Unit 1 Handout: Motion, Forces, and Water Rockets

Physics 200, 25-26 (Stapleton)

Name: Key

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Kinematics: The study of motion; specifically, the study of motion without considering its causes.

Scalar: A quantity with magnitude (strength, expressed as a positive number), but not a direction of movement.

Vector: A quantity with magnitude) and direction (indicating *movement* in that direction).

- In diagrams, arrows are used to indicate the directions of vectors. Magnitude can be indicated by the length of the arrow, or arrows can be labeled with numerical magnitudes.
- For calculations, we use signs to indicate vector direction. Usually, signs follow the same conventions as an x/y grid… upward = positive, downward = negative, rightward = positive, leftward = negative. A -3N force could be either a 3N leftward force or a 3N downward force.

Δ = Delta = "change" Formula: Final - initial = If x changes from 3m to 1m, then Δx = 1m - 3m = -2m.

	Symbol	**Meaning** (what it's *supposed* to mean)	**Vector or Scalar?**	**Common Units**	**How "big" is it?**
Position	x or y	An indicator of distance and direction from some chosen point of origin.	S	Meters (m)	1 long step 0.305m ≈ 1foot
Distance	d	How far something has traveled from its original position, disregarding direction.	S	Meters (m)	1 long step 0.305m ≈ 1foot
Displacement	Δx or Δy,	Final position minus original position(e.g. $x-x_0$); "Change in position." Distance in a direction.	✓	Meters (m)	1 long step 0.305m ≈ 1foot
Time	t (or Δt)	?	S	Seconds (s)	1s = "one mississippi"
Speed	v *(even though v is technically velocity)*	How fast something is moving. A ratio of distance to travel time.	S	Meters per second (m/s)	1m/s ≈ 2.24mph ≈ 1 long step per second
Velocity	v	A measure of how fast and in which direction.	✓	Meters per second (m/s)	1m/s ≈ 2.24 mph 4.5m/s = 6min/mile pace
Acceleration	a	How fast something's velocity is changing, and in which direction.	✓	Meters per second squared (m/s^2 or m/s/s)	Acceleration of gravity on Earth's surface ≈ $9.8m/s^2$

Memorize

Unit conversions by dimensional analysis:

This is a method of changing units without changing the value of a measurement. It works because we can multiply any number by 1 without changing the number.

Example: 1m/s = 2.24mph, so $\frac{1m/s}{2.24mph} = 1$ and $\frac{2.24mph}{1m/s} = 1$. This means we can multiply any measurement by either of these fractions, and we won't change the measurement – but we can get units to cancel. If we're trying to convert 35m/s to mph, we can multiply 35m/s x $\frac{2.24mph}{1m/s}$ and get 78.4mph, because the m/s cancel. We can also multiply 35m/s x $\frac{1m/s}{2.24mph}$, but then then nothing cancels and we get a correct answer with crazy units -- $15.625m^2/s^2mph$.

Velocity and Acceleration

Symbols: Initial velocity = V_0 Final velocity = V Average velocity = $\bar{V}$

If I have a **velocity** of 2 m/s, what does that mean?

Every second, 2m is added to my position,

One definition of **Velocity:**

How many meters of position are added or subtracted every second.

Average Velocity Formula #1:

$$\bar{V} = \frac{\Delta x}{\Delta t} \leftarrow \text{displacement}$$

*The units are the formula (m/s)

Average Velocity Formula #2:

$$\bar{V} = \frac{V_0 + V}{2}$$

If I have an **acceleration** of 2m/s^2 (2 m/s/s), what does that mean?

Every second, 2m/s is added to my velocity

One definition of **acceleration:**

How many m/s of velocity are added or subtracted every second.

Acceleration can happen in two fundamentally different ways:

1) Changing speed
2) Changing direction

"Deceleration" usually means slowing down, so it can apply to either positive or negative acceleration.

positive → slowing down, moving rightward

negative → slowing down, moving leftward

Average Acceleration Formula:

$$a = \frac{\Delta V}{\Delta t} \leftarrow \text{change in velocity}$$

*The units are the formula $\left(\frac{\left(\frac{m}{s}\right)}{s}\right)$

Average Speed formula:

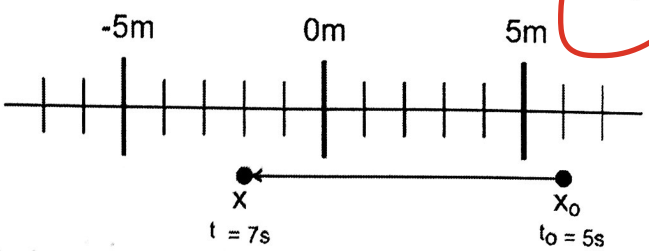
$$\text{speed} = \frac{\text{distance}}{\text{time}}$$

Average vs Instantaneous: when we measure velocity or acceleration, we are measuring average quantities. These are average quantities over some time period. Instantaneous quantities are the velocity or acceleration of an object at a single point in time. For paper/pencil/calculator problems, you will never have to worry about the difference between average and instantaneous acceleration, because accelerations will be constant. Velocities will often change, so it is good to use the average velocity symbol when it applies.

Sign and Direction Conventions: Just as in graphing, in physics upward and rightward are considered to have positive signs, while downward and leftward have negative signs.

$V_0 = 0m/s$

<u>Terminology Practice</u>: Starting from rest (motionlessness), an object leaves its initial position and travels to a new position, undergoing constant acceleration along the way. For each quantity, below, provide the symbol and the value.



Initial Position (X_0) = 6m

Final Position (X) = -2m

Displacement (ΔX) = $X - X_0 = -2m - 6m = \boxed{-8m}$

Distance traveled (d) = $\boxed{8m}$

Change in Time (Δt) = $t - t_0 = 7s - 5s = \boxed{2s}$

Initial Velocity (V_0) = $0m/s$

Average velocity ($\bar{V}$) = $\frac{\Delta X}{\Delta t} = \frac{-8m}{2s} = \boxed{-4m/s}$

Final Velocity (V) = $\boxed{-8m/s}$ ←

$\bar{V} = \frac{V_0 + V}{2} = \frac{0 + V}{2} = -4m/s$

$\Downarrow$

$V = -8m/s$

Average speed ($\bar{v}$) = $\frac{\text{distance}}{\text{time}} = \frac{8m}{2s} = \boxed{4m/s}$

The best we have

Change in Velocity (ΔV) = $V - V_0 = -8m/s - 0m/s = \boxed{-8m/s}$

Acceleration (a) = $\frac{\Delta V}{\Delta t} = \frac{-8m/s}{2s} = \boxed{-4m/s^2}$

Problem-solving with the G.U.E.S.S. method...

