1. a) the tangent line slope is the velocity of the object, and the tangent line slope is greatest at D
b) the object moves left when the slope is negative, and the slope is negative at points C,D,E.
c) the object is speeding up when the magnitude of the velocity (absolute value of the slope) is increasing, which occurs at point C.
d) the object is slowing down when the magnitude of the velocity (absolute value of the slope) is decreasing, which occurs at points A,E.
e) the object is turning around when the slope of the tangent changes sign from positive to negative or negative to positive, which occurs at point B.

2. a) the object is moving with constant velocity when the slope of the velocity vs. time graph is zero (horizontal line) which occurs for line segments A,D.
b) the object is speeding up when a segment trends away from the time axis (either increasing positive velocity or decreasing negative velocity), which occurs for line segment C.
c) the object is slowing down when a segment trends towards the time axis (either decreasing positive velocity or increasing negative velocity), which occurs for line segments B,E.
d) the object is standing still when a segment is along the time axis, which occurs for line segment F.
e) the object is moving to the right when a segment is in the first quadrant where positive velocity is plotted (assuming right = positive), which occurs for line segments A,B.

3. $s_{avg} = \frac{d}{t} = \frac{s_1t_1 + s_2t_2 + s_2t_3}{t_1 + t_2 + t_3}$

$s_{avg} = \frac{80(1) + 50(0.5) + (40)(0.5)}{1 + 0.5 + 0.5}$

$s_{avg} = \boxed{62.5 \text{ km/h}}$

4. If speed is decreasing, acceleration is always directed opposite the motion of the object. Acceleration is a vector, with direction defined by the *change* in velocity. In this case the change in velocity is northward.

5. $v_f^2 = v_i^2 + 2a\Delta x$

$v_f^2 = 0^2 + 2(4.9)(200) \Rightarrow v_f = \boxed{44.3 \text{ m/s}}$

6. Velocity and displacement are vectors, and speed and *distance* are scalars.

7. The area under the graph of velocity vs. time equals the displacement. Car C has the most area under the graph from 0 to 20 seconds.

8. Car A has the largest velocity because it has the largest coordinate on the vertical axis at 30 seconds.

9. The slope of the graph of velocity vs. time equals acceleration. Car B has the highest slope at 40 seconds.

10. $\Delta y = v_{yi}t + \frac{1}{2}gt^2 = 0 + \frac{1}{2}(-9.8)(1)^2 = \boxed{-4.9 \text{ m}}$

$v_{yf} = v_{yi} + gt = 0 + (-9.8)(1) = \boxed{-9.8 \text{ m/s}}$

11. The displacement is a quadratic function of time, with all displacements negative (downward), while the velocity is a linear function of time, again with all velocities negative (downward).

12. The maximum resultant (8 + 5 = 13) is when the vectors are added at a 0° angle. The minimum resultant (8 – 5 = 3) is when the vectors are added at 180° angle. The resultant cannot be 15.

13. At the peak of a projectile's trajectory, the vertical velocity is zero for an instant. At *all* times during the trajectory, the acceleration from gravity is -9.8 m/s^2.

14. $\Delta y = v_{yi}t + \frac{1}{2}gt^2 = \frac{1}{2}(-9.8)(8)^2 = -313.6 \text{ m}$

$s_{avg} = \frac{d}{t} = \frac{313.6}{8} = \boxed{39.2 \text{ m/s}}$

15. $r = \sqrt{(5 - 0.5)^2 + 2.1^2} = \boxed{4.97 \text{ m}}$

$\theta = \tan^{-1}\left(\frac{2.1}{(5 - 0.5)}\right) = 25°$

from north $\theta = 90°\text{-}25° = \boxed{65°}$

16. $\Delta y = v_{yi}t + \frac{1}{2}gt^2 \quad -20 = 0 + \frac{1}{2}(-9.8)t^2 \quad t = 2.02 \text{ s}$

