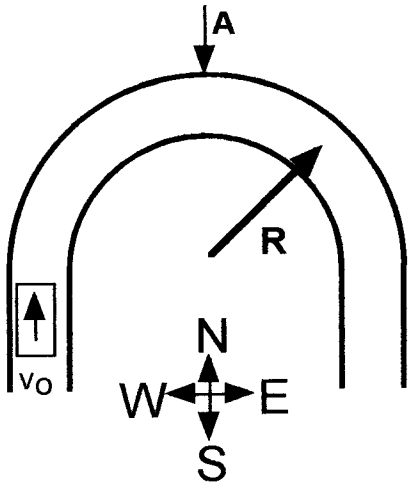
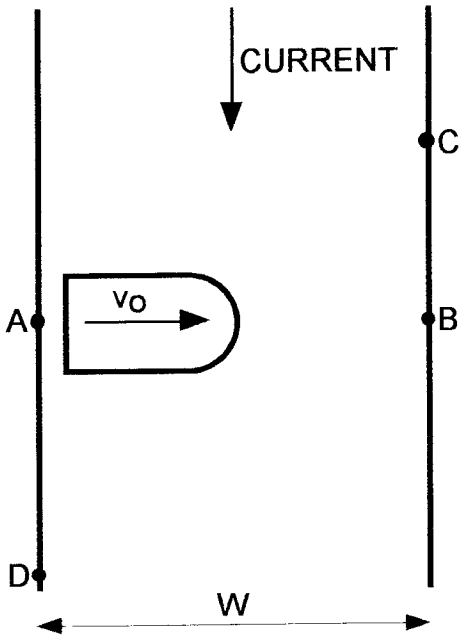
SCIENCE ENGINEERING PHYSICS - TEST CHAPTER 3
MOTION IN TWO DIMENSIONS - 100 PTS - 1993-94

Of the following problems you must do four (4). Be sure to show all work clearly. Please put only one problem per page. An extra problem may be done as a bonus - 5 points - be sure to indicates the bonus clearly! Problems must be stapled together in order.



1. A car is moving with a speed of v =32.0 m/s when it encounters a curve in the road which has a radius of curvature of R = 53.0 meters. The curve is a "hairpin" curve and consists of exactly 1/2 of a circle as shown to the right. As the car passes through the curve the speed of the car is reduced uniformly to a speed of 18.0 m/s as it exits the curve;
   a. How much time will pass from the time the car enters the curve until the car exits the curve? [5 pts]
   b. What will be the direction and magnitude of the linear acceleration of the car as it passes through the midpoint "A" of the curve? [4 pts]
   c. What will be the velocity of the car just as it reaches the midpoint of the curve? [4 pts]
   d. What will be the direction and magnitude of the centripetal acceleration of the car just as it reaches the midpoint of the curve? [4 pts]
   e. What will be the direction and magnitude of the linear acceleration of the car at the midpoint of the curve? [4 pts]
   f. What will be the direction and magnitude of the total acceleration of the car as it passes through the midpoint of the curve? [4 pts]

2. A boat, which can travel at 6.2 m/s in still water, heads directly across a river which has a current of 3.5 m/s and which is 310 meters wide.
   a. How long will it take for the boat to reach the opposite shore of the stream? [5 pts]
   b. What will be the velocity of the boat as measure by an observer standing along the shore of the river? [5 pts]
   c. What will be the final displacement of the boat when it lands on the opposite shore of the river? [5 pts]
   d. Suppose that instead of heading directly across the stream, this boat instead heads downstream a distance of 310 meters then turns around and heads back to the starting point. How much time would be required? [5 pts]
   e. At what angle should the boat head in order to reach a point on the exact opposite shore of the river? [4 pts]
   f. What should the heading of the boat be in order for it to land at a point on the opposite shore exactly 100 meters upstream from the starting point? [4 pts]



3. Chicago is 820 miles East and 150 Miles North of Denver. According to the airline schedule Flight 22 should leave Denver at 8:45 AM and should arrive in Chicago at 10:15 AM.
   a. What average velocity should the airplane have in order to arrive in Chicago on time? [10 pts]
   b. Suppose that on this particular day the wind is blowing with a velocity of 85 mph on a heading of 30^{o} North of West. Assuming that you do not correct for the effect of the wind, what will be the resulting velocity of the airplane? [5 pts]
   c. Suppose that you do NOT correct for the effects of the wind, what will be the displacement of your airplane relative to Chicago when you're supposed to be landing? [5 pts]
   d. What should the velocity of the airplane be in order to correct for the wind and arrive at Chicago on time? [5 pts]

4. A cannon is sitting on top of a castle wall guarding the entrance to a Spanish port. The castle wall is 175 meters above the water level. The cannon fires a cannonball with a speed of 225 meters/second. An enemy ship is moving toward the port with a speed of 12.0 m/s and is currently 10,000 meters from the base of the castle wall. Assuming that you would like to strike the incoming ship at the water line;
   a. What will be the minimum distance between the castle and the ship before the cannon can sink the ship? [5 pts]
   b. How long will it take for the cannonball to arrive at the ship ? [5 pts]
   c. What will be the velocity of the cannonball when it strikes the ship? [5 pts]
   d. How long should you wait before firing your cannon? [5 pts]