- Steps: Identify what is **G**iven. Identify the **U**nknown(s). Identify an **E**quation that helps you find something new with your givens. **S**ubstitute givens into the equation. **S**olve.
- Repeat this process with new equations until you find what you are looking for.
- Other hints:
    - On tricky problems, it can be helpful to list all of the possible variables first. Filling in those blanks is like a crossword puzzle, where each word you find can help you find the next word.
    - On tricky problems, it is also helpful to draw a diagram.

Kinematics Practice with Find Everything problems:

Primary Formulas

$\bar{V} = \frac{\Delta x}{\Delta t}$ ← or Δy Δ = Final - Initial

$\bar{V} = \frac{V_0 + V}{2}$ $a = \frac{\Delta V}{\Delta t}$

Δy V₀

Example . A quadcopter ascends a distance of 30m while undergoing constant acceleration. If its starting velocity was 5m/s, and this ascent lasts 2 seconds, what is the acceleration of the quadcopter?

Δt

v_0 = +5m/s

v = 25m/s

Δv = 20m/s

$\bar{v}$ = 15m/s

a = 10m/s²

Δt = 2s

Δy = +30m

givens

$$\bar{V} = \frac{\Delta Y}{\Delta t} = \frac{30m}{2s} = 15m/s$$

$$\bar{V} = \frac{V_0 + V}{2} \Rightarrow 15m/s = \frac{5m/s + V}{2}$$

$$30m/s = 5m/s + V$$

$$V = 25m/s$$

$$\Delta V = V - V_0 = 25m/s - 5m/s = 20m/s$$

$$a = \frac{\Delta V}{\Delta t} = \frac{20m/s}{2s} = 10m/s^2$$

How far does the nut fall during this time?

V₀ Δt

1. A nut is falling at a rate of -5m/s. Gravity accelerates the nut for 6 additional seconds before hitting the ground. To make the math simpler, use -10 m/s² for the acceleration due to gravity (instead of the actual -9.8m/s²).

a

v_0 = -5m/s

v = -65m/s

Δv = -60m/s

$\bar{v}$ = -35m/s

a = -10 m/s²

Δt = 6s

Δy = -210m

$$a = \frac{\Delta V}{\Delta t} \Rightarrow -10\,m/s^2 = \frac{\Delta V}{6s} \Rightarrow \Delta V = -60m/s$$

$$\Delta V = V - V_0 \Rightarrow -60m/s = V - (-5m/s) \Rightarrow V = -65m/s$$

$$\bar{V} = \frac{V_0 + V}{2} = \frac{-5m/s + -65m/s}{2} = \frac{-70m/s}{2} = -35m/s$$

$$\bar{V} = \frac{\Delta Y}{\Delta t} \Rightarrow -35m/s = \frac{\Delta Y}{6s} \Rightarrow \Delta Y = -210m$$

A bird flies at
flight last
yards

Formulas

4

-Initial

5

$a = 0\,m/s^2$ $\quad x_0 \quad x$

2. A bird flies at a constant speed from the 8 yard line of a football field to the nearest 40 yard line. This flight lasts 8 seconds. Find ~~all of the following~~. *initial velocity. For velocity and acceleration units, use yards/s and yards/s^2.

Δt

$v_0 = 4\,yd/s$

$v = 4\,yd/s$

$\Delta v = 0\,m/s$

$\bar{v} = 4\,yd/s$

$a = \boxed{0\,yd/s^2}$

$\Delta t = \boxed{8\,s}$

$\Delta x = 32\,yd$

$x_0 = \boxed{8\,yd}$

$x = \boxed{40\,yd}$

$$\Delta x = x - x_0 = 40\,yd - 8\,yd = 32\,yd$$

$$a = \frac{\Delta v}{\Delta t} \Rightarrow 0 = \frac{\Delta v}{8\,s} \Rightarrow \Delta v = 0\,m/s$$

$$\bar{v} = \frac{\Delta x}{\Delta t} = \frac{32\,yd}{8\,s} = 4\,yd/s$$

$$\Delta v = v - v_0 \Rightarrow 0 = v - v_0 \Rightarrow v = v_0$$

$$\bar{v} = \frac{v + v_0}{2} = \frac{v + v}{2} \Rightarrow 4\,yd/s = v$$

$$v = v_0 = 4\,yd/s$$

3. A car accelerates from -30mph to -50mph over a time of 4 seconds. Find a~~ll of the following~~ displacement *convert mph to m/s

$v_0 \quad v \quad \Delta t$

$v_0 = \boxed{-13.4\,m/s}$

$v = \boxed{-22.3\,m/s}$

$\Delta v = -8.9\,m/s$

$\bar{v} = -17.9\,m/s$

$a = -2.23\,m/s^2$

$\Delta t = \boxed{4\,s}$

$\Delta x = -71.6\,m$

$$v_0 = -30\,mph\left(\frac{1\,m/s}{2.24\,mph}\right) = -13.4\,m/s$$

$$v = -50\,mph\left(\frac{1\,m/s}{2.24\,mph}\right) = -22.3\,m/s$$

$$\Delta v = v - v_0 = -22.3\,m/s - (-13.4\,m/s) = -8.9\,m/s$$

$$\bar{v} = \frac{v_0 + v}{2} = \frac{-13.4\,m/s + (-22.3\,m/s)}{2} = -17.9\,m/s$$

$$a = \frac{\Delta v}{\Delta t} = \frac{-8.9\,m/s}{4\,s} = -2.23\,m/s^2$$

$$\bar{v} = \frac{\Delta x}{\Delta t} \Rightarrow -17.9\,m/s = \frac{\Delta x}{4\,s} \Rightarrow \Delta x = -71.6\,m$$