$\Delta x = v_x t \quad 15 = v_x(2.02) \quad v_x = \boxed{7.42 \text{ m/s}}$

$v_{yf} = v_{yi} + gt = 0 + (-9.8)(2.02) = 19.8 \text{ m/s}$

$v = \sqrt{v_x^2 + v_{yf}^2} = \sqrt{7.42^2 + 19.8^2} = \boxed{21.1 \text{ m/s}}$

17. $v_x = v_i \cos\theta = 89 \cos 40° = 68.18 \text{ m/s}$

$v_{yi} = v_i \sin\theta = 89 \sin 40° = 57.21 \text{ m/s}$

$\Delta x = v_x t \Rightarrow 300 = 68.18t \Rightarrow t = \boxed{4.40 \text{ s}}$

18. $\Delta y = v_{yi}t + \frac{1}{2}gt^2 = (57.21)(4.40) + \frac{1}{2}(-9.8)(4.40)^2$

$\Delta y = \boxed{157 \text{ m}}$

19a. $v_f^2 = v_i^2 + 2a\Delta x = 0 + 2(4.5)(100)$

$v_f = \sqrt{2(4.5)(100)} = \boxed{30 \text{ m/s}}$

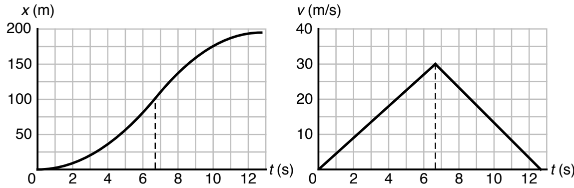
19b. $\Delta x = \frac{1}{2}(v_i + v_f)t = \frac{1}{2}(30 + 0)(6) = 90 \text{ m}$

$\text{total} = 100 + 90 = \boxed{190 \text{ m}}$

19c. $\Delta x = v_i t + \frac{1}{2}at^2 \quad 100 = \frac{1}{2}(4.5)t^2 \quad t = 6.67 \text{ s}$

$\text{total} = 6.67 + 6 = \boxed{12.67 \text{ s}}$

19d.



20a. $v_{yf}{}^2 = v_{yi}{}^2 + 2g\Delta y \quad v_{yf}{}^2 = (-2)^2 + 2(-9.8)(-40)$

$v_{yf} = \pm\sqrt{788} = \boxed{-28.1 \text{ m/s}}$ (downward)

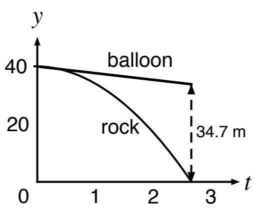
20b. $\Delta y_{phone} = \frac{1}{2}(v_{yi} + v_{yf})t \quad -40 = \frac{1}{2}(-2 + -28.1)t$

$t = 2.66$ s

$\Delta y_{balloon} = v_y t = (-2)(2.66) = -5.32$

height $= |-40| - |-5.32| = \boxed{34.7 \text{ m}}$

20c.



21. $v_x = v_i \cos\theta = 20\cos(-5°) = 19.9$ m/s

$v_{yi} = v_i \sin\theta = 20\sin(-5°) = -1.74$ m/s

$\Delta x = v_x t \quad 7.0 = 19.9t \quad t = 0.351$ s

$\Delta y = v_{yi}t + \frac{1}{2}gt^2 = (-1.74)(0.351) + \frac{1}{2}(-9.8)(0.351)^2$

$\Delta y = -1.217$ m so hits the net $\boxed{-0.217 \text{ m}}$ from top

22. $\Delta x = v_x t \qquad 90 = v_x(3.5) \qquad v_x = \boxed{25.7 \text{ m/s}}$

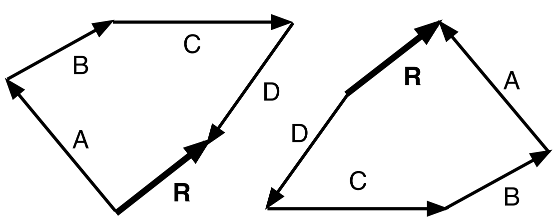
$\Delta y = v_{yi}t + \frac{1}{2}gt^2 \quad -2 = v_{yi}(3.5) + \frac{1}{2}(-9.8)(3.5)^2$

$v_{yi} = \boxed{16.6 \text{ m/s}}$

$v_i = \sqrt{v_x{}^2 + v_{yi}{}^2} = \sqrt{25.7^2 + 16.6^2} = \boxed{30.6 \text{ m/s}}$

$\theta = \tan^{-1}\left(\frac{v_{yi}}{v_x}\right) = \tan^{-1}\left(\frac{16.6}{25.7}\right) = \boxed{32.8°}$

23.



