boldsymbol{a}} = \frac{d\vec{\boldsymbol{v}}}{dt}$

$x_1 = x_0 + v_0 t + \tfrac{1}{2} a t^2$ $\quad v_1 = v_0 + a t$ $\quad a_{\text{rad}} = \frac{v^2}{R} = \frac{4\pi^2 R}{T^2}$ $\quad \sum \vec{\boldsymbol{F}} = m\vec{\boldsymbol{a}}$

$v_1^2 = v_0^2 + 2a(x_1 - x_0)$ $\quad x = \frac{1}{2}(v + v_0)t + x_0$ $\quad \vec{\boldsymbol{w}} = m\vec{\boldsymbol{g}}$

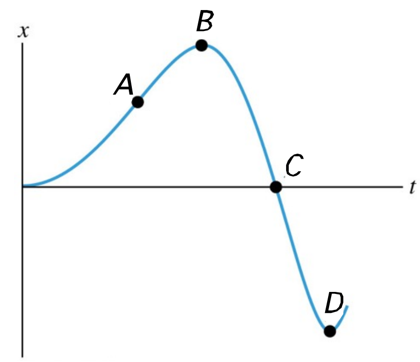
Each of the problems 1–11 is worth 5 points.

1. A cat sits on the floor for a few seconds, crouches, jumps up to a window ledge, sits there for a few seconds, and then jumps back down to the floor. Which position-time graph below best describes the cat's vertical position over time?




A. B. C. D. E.

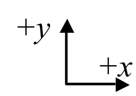
2. To the right is the $x$-$t$ graph of the motion of a particle. Of the four points $A$, $B$, $C$, and $D$, the velocity $v_x$ is greatest (most positive) at

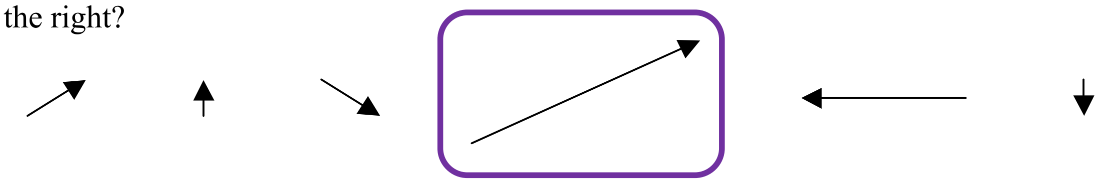



A. $A$
B. $B$
C. $C$
D. $D$
E. Not enough information in the graph to determine

Velocity is the slope of the (tangent to the) position-time plot. It is positive only at $A$.

3. Which vector has the largest component in the y-direction, as defined by the axes to the right?



4. Assume you are driving a car around a circular track at a constant speed. Which of the following statements is correct?

A. Your speed is constant and your velocity is constant.
B. Your speed changes and your velocity is constant.
C. Your speed changes and your velocity changes.
D. Your speed is constant and your velocity changes.

We are told the speed is constant. But since the car is driving in a circle, the direction of the velocity is constantly changing. Every half-circle, the car's velocity *reverses*!

5. A ball moves in a circular path with constant speed on a horizontal, frictionless surface. It is attached by a rope to a vertical post set at the center of the circle. If the rope breaks,

   A. the ball will keep moving in a circle.
   B. the ball will move on a curved path, but not a circle.
   C. the ball will follow a curved path for a while, then move in a straight line.
   D. the ball will move in a straight line.
   E. None of the above will happen.

   With the accelerating force of tension removed, the ball will move at constant velocity.

6. A large truck and a small compact car have a head-on collision. Which of the following statement is correct?

   A. During the collision, the force exerted on the truck by the car is larger than the force exerted on the car by the truck.
   B. During the collision, the force exerted on the truck by the car is equal to the force exerted on the car by the truck.
   C. During the collision, the force exerted on the truck by the car is smaller than the force exerted on the car by the truck.
   D. None of the above is correct.

   Newton's third law. Interaction forces are equal in magnitude, opposite in direction.

7. A rock flies through the air without air resistance. During its trajectory, which one of the statements below is true?

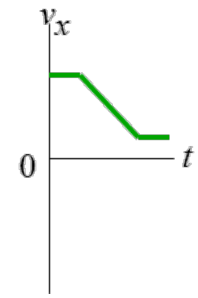
   A. Its acceleration is constant and its speed is constant.
   B. Its acceleration changes and its speed is constant.
   C. Its acceleration is constant and its speed changes.
   D. Its acceleration changes and its speed changes.