$\Delta x = -40m$

moving leftward, so

V_0

$V=0$

4. A child is traveling at a rate of -15m/s along a zip line. After slowing down at a constant rate over a distance of 40m, the child comes to a stop. Find all ~~of the following for this event~~. acceleration

$v_0 = \boxed{-15m/s}$

$v = \boxed{0m/s}$

$\Delta v = 15m/s$

$\bar{v} = -7.5m/s$

$a = 2.81m/s^2$

$\Delta t = 5.33s$

$\Delta x = \boxed{-40m}$

$$\Delta V = V - V_0 = 0 - (-15m/s) = 15m/s$$

$$\bar{V} = \frac{V_0 + V}{2} = \frac{-15m/s + 0m/s}{2} = -7.5m/s$$

$$\bar{V} = \frac{\Delta x}{\Delta t} \Rightarrow -7.5m/s = \frac{-40m/s}{\Delta t} \Rightarrow \Delta t = 5.33s$$

$$a = \frac{\Delta V}{\Delta t} = \frac{15m/s}{5.33s} = \boxed{2.81m/s^2}$$

Δt

5. A driver sees a turtle in the road and hits the brakes. After slowing down for a time of 3 seconds over a displacement of +20m, the driver has reduced his velocity to 4m/s. Find all ~~of the following for this 3 second period~~. acceleration

Δx

V

$v_0 = 9.34m/s$

$v = \boxed{4m/s}$

$\Delta v = -5.34m/s$

$\bar{v} = 6.67m/s$

$a = -1.78m/s^2$

$\Delta t = \boxed{3s}$

$\Delta x = \boxed{+20m}$

$$\bar{V} = \frac{\Delta x}{\Delta t} = \frac{20m}{3s} = 6.67m/s$$

$$\bar{V} = \frac{V_0 + V}{2} \Rightarrow 6.67m/s = \frac{V_0 + 4m/s}{2} \Rightarrow V_0 = 9.34m/s$$

$$\Delta V = V - V_0 = 4m/s - 9.34m/s = -5.34m/s$$

$$a = \frac{\Delta V}{\Delta t} = \frac{-5.34m/s}{3s} = -1.78m/s^2$$

6. You shoot a projectile directly upward. When it leaves your launcher, its velocity is 29.4m/s. From the moment it leaves the launcher, your projectile is accelerated at a rate of -9.8m/s² by gravity *[the negative means that acceleration is directed downward, even though the projectile is going upward]*. When your projectile gets to its highest point, it slows down to zero m/s and then begins to fall. Find all of the following for your projectile's trip from the end of the barrel to its apogee (highest point reached).

a

v_o

$V = 0m/s$

$v_0 = \boxed{29.4m/s}$

$v = \boxed{0m/s}$

$\Delta v = -29.4m/s$

$\bar{v} = 14.7m/s$

$a = \boxed{-9.8m/s^2}$

$\Delta t = 3s$

$\Delta y = 44.1m$

$$\Delta V = V - V_0 = 0 - 29.4m/s = \boxed{-29.4m/s}$$

$$\bar{V} = \frac{V_0 + V}{2} = \frac{29.4m/s + 0}{2} = 14.7m/s$$

$$a = \frac{\Delta V}{\Delta t} \Rightarrow -9.8m/s^2 = \frac{-29.4m/s}{\Delta t}$$

$$\Downarrow$$

$$\Delta t = 3s$$

$$\bar{V} = \frac{\Delta y}{\Delta t} \Rightarrow 14.7m/s = \frac{\Delta y}{3s}$$

$$\Downarrow$$

$$\Delta y = 44.1m$$

7. **Consider the same shot as in the previous problem, but now find all of the following for the projectile's round trip from the launcher barrel, up into the sky, and back down to the launcher barrel.

$v_0 = 29.4m/s$

$v = -29.4m/s$

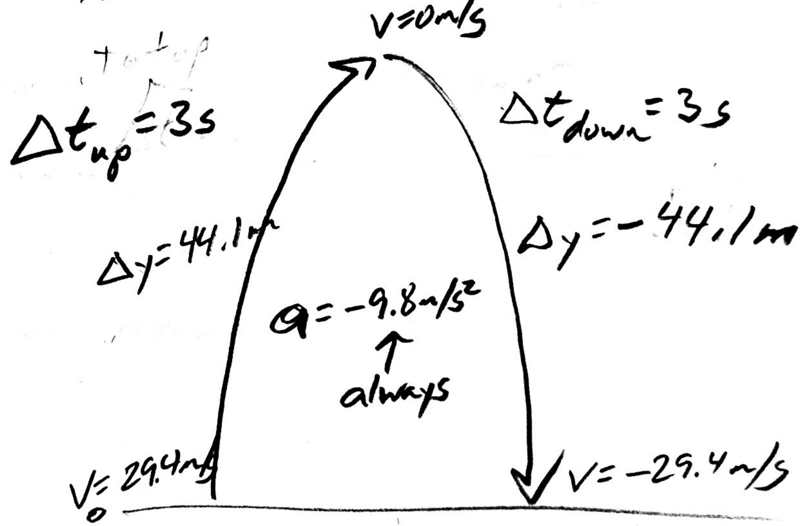
$\Delta v = -58.8m/s$

$\bar{v} = 0m/s$

$a = -9.8m/s$

$\Delta t = 6s$

$\Delta y = 0m$



The trips up and down are the same, but with opposite displacements and velocities

Motion Matching Activity Questions:

On a motion sensor graph of position vs. time…

1. What does a positive (upward) slope tell you about the object's motion?

   The Motion is away from the sensor

2. What does a negative slope indicate?

   Motion toward the sensor

3. What does the steepness of a slope tell you about the object's motion?

   Speed (steeper = faster)

4. What does a constant (straight line) slope indicate?

   Constant speed (no acceleration)

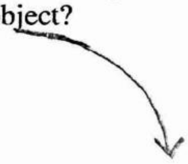
5. What might a smoothly curving line indicate?

