5. Kinematics challenge:
A stone is dropped from a 45m high cliff. At the same instant, a second stone is thrown upward from the base of the cliff with a speed of 15m/s.

a) At what height above the ground do the stones pass eachother?

$a = -9.8\ m/s^2$

$h(of\ Cliff) = 45m$

Stone A (falling)

- $v_{A_0} = 0\ m/s$ (initial velocity) $\rightarrow y_A(t) = 45 - \frac{1}{2} g t^2$
- $y_{A_0} = 45m$ (inital height) $= 45 - 4.9t^2$

Stone B (rising)

- $v_{B_0} = 15\ m/s \uparrow$ (initial velocity)
- $y_{B_0} = 0m$ (initial height) $\rightarrow y_B(t) = v_{B_0} t + \frac{1}{2}(-g)t^2$

$= 15t - 4.9t^2$

$y_B = 15(3) - 4.9(3)^2 = 45 - 44.1 = \boxed{0.9m}$

b) How much time after release does this occur?

$y_{A(t)} = y_{B(t)}$

$45 - 4.9t^2 = 15t - 4.9t^2$

$+4.9t^2 \quad +4.9t^2$

$\frac{45}{15} = \frac{15t}{15} \rightarrow \boxed{t = 3s}$

4. Relative velocity:

A river flows east at 2 m/s. A boat heads North at 4 m/s relative to the water.

a) what is the boat's speed relative to the ground?

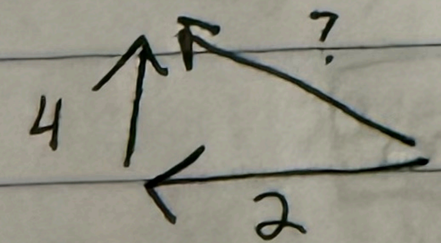
$V_r = 2\,m/s$ (River that flows east)

$V_b = 4\,m/s$ (boat that moves North)

$$V = \sqrt{V_r^2 + V_b^2} = \sqrt{(2)^2 + (4)^2} = \sqrt{4 + 16} = \sqrt{20}$$

$$\boxed{V = 4.47\,m/s}$$

b) At what angle (relative to North) does it move as seen from the shore?



$$\tan\theta = \frac{opp.}{Adj.} \quad \tan\theta = \frac{2}{4}$$

$$\theta = \tan^{-1}\left(\frac{2}{4}\right)$$

$$\theta = \tan^{-1}\left(\frac{1}{2}\right)$$

$$\boxed{\theta = 26.6^\circ}$$

3. Projectile (2D):

A soccer ball is kicked from ground level at 18 m/s at a 30° angle above the horizontal.

a) How long is the ball in the air?

$V_0 = 18\ m/s$

$\theta = 30°$

$g = 9.8\ m/s^2$

$V_{0x} = V_0 \cos(\theta) = 18\cos(30°) = 18 \times 0.866 = 15.59\ m/s$

$V_{0y} = V_0 \sin(\theta) = 18\sin(30°) = 18 \times 0.5 = 9.00\ m/s$

$$t = \frac{2V_{0y}}{g} = \frac{2(9)}{9.8} = \frac{18}{9.8} = \boxed{1.84\ s}$$

b) How far does it travel horizontally before hitting the ground?

$$x = V_{0x} \cdot t = 15.59 \times 1.84 = \boxed{28.7\ m}$$

2. Free Fall:

A ball is thrown straight upward with an initial speed of 12 m/s.

a) How long does it take to reach its highest point?

$V_0 = 12 m/s \uparrow$

$a = -9.8 m/s^2$

$V = 0 m/s$ - stops at top

$V = V_0 + at$

$0 = 12 + (-9.8)t$

$-12 \quad -12$

$\frac{-12}{-9.8} = \frac{-9.8t}{-9.8}$

$1.22 = t$

$t = 1.22 s$

b) what is the maximum height it reaches?

$x = V_0 t + \frac{1}{2} a t^2$

$x = (12)(1.22) + \frac{1}{2}(-9.8)(1.22)^2$

$x = 14.64 - 7.29$

$x = 7.35 m$

1. Constant acceleration (1D):

A car starts from rest and accelerates uniformly at $2.5\ m/s^2$ for 8 seconds.

a) what is it's final velocity?

V_0 (initial) = 0 - starts from rest

$a = 2.5\ m/s^2$

$t = 8$ sec.

$V = V_0 + at$

$V = 0 + (2.5)(8)$

$\boxed{V = 20\ m/s}$

b) How far does it travel in this time?

$x = V_0 t + \frac{1}{2} a t^2$

$x = 0 + \frac{1}{2}(2.5)(8)^2$

$x = (1.25)(64)$

$\boxed{x = 80\ m}$