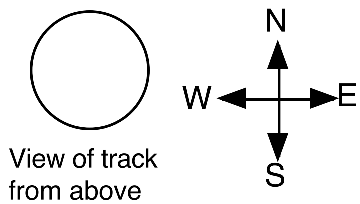
AP Physics
Test - Serway (4th) - Ch. 3, 4
Vectors, and Motion in Two Dimensions

Part I. Multiple Choice (5 points each)

Choose the one best answer to each of the following problems. You do not need to show your work. Note that the length of the diagonal across a unit square is $2^{1/2}$ (or "root 2"), and that the acceleration due to gravity in American units is 32 ft/s^2, down.



1 (AP).
A racing car is moving around the circular track of radius 300 meters shown above. At the instant when the car's velocity is directed due east, its acceleration is directed due south and has a magnitude of 3 meters per second squared. When viewed from above, the car is moving

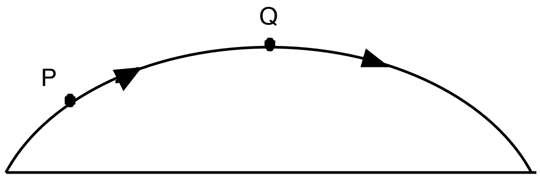
a) clockwise at 30 m/s
b) clockwise at 10 m/s
c) counterclockwise at 30 m/s
d) counterclockwise at 10 m/s
e) with constant velocity

2. A rock is projected from the edge of the top of a building with an initial velocity of 40 ft/s at an angle of 53° above the horizontal. The rock strikes the ground a horizontal distance of 82 ft from the base of the building. Assume that the ground is level and that the side of the building is vertical. How tall is the building?

a) 83 ft b) 97 ft c) 90 ft d) 77 ft e) 62 ft

3 (AP). A spring-loaded gun can fire a projectile to a height *h* if it is fired straight up. If the same gun is pointed at an angle of 45° from the vertical, what maximum height can now be reached by the projectile?

a) h/4
b) h / (2 • ($2^{1/2}$))
c) h/2
d) h/$(2)^{1/2}$
e) h



4 (AP).
A ball is thrown and follows a parabolic path as shown above. Air friction is negligible. Which of the following best indicates the direction of the net force on the ball at point P?

a)  b)  c)  d)  e) 

5. A river has a steady speed of 0.30 m/s. A student swims downstream a distance of 1.2 km and returns to the starting point. If the student swims with respect to the water at a constant speed and the downstream portion of the swim requires 20 minutes, how much time is required for the entire swim?
a) 50 minutes b) 80 minutes c) 90 minutes d) 70 minutes e) 60 minutes

6. A carnival merry-go-round has a 30 foot radius and rotates about a vertical axis at a constant rate. If a passenger standing on the edge of the merry-go-round experiences an acceleration of 4.0 ft/s^2 toward the center of the merry-go-round, how long does it take the merry-go-round to make one revolution?
a) 17 s b) 20 s c) 24 s d) 14 s e) 29 s

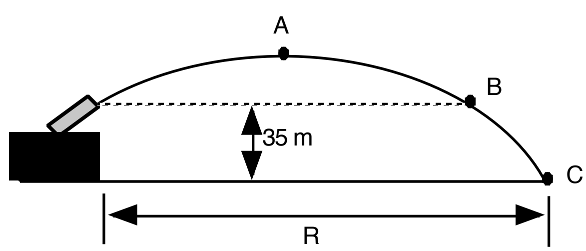
7. A radio-controlled car moves in the xy plane with constant acceleration = -4.0 $\mathbf{j}$ m/s^2. At t = 0, its position and velocity are 10 $\mathbf{i}$ m and (-2.0 $\mathbf{i}$ + 8.0 $\mathbf{j}$) m/s, respectively. What is the distance from the origin to the particle at t = 2.0 s?
a) 6.4 m b) 10 m c) 8.9 m d) 2.0 m e) 6.2 m

8 (AP). At a particular instant, a stationary observer on the ground sees a package falling with speed v_1 at an angle to the vertical. To a pilot flying horizontally at constant speed relative to the ground, the package appears to be falling vertically with a speed of v_2 at that instant. What is the speed of the pilot relative to the ground?
a) $v_1 + v_2$ b) $v_1 - v_2$ c) $v_2 - v_1$ d) $(v_1^2 - v_2^2)^{1/2}$ e) $(v_1^2 + v_2^2)^{1/2}$

Part II. Free Response Questions (15 points each)
Answer each of the following problems in as much detail as possible, being sure to *show all work!*

9. A fast duck is flying (20 **i** + 40 **j**) mi/h at the same altitude as a slow airplane flying with a velocity of (-80 **i** + 40 **j**) mi/h. How fast and in what direction is the duck moving relative to the airplane?

10. An artillery shell is fired with an initial velocity of 300 m/s at 55° above the horizontal. It explodes on a mountainside 42 s after firing. If x is horizontal and y vertical, find the (x,y) coordinates where the shell explodes.



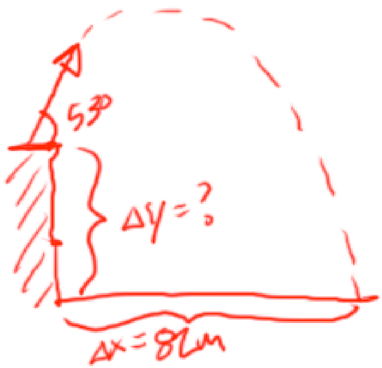
11 (AP).
A projectile is launched from the top of a cliff as shown above. At launch the projectile is 35 meters above the base of the cliff and has a velocity of 50 meters per second at an angle 37° above the horizontal. Air resistance is negligible. Calculate the total time from launch until the projectile hits the ground at point C, and the horizontal distance R that the projectile travels before it hits the ground.