   Acceleration (either positive or negative)

6. Sketch a negative slope that is becoming less steep. What does this curve indicate about the motion of an object?

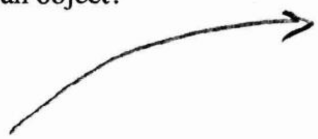
   The object is moving toward the sensor, and it is slowing down

7. Sketch a negative slope that is getting steeper What does this curve indicate about the motion of an object?



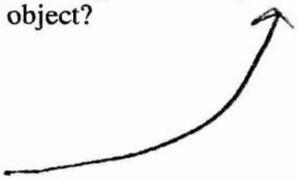
   Moving toward the sensor and Speeding up

8. Sketch a positive slope that is becoming less steep. What does this curve indicate about the motion of an object?



   Moving away, Slowing down

9. Sketch a positive slope that is getting steeper What does this curve indicate about the motion of an object?



   Moving away, speeding up

Relationship between speed and velocity/acceleration:

When an object's speed is increasing its velocity and acceleration have the same sign. When an object's speed is decreasing, its velocity and acceleration have opposite signs.

Motion Graphs:

Each row of graphs below comprises a position vs. time graph, a velocity vs. time graph, and an

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Acceleration Formula Practice Problems:

1. Suppose your velocity is 2m/s. One second later, your velocity is 6m/s. What is your average acceleration over this time period?

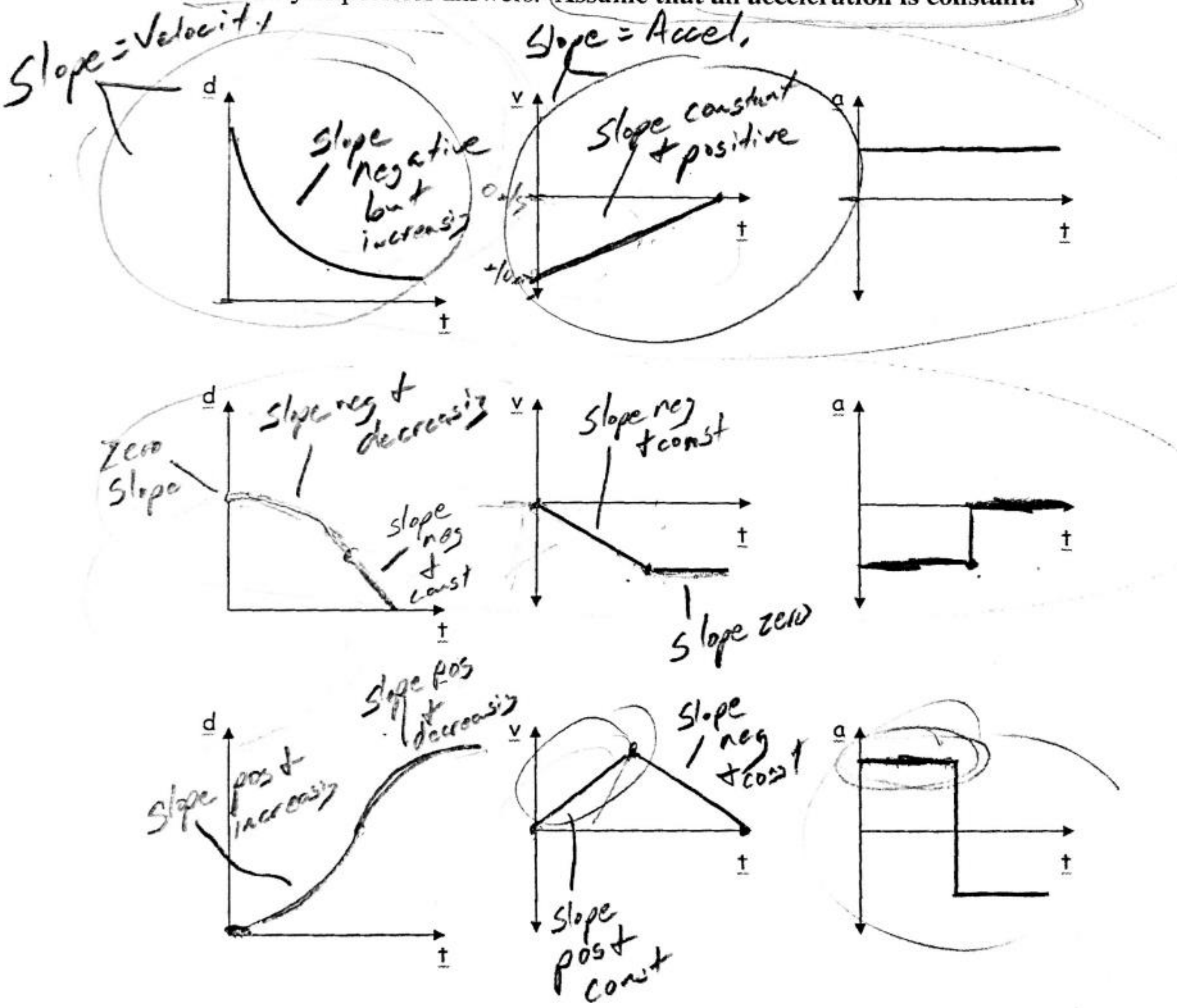
$$\bar{a} = \frac{\Delta V}{\Delta t} = \frac{4 m/s}{1 s} = \boxed{4 m/s^2}$$

2. When your watch reads 8:01:32 AM, your velocity is 6m/s. At 8:01:40 AM (on the same day), your velocity is 2m/s. What is your average acceleration over this time period?

$$\bar{a} = \frac{\Delta V}{\Delta t} = \frac{-4 m/s}{8 s} = -0.5 m/s^2$$

Motion Graphs:

Each row of graphs below comprises a position vs. time graph, a velocity vs. time graph, and an acceleration vs. time graph. Every graph in a row conveys the same motion. For each row, use the one completed graph to fill in the incomplete graphs with reasonable curves. Some rows will have a wider variety of possible answers. **Assume that all acceleration is constant.**



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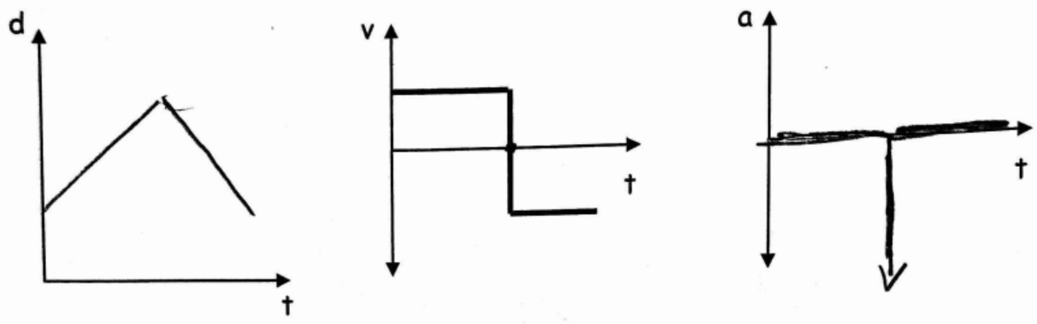
Essex High School
Physics 200