24. $v_x = v_i \cos\theta = 23\cos 40° = 17.6$ m/s

$v_{yi} = v_i \sin\theta = 23\sin 40° = 14.8$ m/s

$\Delta y = v_{yi}t + \frac{1}{2}gt^2$

$3.05 = 14.8t + \frac{1}{2}(-9.8)t^2 \quad \Rightarrow \quad t = 2.79$ s

$\Delta x = v_x t = 17.6(2.79) = \boxed{49.2 \text{ m}}$

25a. positive (thrust) acceleration

$\Delta y = v_i t + \frac{1}{2}at^2$

$\Delta y = 0(5) + \frac{1}{2}(30)(5)^2 = 375$ m

$v_f = v_i + at$

$v_f = 0 + (30)(5) = 150$ m/s

freefall (coast) acceleration

$v_{yf}{}^2 = v_{yi}{}^2 + 2g\Delta y$

$0^2 = 150^2 + 2(-9.8)\Delta y$

$\Delta y = 1148$ m

total $= 375 + 1148 = \boxed{1523 \text{ m}}$

25b. The rocket is displaced -375 m from the moment the fuel runs out until it lands:

$\Delta y = v_{yi}t + \frac{1}{2}gt^2$

$-375 = 150t + \frac{1}{2}(-9.8)t^2$

$t = 32.9$ s

total time of flight $= 5.0 + 32.9$ s $= \boxed{37.9 \text{ s}}$

26a. $\theta = \sin^{-1}\left(\frac{4}{9}\right) = 26.4°$

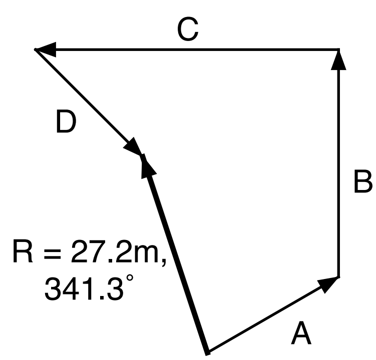
$90° - 26.4° = \boxed{63.6° \text{ from river}}$

26b. $\vec{v}_{bs} = \vec{v}_{bw} + \vec{v}_{ws}$ (vector sum)

$v_{bw}{}^2 = v_{bs}{}^2 + v_{ws}{}^2$ (right triangle geometry)

$v_{bs} = \sqrt{9^2 - 4^2} = \boxed{8.06 \text{ km/hr}}$

27.



$R_x = 20\cos 30° + 30\cos 90° +$
$40\cos 180° + 20\cos 315° = -8.54\ \text{m}$

$R_y = 20\sin 30° + 30\sin 90° +$
$40\sin 180° + 20\sin 315° = 25.86\ \text{m}$

$R = \sqrt{R_x^2 + R_y^2} =$
$\sqrt{(-8.54)^2 + (25.86)^2} = \boxed{27.2\ \text{m}}$

28. $\theta_{ref} = \tan^{-1}(25.86 / -8.54) = -71.7°$
$\theta = \boxed{341.3°\ \text{from north}}$