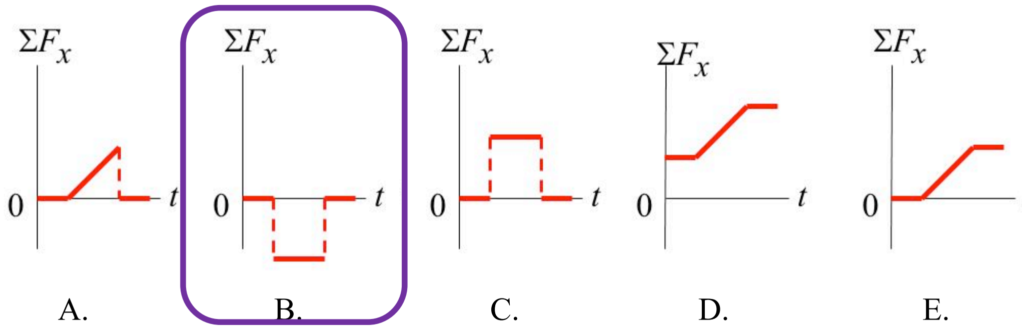
8. A hiker finds two abandoned mine shafts, and drops a rock from rest down each. In shaft 1, the rock falls for time $T$ before it hits the bottom. In shaft 2, the rock falls for time $2T$ before it hits the bottom. What can you conclude about the depths of these two mine shafts?
   A. Shaft 2 is deeper than shaft 1, but less than twice as deep: $D_1 < D_2 < 2D_1$.
   B. Shaft 2 is twice as deep as shaft 1: $D_2 = 2D_1$.
   C. Shaft 2 is more than twice as deep as shaft 1: $D_2 > 2D_1$.
   D. Shaft 2 is deeper than shaft 1, but that's all you know for certain: $D_2 > D_1$.

   In free-fall, distance fallen as a function of time is $\Delta y = v_0 t + gt^2/2$. From rest, $v_0 = 0$, so $\Delta y = gt^2/2$.

   Distance fallen is proportional to $t^2$, so doubling $t$ quadruples the fall distance.

9. The graph to the right shows the velocity of an object as a function of time. Which of the graphs below best shows the net force versus time for this object?



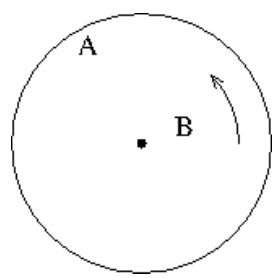

A downward acceleration means a downward net force. A constant velocity means zero net force.

10. A curve on the highway has a radius of 400 m. A construction crew widens the turn so that its radius is 600 m. If vehicles travel on the turn at the same speed as before, how does their centripetal acceleration $a$ compare to their previous centripetal acceleration $a_0$?

A. $a/a_0 = 400/600$.
B. $a/a_0 = 600/400$.
C. $a/a_0 < 400/600$.
D. $a/a_0 > 600/400$.

Centripetal acceleration is $v^2/r$. Both cases have the same $v$ but different $r$: $a = v^2/(600\text{ m})$ and $a_0 = v^2/(400\text{ m})$; thus $a/a_0 = 400/600$.

11. Alice and Bob are both on a merry-go-round that is rotating uniformly. The top-down view of the merry-go-round to the right shows the relative positions of Alice (A) and Bob (B). Who is accelerating the most?

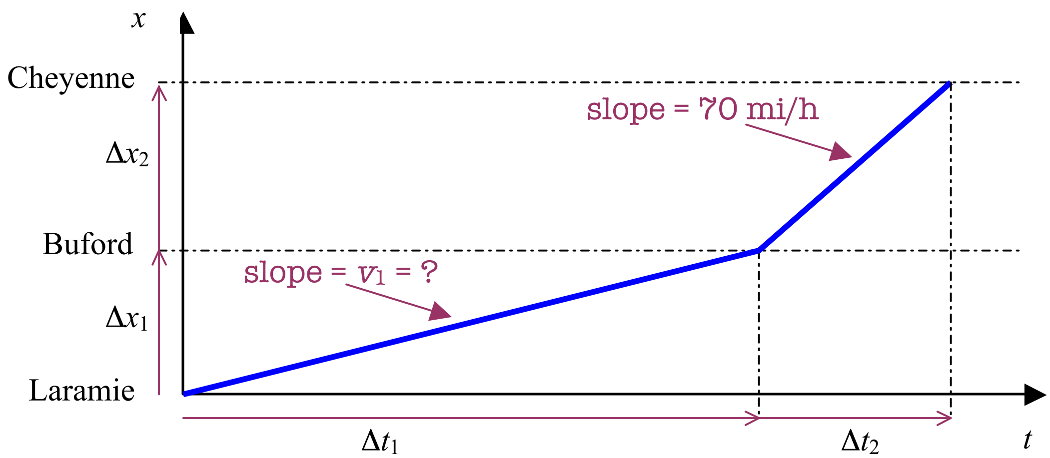



A. Alice.
B. Bob.
C. They are both accelerating at the same rate.
D. Need more information.

Alice and Bob both reverse their velocity in the same time period, but Alice's speed is greater, so her acceleration is correspondingly of larger magnitude.