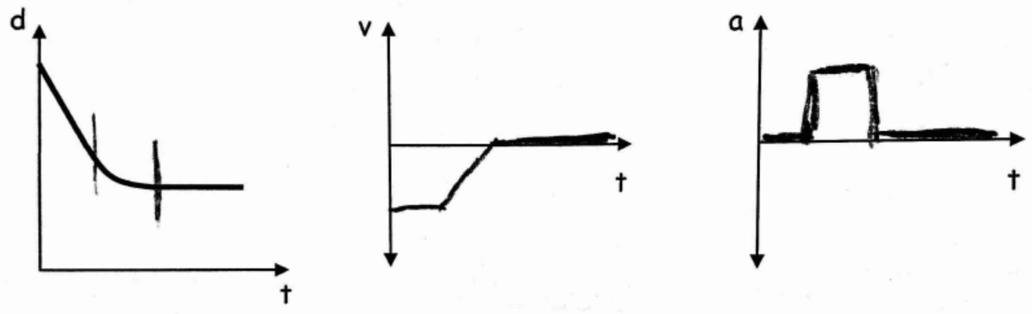
Name Key

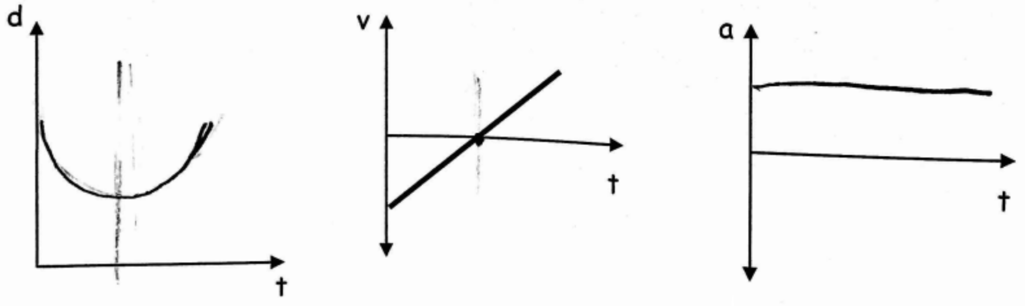
Graph Comparisons

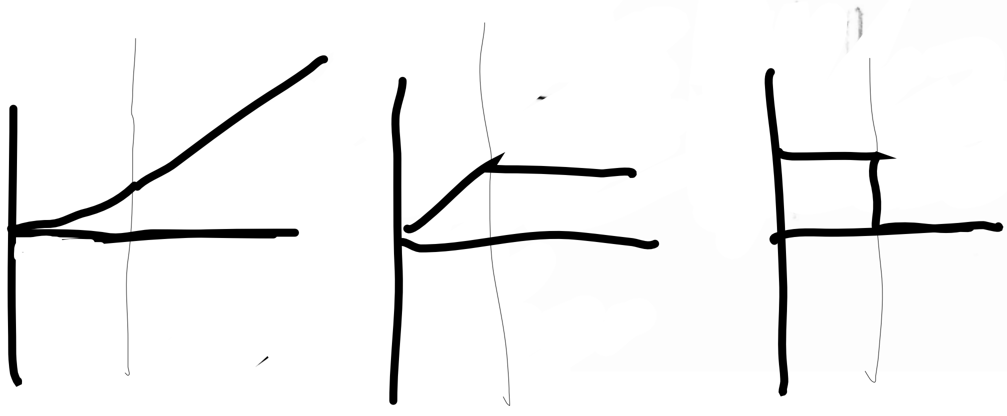
Graph Analysis (20 pts)

Using the information provided in one graph, complete the other 2.









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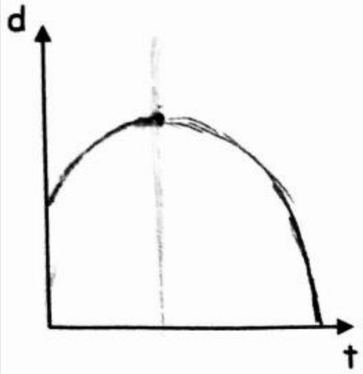

