Crack the OAT

Crack Notes [Physics 1]
Translational Motion

Drawing the Diagram
- Try to draw it as to scale as possible
- Draw arrows for all forces, including ones they don't mention explicitly
- Make sure your drawn forces make sense – are there any unbalanced ones? Then there has to be acceleration. If there's no acceleration (object not moving or moving at constant velocity) and you have unbalanced forces, you're missing something

Vectors vs. Scalars, Vector Mathematics
- Vectors have magnitude and direction, scalars have magnitude but no direction
- ALWAYS convert to x and y components when dealing with vectors:

$$V_x = V\cos\theta\,, \qquad V_y = V\sin\theta\,, \qquad V = \sqrt{V_x^2 + V_y^2}$$

- Can add/subtract vectors mathematically or graphically (mathematically: just add components)
- Multiplying vector by scalar: just multiply each component by the scalar
- Multiplying vector by vector:
  - Cross product → vector, $V_1 \times V_2 = V_1 V_2 \sin\theta$, usually V_1 and V_2 are perpendicular so $V_1 \times V_2 = V_1 V_2$
  - Dot product → scalar, $V_1 \cdot V_2 = V_1 V_2 \cos\theta$, usually V_1 and V_2 are parallel so $V_1 \cdot V_2 = V_1 V_2$

Kinematics
- Scalars: distance, speed

$$\text{speed} = \frac{\text{distance}}{\text{time}}$$

- Vectors: displacement, velocity, acceleration
  - Velocity is the slope of displacement, or

$$\text{velocity} = \frac{d\text{distance}}{d\text{time}}$$

  - Acceleration is the slope of velocity, or

$$\text{acceleration} = \frac{d\text{velocity}}{d\text{time}}$$

- Special cases:
  - When displacement is flat, velocity is zero
    When displacement is going up, velocity is positive
    When displacement is going down, velocity is negative
  - When velocity is flat, acceleration is zero
    When velocity is going up, acceleration is positive
    When velocity is going down, acceleration is negative
- Note it doesn't matter whether displacement is positive/negative for velocity, and whether velocity is positive/negative for acceleration!
- Always use x and y components when doing these problems!

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Uniformly Accelerated Motion

- The most important equations you will use:

$$x = x_0 + v_{0x}t + \frac{1}{2}a_x t^2, \qquad v_x = v_{0x} + a_x t, \qquad v_x^2 = v_{0x}^2 + 2a_x x$$
$$y = y_0 + v_{0y}t + \frac{1}{2}a_y t^2, \qquad v_y = v_{0y} + a_y t, \qquad v_y^2 = v_{0y}^2 + 2a_y y$$

- Know what each equation relates, then see what you know and what you need
  - Left: x, a_x, t or y, a_y, t
  - Middle: v_x, a_x, t or v_y, a_y, t
  - Right: v_x, a_x, x or v_y, a_y, y
- t ties the x and y components together
- Special formulas:
  - Average velocity when there's constant acceleration:
  $$v_{avg} = \frac{1}{2}(v_{final} + v_{initial})$$
  - Average acceleration:
  $$a = \frac{v_{final} - v_{initial}}{t_{total}}$$
  - Total distance traveled when there's constant acceleration:
  $$x_{total} = t_{total} v_{avg}$$

Reading Graphs

- LOOK AT AXES FIRST (to figure out what you're looking at!)
- Displacement vs. time graph:
  - Slope is velocity
  - Crossing X axis = back to initial location
  - Increasing = moving forward, decreasing = moving backwards
- Velocity vs. time graph:
  - Slope is acceleration
  - Sum of areas under curve (subtracting areas below axis) = displacement
  - Sum of areas under curve (adding areas below axis) = distance
  - Crossing X axis = zero velocity or stationary
  - Increasing = accelerating, decreasing = decelerating

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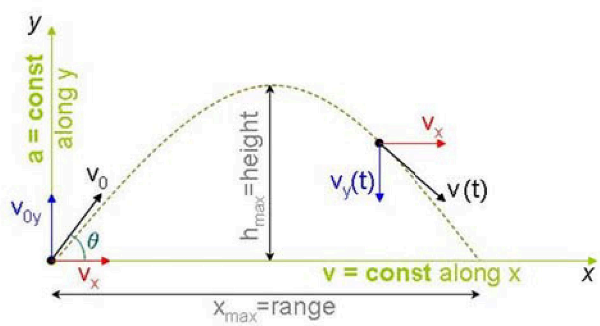
Projectile motion

- Separate motion into vertical and horizontal components
- Most of the time, you only have acceleration in the vertical direction:
$$a_y = -10\ \mathrm{m/s^2} = -g$$
and no acceleration in the horizontal direction:
$$a_x = 0$$
This means initial velocity in the x direction will be maintained through the course of the entire motion

Most basic situation:

- Object being launched at a velocity v_0 and angle θ from the ground, then hits the ground some time/distance later
- Useful to draw a table for important points in the object's flight: (leave stuff you don't know blank)

	Initially	**At peak height**	**At landing**
x	0	$\frac{1}{2}x_{max}$	x_{max}
y	0	y_{max}	0
v_x	$v_0\cos\theta$	$v_0\cos\theta$	$v_0\cos\theta$
v_y	$v_0\sin\theta$	0	$-v_0\sin\theta$
a_x	0	0	0
a_y	-10	-10	-10
t	0	$\frac{1}{2}t_{max}$	t_{max}



- Specific things they can ask: (note $a_y = -g$ below)
  - Total time of flight:
$$y = y_0 + v_{0y}t + \frac{1}{2}a_y t^2 \rightarrow 0 = 0 + v_{0y}t + \frac{1}{2}a_y t^2 \rightarrow t_{max} = \frac{2v_0 y}{g}$$
  - Total distance traveled:
$$x_{max} = v_{0x}t_{max} = \frac{2v_{0x}v_{0y}}{g} = \frac{2v_0^2\sin\theta\cos\theta}{g} = \frac{v_0^2\sin 2\theta}{g}$$
  - Peak height:
$$v_y^2 = v_{0y}^2 + 2a_y y \rightarrow 0 = v_{0y}^2 + 2a_y y \rightarrow y_{max} = \frac{v_{0y}^2}{2g}$$
- One more useful formula: for an object starting at rest in the y direction, after t seconds it will fall $\frac{1}{2}gt^2$
$$y = y_0 + v_{0y}t + \frac{1}{2}a_y t^2 \rightarrow y_0 - y = -\frac{1}{2}a_y t^2 \rightarrow \text{distance fell} = \frac{1}{2}gt^2$$

Air resistance: object is affected more if it has larger surface area or is less streamlined, or if it is traveling at a higher velocity
Terminal velocity: when an object's air resistance equals its weight, causing no acceleration/constant velocity