12 (AP). Continuing the problem above, calculate the speed of the projectile at points A, B, and C.

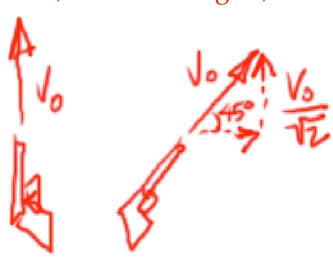
ANSWERS/SOLUTIONS:

1. a. a_c=3m/s^2=v^2/r, so v=30 m/s.

2. Split 40 ft/s into horizontal and vertical components, then solve horizontal equation x=vt to get *t*=3.41s. Substitute that value into vertical ($y=v_i t+(1/2)at^2$) to Δy=-77ft. (Note that it's easier to use a=-32ft/s^2 than it is to convert from ft/s to m/s, then convert back to meters after solving!)



3. By playing with the equations, you can determine that y is proportional to v_o^2. By pointing the gun at a 45° angle, the gun's new vertical component of velocity is v_o√2 (v_o times the square root of 2). Solve for h', the new height , in terms of the old height, to find that h'=h/2.

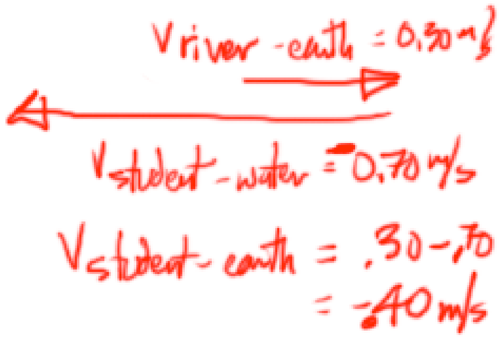


The math looks like this: $v_f^2=v_i^2+2ah$, and if v_f=0 and a=g, we can write h= $-(v_o)^2/2g$.

Okay, now we tilt the gun at a 45 degree angle. The original v_o is now changed to $v_o/\sqrt{2}$ (see diagram). So h', the new height, is now equal to - $(v_o /2)^2/2g$, which simplifies to be 1/2 of the original h value.

4. The only force acting on the ball throughout the entire flight is the force of gravity, which acts.... down!

5. $v_{\text{river relative to earth}}$ = 0.30 m/s --->
$v_{\text{student relative to river}}$ = ? (We need to figure out how fast the student swims ordinarily, in still water.)



Δx=1200m, t=20 min = 1200s, so $v_{\text{student relative to earth}}$ = 1 m/s downstream. Subtract out the v_{river}, and we see that the $v_{\text{student relative to river}}$=0.70m/s

So, how much time to come back 1200 m?
t=Δx/v = -1200m/-.40s = 3000 seconds, or 50 minutes.

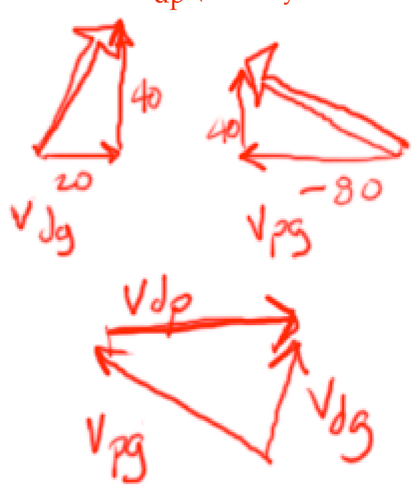
Total time for "there and back" adds the original 20 minutes, for a total of 70 minutes.

6. r=30 feet, a_c=4.0 ft/s, 1rev = 2πr = 188ft
v=$\sqrt{(a_c \bullet r)}$ = 11.0 ft/s, so t=x/v = 17.1 s

7. Use $r=r_o+v_ot+1/2\ at^2$ to get r=(6i+8j)m. Then use Pythagorean theorem to get 10m.

8. This problem is a perfect example of how drawing a good diagram will help you figure everything out. Use Pythagorean theorem to get $\sqrt{(v_1^2-v_2^2)}$.

9. This is a pretty tricky problem, and again, the diagram is critical. We've been given the velocity of the plane relative to the ground (v_{pg}), and the velocity of the duck relative to the ground (v_{dg}), and need to find v_{dp} (velocity of duck relative to plane).



$v_{pg} + v_{dp} = v_{dg}$, or $v_{dp} = v_{dg} - v_{pg}$
$v_{dp} = (20i+40j) - (-80i + 40j)$
$v_{dp} = (100i + 0j)$ m/s
$v_{dp} = 100$ m/s at 0°

10. Split initial velocity into x and y components: $v_x = 172$ m/s, $v_y = 246$ m/s. Then solve for x and y coordinates at time $t = 42$ s: (7224, 1688) m

11. Yet again, we need to split the original velocity into two components, with v_x=39.9 m/s, and v_y = 30.1 m/s. Solve for $y=v_i t + 1/2\ at^2$ to get $t = 7.14$s. The horizontal distance x (or R in this problem) =vt = 285 m.

12. v_A = 39.9 m/s (because there is no vertical velocity, only the constant horizontal velocity)
v_B = 50 m/s (by symmetry!)
v_C = 56.3 m/s. (Use $v_y=v_{oy}+at$) to get -39.7m/s for the vertical velocity right before it lands. The horizontal velocity is still constant, 39.9 m/s. Use Pythagorean to get the resultant velocity of 56.3 m/s.