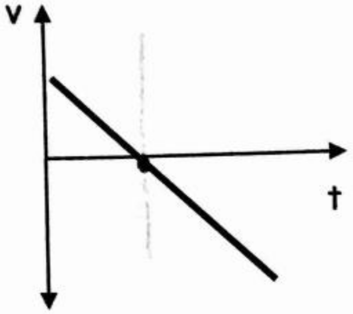

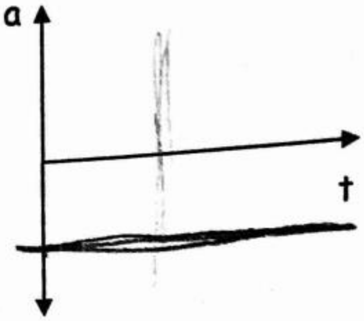

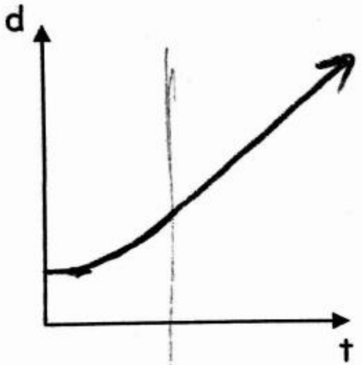

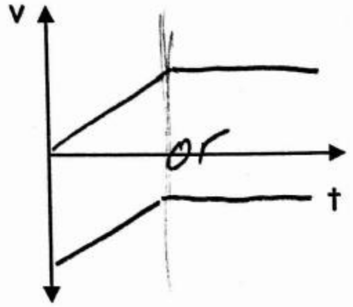

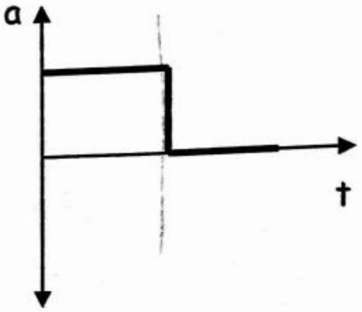

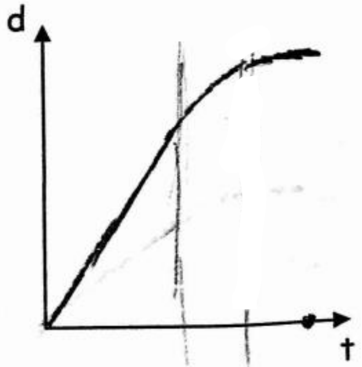

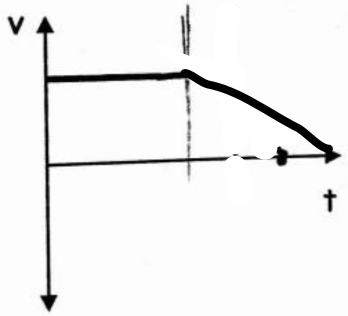

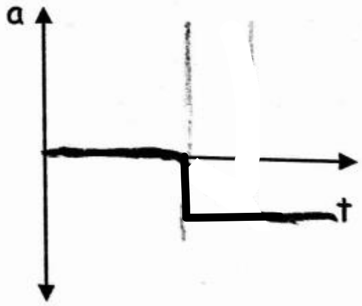

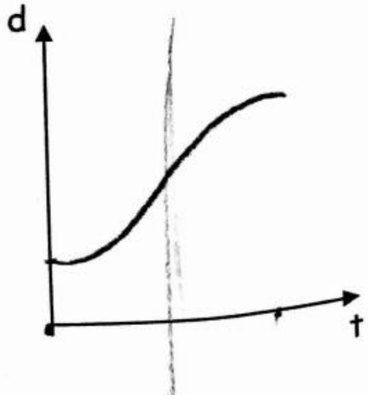

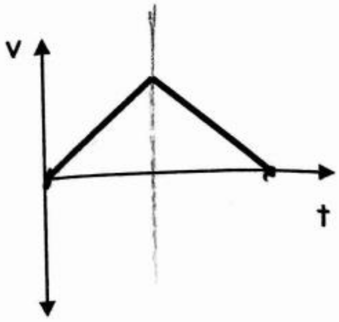

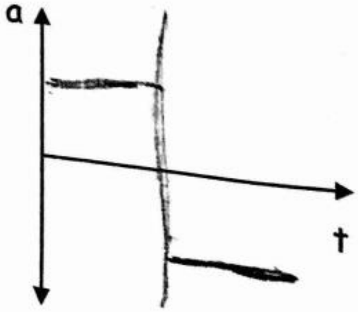

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Forces and Newton's Laws of Motion:

Force: A push or a pull

Force units: Newtons 1N ≈ 0.225 lbs

A banana (or a hamburger patty) weighs about 1N.

Net force (F_{net} or ΣF):

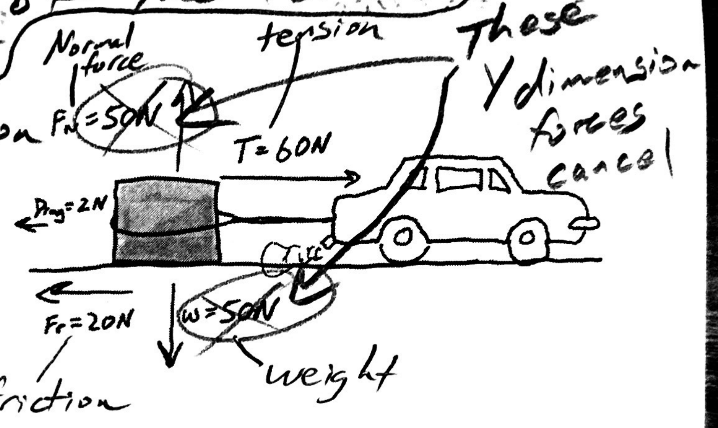
The vector sum of all of the forces acting on an object

Is force a [✓ vector] or scalar?

Forces have direction

What is the net force that is acting on the box in the picture?

38N rightward



Some forces we will be working with:

Weight (w): The force of gravity pulling an object toward a planet

Normal Force (F_N): A force exerted by one surface, pushing perpendicularly outward against another surface

Tension (T): The pulling force along the length of a string, chain, cable, etc. *[For simplicity, we will pretend that these objects are massless, so tension is exactly equal in every part of the rope.]*

Friction (F_R?): A force resisting the sliding of two surfaces across one another.

Drag (F_D): A force resisting the movement of an object through a fluid (e.g. through air, water, or oil)

Newton's 1st Law (usual version): Objects in motion remain in motion in a straight line and at a constant speed, and objects at rest stay at rest unless they are acted upon by an outside (or unbalanced) force.

- Simpler version: Objects do not accelerate unless they experience a net force

If there is no net force acting on an object (i.e. the vector sum of all individual forces on the object is zero), what might that object be doing? What are the options?

-sitting motionless

-Moving at a constant velocity

What are the options for what an object might be doing if there is a net force acting on an object?

-speeding up

-slowing down

-changing direction

Newton's 1st Law is called the "Law of Inertia." Inertia is: resistance to acceleration

What kinds of objects have the most inertia? Massive objects

<u>Newton's 2nd Law:</u> is an equation that actually takes care of the first law, too.. $\Sigma F = ma$

If net force $= 0$, there is no acceleration

One definition of **Mass**:

A measure of an object's inertia.

The unit we will use for Mass in force equations is the Kilogram, which is abbreviated **kg**.

On Earth, a 1kg mass weighs about 9.8 Newtons or about 2.2 pounds. The water in a 1Liter bottle has a mass of 1kg.