   Assuming that the minimum angle between the cannon and the horizontal is zero degrees [Any lower and the cannonballs will roll out of the cannon!]
   e. What will be the minimum distance between the castle and the enemy ship before the cannon can no longer strike the enemy ship? [5 pts]

5. A baseball, which has a mass of 650 grams, is struck by a bat and 5.0 seconds later it is caught 46.0 meters away. If the baseball was 1.2 meters above the ground when it was struck and was caught when it was 0.5 meters above the ground;
   a. What was the greatest height reached by the ball? [5 pts]
   b. What were the vertical [5 pts] and horizontal [5 pts] components of its velocity when it was struck?
   c. What was the speed of the ball when it was caught? [5 pts]
   d. At what angle with the horizontal did the ball leave the bat? [5 pts]

1. (a) $r = 53\,m$

$C = \pi r = 166.5\,m$

$D = \bar{v}\,t = 25t = 166.5$

$\boxed{t = 6.66\,s}$ (a) 5

$v_0 = 32,\ v_5 = 18$ $\qquad a = \frac{\Delta v}{\Delta t}$

$\bar{v} = \frac{18+32}{2} = 25$

(b) $v = at + v_0$

$18 = a(6.66) + 32$

$-14 = a(6.66)$

$a = \boxed{-2.10\,m/s^2 \text{ WEST}}$ (b) 4

(c) $D = \frac{1}{2}at^2 + v_0 t = \frac{-2.1}{2}t^2 + 32t = \frac{166.5}{2}$

$-1.05t^2 + 32t - 83.25 = 0$

$t = 2.87,\ 27.6\,s$

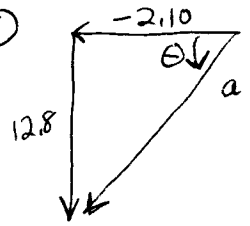
$v = at + v_0 = -2.1(2.87) + 32 = 25.97 = \boxed{26.0}$ (c)

EAST

(d) $a_c = \frac{v^2}{r} = \frac{26^2}{53} = 12.76 = \boxed{12.8\,m/s^2 \text{ SOUTH}}$ (d) 4

(e) SAME AS B

(f)



$a = \sqrt{12.8^2 + 2.1^2} = \boxed{12.93\,m/s^2 \text{ at } 80.7°\text{SW OR } 201°}$ (f) 4

at

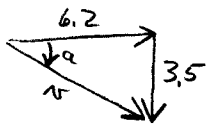
$\tan\theta = \frac{12.8}{2.1} \Rightarrow \theta = 80.7°\,\text{SW}$

2. (a) $D = \bar{v}t$

$310 = 6.2t$

$\boxed{t = 50\,s}$ (a) 5

(b)



$v = \sqrt{6.2^2 + 3.5^2} = \boxed{7.12\,m/s \text{ at } 29.4° \text{ DOWNSTREAM}}$ (b) (a)

OR

$\tan a = \frac{3.5}{6.2} \Rightarrow a = 29.4°$

OR

$v = (6.2\hat{i} - 3.5\hat{j})\,m/s$

(c) $7.12 \text{ at } 29.4° \times 50\,s = \boxed{356\,m \text{ at } 29.4° \text{ DOWNSTREAM}}$ (c) 4

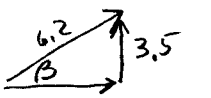
OR

OR

$(6.2\hat{i} - 3.5\hat{j})\,m/s \times 50\,s = (310\hat{i} - 175\hat{j})\,m$

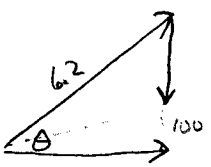
(d) $D_0 = \frac{310}{6.2+3.5} + \frac{310}{6.2-3.5} = 31.96\,s + 114.8\,s = 146.8\,s = \boxed{147\,s}$ (d) 4

(e)



$\sin\beta = \frac{3.5}{6.2} = \boxed{34.4° \text{ UPSTREAM}}$ (e) 4

(f)



$t = \frac{310}{6.2\cos\theta} \Rightarrow t\cos\theta = 50$

$100 = (6.2\sin\theta - 3.5)t$

$100 = 6.2t\sin\theta - 3.5t$

$50 = t\cos\theta$

$2 = 6.2\tan\theta - \frac{3.5}{\cos\theta} = \frac{6.2\sin\theta}{\cos\theta} - \frac{3.5}{\cos\theta} = \frac{6.2\sin\theta - 3.5}{\cos\theta}$

$2\cos\theta = 6.2\sin\theta - 3.5$

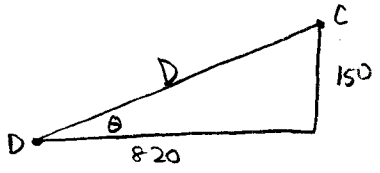
$1.29 \qquad 1.25$

$\boxed{\theta = 50.4°}$ (f) 4

✓

$127.5 = 127.7$

3.