By formulas, centripetal acceleration $a = v^2/R = 4\pi^2 R/T^2$. Alice and Bob rotate with the same period $T$, but Alice with a larger radius $R$, so her acceleration is proportionally larger.

12. (15 pts) You drive 50 miles from Laramie to Cheyenne in 57 minutes. The first 22 miles of the trip, from Laramie to Buford, was on icy roads with heavy traffic. The last part of the trip, from Buford to Cheyenne, was in more favorable conditions, so you were able to travel at 70 mi/h. What was your average speed traveling from Laramie to Buford?




$\Delta t = \Delta t_1 + \Delta t_2 = 57\ \text{min}\cdot(\text{h}/60\ \text{min}) = 0.95\ \text{h}$

$\Delta x = \Delta x_1 + \Delta x_2 = 50\ \text{mi}$

$\Delta x_1 = 22\ \text{mi}$

$v_2 = 70\ \text{mi/h}$

**Part 2: Buford to Cheyenne**

$\Delta x_2 = \Delta x - \Delta x_1 = 50\ \text{mi} - 22\ \text{mi} = 28\ \text{mi}$

$v_2 = \Delta x_2/\Delta t_2$, so

$\Delta t_2 = \Delta x_2/v_2 = (28\ \text{mi})/(70\ \text{mi/h}) = 0.4\ \text{h}$

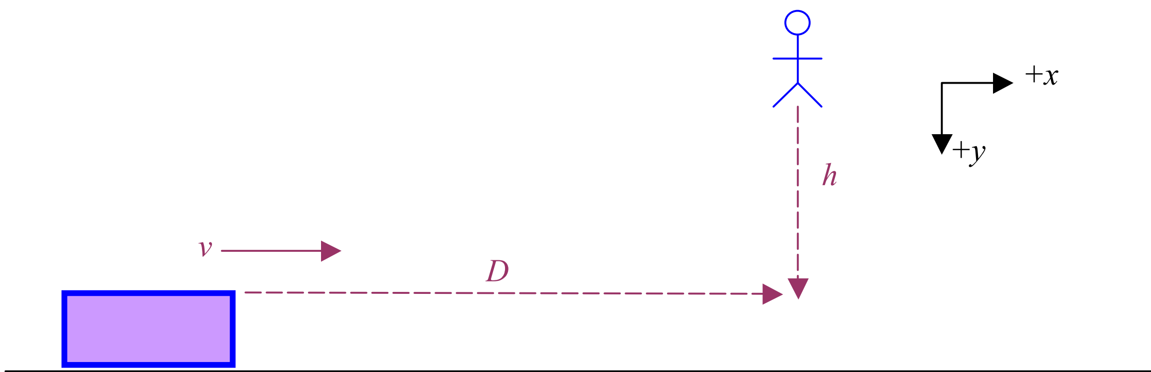
**Part 1: Laramie to Buford**

$\Delta x_1 = 22\ \text{mi}$

$\Delta t_1 = \Delta t - \Delta t_2 = 0.95\ \text{h} - 0.4\ \text{h} = 0.55\ \text{h}$

$v_1 = \Delta x_1/\Delta t_1 = (22\ \text{mi})/(0.55\ \text{h}) = \boxed{40\ \text{mi/h}}$

13. (15 pts) As a typical scene in an action movie, a car is moving towards a bridge and an action hero jumps off the bridge and lands on the top of the car at the moment it is passing through. Assuming that the car is moving at a constant speed of 45 mph (20.1 m/s), the bridge is 6.0 m above the car, and the actor is in free fall, calculate where the car should be when the actor starts his action. You can treat both the car and the actor as point objects.