2^{nd} Law and Free fall:

- "Free fall" is the state of being acted upon by only the force of gravity (a.k.a. weight).
- Note that, according to this definition, an upward-moving object may be in free fall.
- **g**: the absolute value of free fall acceleration near the Earth's surface *(also the symbol for gravitational field – the ratio of force per unit of mass at a given location)*
- **Free fall acceleration:** -g or -9.8m/s^2

Weight = net force on an object if it were in free fall, so Weight = $ma_{\text{free fall}}$ or $\mathbf{w = mg}$

The sensation of weight comes from forces pushing (like a chair) or pulling our bodies. We can have weight even when we feel weightless, as in free fall. We can also feel weight that isn't there, when a push or pull accelerates us.

Primary strategy for solving force problems:

1. Draw a force diagram showing all of the individual forces acting <u>on the object</u>
2. Write an equation setting Net Force (from Newton's 2^{nd} Law) equal to Net force (from vector addition of individual forces)
3. Solve for whatever is missing

<u>Newton's Third Law of Motion:</u> Forces <u>always</u> occur in pairs of equal and opposite forces.

A single force cannot exist alone in the universe without an equal and opposite force

This is sometimes referred to as action-reaction, but the forces occur simultaneously.

Identify the important Newton's 3^{rd} Law pairs of forces in these situations.

Someone walks to the right: Foot pushes ground leftward, Ground pushes foot rightward

Car brakes as it travels leftward, slowing down: Tires push road leftward. Road pushes tires rightward.

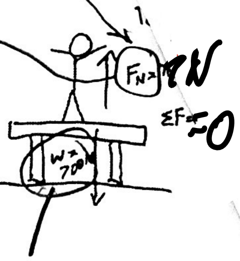
Bird flies upward: Wings push air downward. Air pushes wings upward.

A rocket accelerates in the vacuum of space: Rocket pushes exhaust backward. Exhaust pushes rocket forward.

make space *

3rd Law partner is F_N of person pushing table

Normal forces



3rd Law Peril: A person with a weight of 700N stands motionless on a table. The table exerts a 700N normal force against the person.

No! — Are these two forces a Newton's 3rd Law pair (if not, what are their 3rd law partners)?

What test can we conduct to see if they are a 3rd Law pair?

Lift the table and show that the Normal force and the person's weight can be unequal.

• Or have the person jump, increasing F_N

Partner, F_N is Person's gravity pulling Earth up

Example Force Problems

Example 1. A 1,200kg car is being acted upon by two forces. The car's motor is providing a 1,000N rightward force, and friction is providing a 300N leftward force. What is the car's acceleration?

Vector sum of forces → $\Sigma F = 1{,}000N - 300N = 700N$

Newton's 2nd Law → $\Sigma F = 1{,}200kg\,(a)$

$700N = 1200kg\,(a)$

$\boxed{a = 0.583\,m/s^2}$

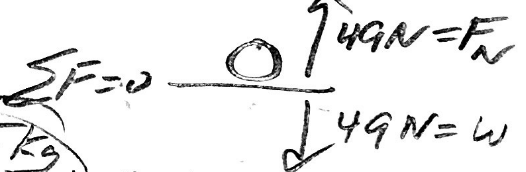
Example 2. A bowling ball is sitting motionless on the ground. The ground is exerting an upward normal force (F_N) of 49N on the bowling ball. What is the bowling ball's mass?

$\Sigma F = ma = m0 = 0\,m/s^2$

So there has to be another downward force … weight!

$W = mg$

$49N = m(9.8m/s^2) \Rightarrow \boxed{m = 5kg}$



Example 3. A 50kg person is climbing down a rope. They are accelerating downward at a rate of $1.5m/s^2$.

a. What is the person's weight, in Newtons? $\boxed{490N}$

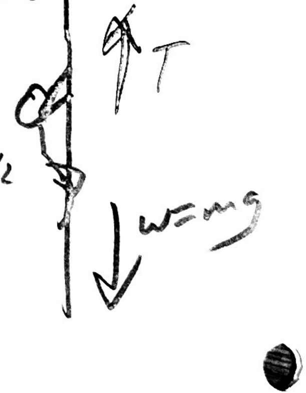
b. What is the tension in the rope? $\boxed{415N}$

$W = mg$

$W = 50kg(9.8m/s^2)$

$\boxed{W = 490N}$

$a = -1.5m/s^2$



$\Sigma F = T - mg$

$\Sigma F = ma$ → $T - mg = ma$

$T = mg + ma$

$T = m(g + a)$

$T = 50kg(9.8m/s^2 + (-1.5m/s^2))$

$\boxed{T = 415N}$

15

Problems

1. $\boxed{\Sigma F = ma}$ $\Sigma F = 60kg(1.25m/s^2)$

$\boxed{\Sigma F = 75N}$

2. $\boxed{\Sigma F = ma}$ $265N = m(2.3m/s^2)$

$\boxed{m = 115kg}$

3. a) $w = mg_{Earth} = 76kg(9.8m/s^2) = \boxed{745N}$

b) $w = mg_{moon} = 76kg(1.7m/s^2) = \boxed{129N}$

c) $w = mg_{mars} = 76kg(3.7m/s^2) = \boxed{281N}$

d) $w = mg_{\text{outerspace with constant velocity}} = 76kg(0m/s^2) = \boxed{0N}$

Example 3. A 50kg person is climbing down a rope. They are accelerating downward at a rate of 1.5m/s².

a. What is the person's weight, in Newtons?
b. What is the tension in the rope?

Practice Problems

1. What force is needed to accelerate a child on a sled (total mass = 60.0 kg) at $1.25\ \mathrm{m/s^2}$?

2. A net force of 265 N accelerates a bike and rider at $2.30\ \mathrm{m/s^2}$. What is the mass of the bike and rider together?

3. What is the weight of a 76-kg astronaut (*a*) on Earth, (*b*) on the Moon $\left(g = 1.7\ \mathrm{m/s^2}\right)$, (*c*) on Mars $\left(g = 3.7\ \mathrm{m/s^2}\right)$, (*d*) in outer space traveling with constant velocity?