29. Each lap is equal distance, d

$d = s_1 t_1$ (first lap) equals $d = s_2 t_2$ (second lap)

since each lap is the same distance

$$s_{avg} = \frac{d+d}{t_1+t_2} = \frac{d+d}{\frac{d}{s_1}+\frac{d}{s_2}} = \frac{1+1}{\frac{1}{s_1}+\frac{1}{s_2}}$$

$$s_{avg}\ \frac{2}{\frac{1}{200}+\frac{1}{220}} = \boxed{209.5\ \text{mph}}$$

30. reaction phase

$\Delta x_1 = v_i t_r = 20(1) = 20\ \text{m}$

braking (acceleration) phase

$\Delta x_2 = \tfrac{1}{2}(v_i + v_f)t_b$

$200 - 20 = \tfrac{1}{2}(20 + v_f)(15-1)$

$v_f = 5.71\ \text{m/s}$

31. Consider the vector drawing to the right

$v_{pg,x} = v_{pg}\cos 58° \quad v_{pg,y} = v_{pg}\sin 58°$

for the larger right triangle in the vector diagram:

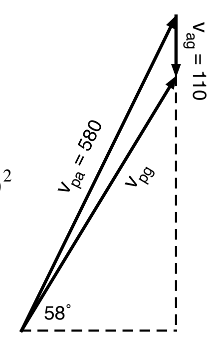
$580^2 = (v_{pg}\cos 58)^2 + (v_{pg}\sin 58 + 110)^2$

$0 = v_{pg}^2[(\cos 58)^2 + (\sin 58)^2] + (220\sin 58)v_{pg} + 110^2 - 580^2$

quadratic solution with $a = 1,\ b = 186.57,\ c = -324300$

$v_{pg} = 483.8\ \text{m/s}$

$$\theta = \tan^{-1}\left(\frac{483.8\sin 58 + 110}{483.8\cos 58}\right) = 63.77°$$



32. stone dropped | stone thrown

$y_f = 22 + -8t - 4.9t^2 \qquad y_f = 2 + 17t - 4.9t^2$

combine: $22 - 8t - 4.9t^2 = 2 + 17t - 4.9t^2$

$$t = \frac{22-2}{17+8} = \frac{20}{25} = \boxed{0.8\ \text{s}}$$

$y_f = 22 - 8(0.8) - 4.9(0.8)^2 = \boxed{12.5\ \text{m}}$

or $y_f = 2 + 17(0.8) - 4.9(0.8)^2 = 12.5\ \text{m}$

33a. Set up equations for horizontal and vertical motion:

$\Delta y = v_{yi}t + \tfrac{1}{2}gt^2 = v_i(\sin\ \theta)t + \tfrac{1}{2}gt^2$

$$\Delta y = v_i(\sin\theta)\left(\frac{\Delta x}{v_i(\cos\theta)}\right) + \tfrac{1}{2}gt^2 = \Delta x\tan\theta + \tfrac{1}{2}gt^2$$

$$6.0 = 72\tan 38° - 4.9t^2 \Rightarrow t = \sqrt{\frac{72\tan 38° - 6.0}{4.9}} = \boxed{3.20\ \text{s}}$$

33b. Substitute t into the horizontal (or vertical) equation:

$$\Delta x = (v_i\cos\ \theta)t \ \Rightarrow\ v_i = \frac{\Delta x}{t\ \cos\ \theta}$$

$$v_i = \frac{72}{(3.2)\cos 38°} = \boxed{28.5\ \text{m/s}}$$

34. acceleration phase

$v_f = v_i + at = 0 + 2.68t$

$\Delta x_1 = v_i t + \tfrac{1}{2}at^2 = 0 + \tfrac{1}{2}(2.68)t^2$

constant velocity phase ($v_f = v_i$ from before)

$\Delta x_2 = v_i t + \tfrac{1}{2}at^2 = (2.68t)(12-t)$

full race

$\Delta x_1 + \Delta x_2 = 100$

$\tfrac{1}{2}(2.68)t^2 + (2.68t)(12-t) = 100$

$1.34t^2 - 32.16t + 100 = 0$

$t = \boxed{3.671\ \text{s}}$

constant velocity phase

$\Delta x_2 = (2.68t)(12-t)$

$\Delta x_2 = 2.68(3.671)(12 - 3.671) = \boxed{81.9\ \text{m}}$

or $\Delta x_2 = 100 - \tfrac{1}{2}(2.68)(3.671)^2 = 81.9\ \text{m}$