(a) $D = \sqrt{820^2 + 150^2} = 833.6$ miles

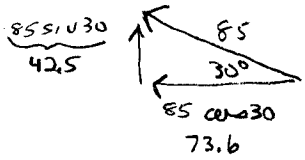
$\tan\theta = \frac{150}{820} = 10.37^\circ$ NE

OR $\frac{820}{1.5}\hat{i} + \frac{150}{1.5}\hat{j} = (547\hat{i} + 100\hat{j})$ mph

$\frac{833.6 \text{ mi}}{1.5 \text{ hr}} =$ **556 mph at 10.4° NE** (a) 5

10:15 − 8:45 = 1:30

(b)



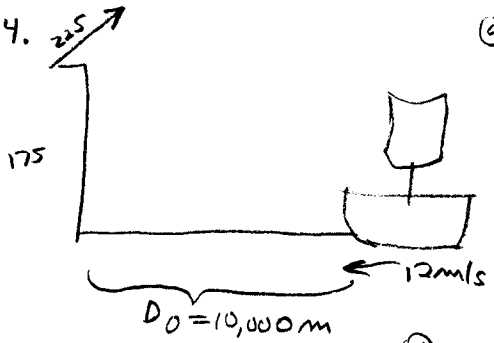
$v_{WIND} = -73.6\hat{i} + 42.5\hat{j}$

$+ 547\hat{i} + 100\hat{j} = (473\hat{i} + 142.5\hat{j})$ m/s = **494 mph at 16.8° N** (b) 5

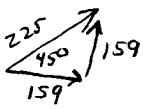
(c) $(-73.6\hat{i} + 42.5\hat{j})\,1.5 \text{ hrs} = (-110\hat{i} + 63.8\hat{j})$ miles OR **127 miles at 30.1° NW** (c) 5

(d) $547\hat{i} + 100\hat{j} - (-73.6\hat{i} + 42.5\hat{j}) = 620.6\hat{i} + 57.5\hat{j} =$ **623 at 5.3° mph** (d) 5

4.



(a)



$0 = -4.9t^2 + 159t + 175$

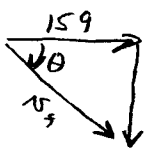
$t =$ **33.5 s** (b) 5

$D_H = v_H t$

$= 159(33.5) =$ **5327 m**

(b)

(c)



$v_f = -9.8(33.5) + 159$

$v_f = \sqrt{159^2 + 169.3^2} =$ **232 m/s at 46.8° DOWN** (c) 5

OR

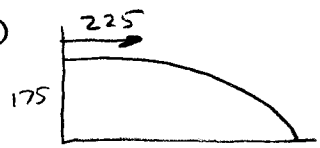
$\tan\theta = \frac{169}{159} = 46.8^\circ$ $(159\hat{i} - 169\hat{j})$ m/s

(d)

$10{,}000 - 5327 = 4673 \text{ m} \div 12 = 389.4 \text{ s}$

$389.4 - 33.5 =$ **356 s** (d) 5

(e)



$0 = -4.9t^2 + 0 + 175$

$t = 5.98$ s

$R = 225(5.98)$

$=$ **1345 m** (e) 5

5.

$(v\cos a)t = 46$

$t = 5$ s

$v\cos a = \frac{46}{5}$

$v\cos a = 9.2$

$D_f = \frac{1}{2}at^2 + v_0 t + D_0$

$.5 = -4.9(5)^2 + v\sin a\,(5) + 1.2$

$\frac{v\sin a = 24.36}{v\cos a = 9.2} = 2{,}648 = \tan a$

$a =$ **69.3°** (d) 5

$v = at + v_0$

$0 = -9.8t + 24.3$

$t = 2.48$ s

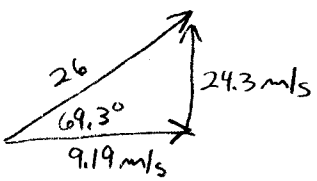
$D_f = \frac{1}{2}at^2 + v_0 t + D_0$

$= -4.9(2.48)^2 + 24.3(2.48) + 1.2$

$H =$ **31.3 m** (a) 5

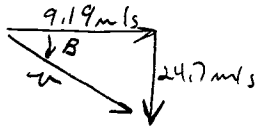
$v\sin(69.3) = 24.36$

$v = 26.0$ m/s



$9.19\hat{i}$ m/s + $24.3\hat{j}$ m/s (b) 5

(c)



$v = -9.8(5) + 24.3$

$\sqrt{24.7^2 + 9.19^2} =$ **26.4 m/s** at 69.6° (c) 5

$\tan^{-1}\left(\frac{24.7}{9.19}\right) = 69.6^\circ$