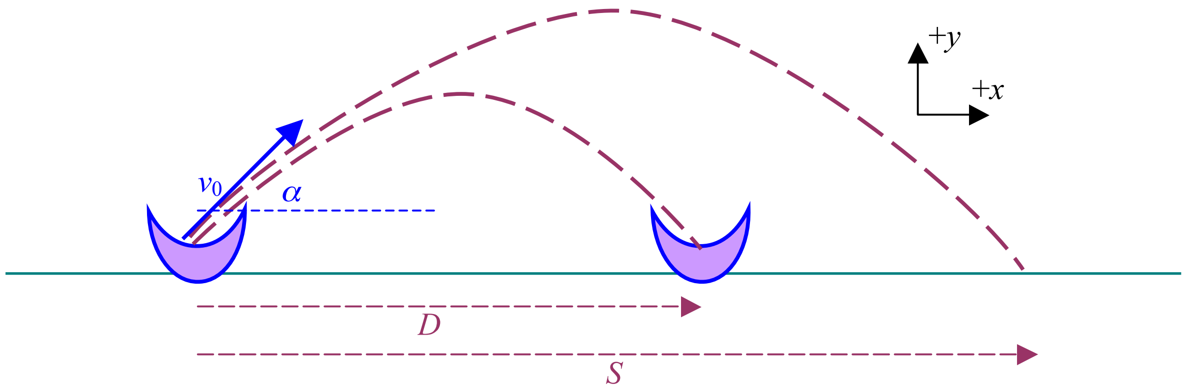

$h = 6$ m
$v = 20.1$ m/s
We want to find $D$ traveled by the car in the time the actor drops $h$

**Fall time**
$y = gt^2/2 = h$, so $t^2 = 2h/g$ and $t = \sqrt{2h/g}$

**Travel distance**
$D = x = vt = v\sqrt{2h/g} = (20.1\text{ m/s})\sqrt{2(6\text{ m})/(9.8\text{ m/s}^2)} = (20.1\text{ m/s})(1.11\text{ s}) =$
$= \boxed{22.24\text{ m}}$

14. (15 pts) September 19 was International Talk Like a Pirate Day. To celebrate, you and your friends stage a mock battle with boats in the Corbett Pool, firing water balloons at each other. Your enemy's boat is 10m away. You aim your water balloon launcher at a 45° angle with respect to the horizontal, and you overshoot the enemy's boat by 4m. Assume that the launcher is at the same level as the boats, and that air resistance is negligible.

a) What is the initial speed at which the water balloon was fired?
b) Assume that the launcher fires all balloons at the same initial speed. At what angle must you aim the launcher in order to make a direct hit?




$D = 10$ m; $S = 14$ m
$v_{0y} = v_0 \sin(\alpha)$
$v_x = v_0 \cos(\alpha)$

**Distance traveled as a function of $v_0$ and $\alpha$**
$y = v_{0y}t - gt^2/2$
At landing, $y = 0 = v_{0y}t - gt^2/2 = t\,(v_{0y} - gt/2)$
$t = 0$ is launch; $0 = v_{0y} - gt/2 \Rightarrow t = 2v_{0y}/g$
$x = v_x t = v_x \cdot 2v_{0y}/g = v_0 \cos(\alpha) \cdot 2v_0 \sin(\alpha)/g = (v_0^2/g) \cdot 2 \sin(\alpha) \cos(\alpha)$
There is a trigonometric identity in here: $\sin(2\alpha) = 2 \sin(\alpha) \cos(\alpha)$, so
$x = v_0^2 \sin(2\alpha)/g$. This is the *range equation*.

**Part a: $\alpha = 45°$ and $x = S$, find $v_0$**
$S = x = v_0^2 \sin(2\alpha)/g = v_0^2\,(1)/g = v_0^2/g$
$v_0^2 = Sg$, so $v_0 = \sqrt{Sg} = \sqrt{(14\text{ m})(9.8\text{ m/s}^2)} = \sqrt{137.2}$ m/s $= \boxed{11.71\text{ m/s}}$

**Part b: $x = D$, find $\alpha$**
$D = x = v_0^2 \sin(2\alpha)/g$
$\sin(2\alpha) = Dg/v_0^2$
$2\alpha = \arcsin(Dg/v_0^2)$ or $2\alpha = 180° - \arcsin(Dg/v_0^2)$, so
$Dg/v_0^2 = (10\text{ m})(9.8\text{ m/s}^2)/(137.2\text{ m}^2/\text{s}^2) = 0.7143$ (unitless)
Thus
$2\alpha = 45.59°$ or $2\alpha = 180° - 45.59° = 134.41°$, so
$\alpha = 45.59°/2 = \boxed{22.79°}$ or $\alpha = 134.41°/2 = \boxed{67.21°}$