4. What average force is required to stop an 1100-kg car in 8.0 s if the car is traveling at 95 mph?

$$95\cancel{mph}\left(\frac{1 m/s}{2.24\cancel{mph}}\right) = 42.4 m/s$$

$$\Delta V = V - V_0 = 0 - 42.4 m/s$$

$$\Delta V = -42.4 m/s$$

$$\boxed{a = \frac{\Delta V}{\Delta t}} = \frac{-42.4 m/s}{8s} = -5.3 m/s$$

$$\boxed{\Sigma F = ma} = 11{,}000 kg(-5.3 m/s) = \boxed{-5830N}$$

m V_0 $V=0$

5. A 0.140-kg baseball traveling 35.0 m/s strikes the catcher's mitt, which, in bringing the ball to rest, recoils backward 11.0 cm. What was the average force applied by the ball on the glove?

$\Delta x = 0.11 m$

$\boxed{\Delta V = V - V_0} = 0 m/s - 35 m/s = -35 m/s$

$\boxed{\bar{V} = \frac{V_0 + V}{2}} = \frac{35 m/s + 0 m/s}{2} = 17.5 m/s$

$\boxed{\bar{V} = \frac{\Delta x}{\Delta t}} \Rightarrow 17.5 m/s = \frac{0.11 m}{\Delta t} \Rightarrow \Delta t = 0.00626 s$

$\boxed{a = \frac{\Delta V}{\Delta t}} = \frac{-35 m/s}{0.00626 s} = -5{,}568 m/s^2$

$\boxed{\Sigma F = ma}$

$\Sigma F = 0.14 kg (-5{,}568 m/s^2)$

$= -780 N$

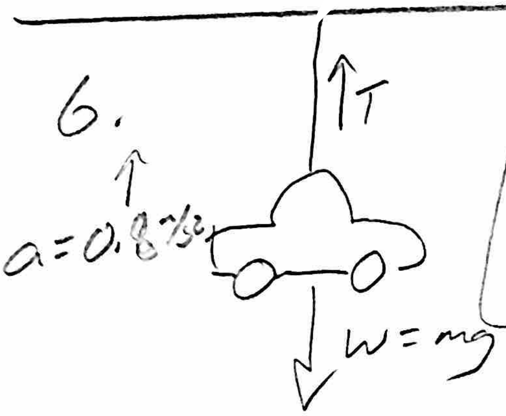
Force applied to ball.

Force applied to glove = +780N

6. How much tension must a rope withstand if it is used to accelerate a 1200-kg car vertically upward at $0.80 m/s^2$?

16

6.



$$\boxed{\begin{array}{l}\Sigma F = ma \\ \Sigma F = T - mg\end{array}} \Rightarrow ma = T - mg$$

$$ma + mg = T$$

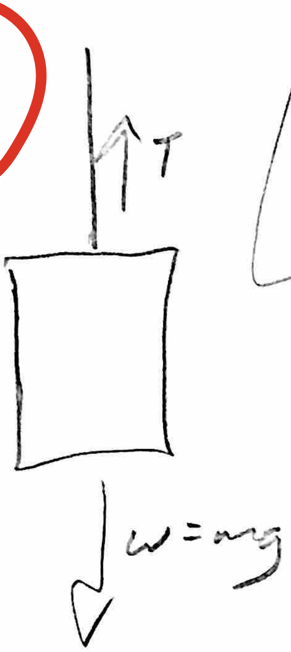
$$m(a+g) = T$$

$$1200kg(0.8m/s^2 + 9.8m/s^2) = T$$

$$\boxed{T = 12{,}720N}$$

7. The elevator can accelerate up or down

16



$$\boxed{\begin{aligned} \Sigma F &= ma \\ \Sigma F &= T - mg \end{aligned}}$$

$$0.068g = 0.068(9.8 m/s^2) = 0.67 m/s^2$$

$$\Downarrow$$

$$ma = T - mg$$

$$ma + mg = T$$

$$\boxed{m(a+g) = T}$$

When the elevator is going up...

$$a = +0.67 m/s^2 ..$$

$$T = 4850 kg (0.67 m/s^2 + 9.8 m/s^2)$$

Max force

$$\boxed{T = 50,800 N}$$

When the elevator is descending...

$$a = -0.67 m/s^2$$

$$T = 4850 kg (-0.67 m/s^2 + 9.8 m/s^2)$$

Min force

$$\boxed{T = 44,280 N}$$

8.

⑯

$$\boxed{\begin{array}{l}\Sigma F = ma \\ \Sigma F = T - mg\end{array}}$$

$$\Downarrow$$

$T - mg = ma$

$T = mg + ma$

$T = m(g + a)$

max tension is 568N

m: 75kg

g: 9.8m/s2

$$\Downarrow$$

$568N = 75kg(9.8m/s^2 + a)$

$\boxed{a = -2.23 m/s^2}$

"Supporting a mass of 58kg" means supporting a weight of:

$W = mg = 58kg(9.8m/s^2)$

$\boxed{= 568N}$

If the thief can manage to accelerate downward at a rate of $-2.23 m/s^2$, then the force on the rope will only be 568N. One way to do this is to grip the rope lightly and slide down.

Unit 1 Practice Test
Physics 200 (25-26)

Name: Key

Multiple Choice, Matching, and Short Answer

1. Circle **all** of the quantities that are vectors
Position [✓ Displacement] Distance [✓ Force] Speed [✓ Velocity] [✓ Acceleration]

2. This tells us whether velocity increases or decreases during each second~~, and~~ by how much.
Position Displacement Velocity Speed [✓ Acceleration]

3. This tells us how fast something is moving, but it does not tell us the direction of movement.
Position Displacement Velocity [✓ Speed] Acceleration

4. This tells us how far something has moved, and in which direction.
Position [✓ Displacement] Velocity Speed Acceleration

#5-9 Answer Choices: A. Weight B. Normal Force C. Friction ~~D. Drag~~ E. Tension

☆ 5. A ~~Air resistance~~ Force exerted by gravity

6. D Resistance acting on an object moving through a fluid

7. C Resistance between two surfaces sliding across one another

8. E The pulling force ~~in~~ exerted along the entire length a rope, cable, or chain

9. B A force exerted perpendicularly outward by a surface

Fill in the blanks...

10. 1 foot = 0.305 meters

11. 1 m/s = 2.24 mph

12. 1N = 0.225 pounds

13. 1kg = 2.2 pounds

14. Which choice describes the person who is closest to actually being weightless?
a. An astronaut orbiting in the Earth in the ISS
b. A child falling at nearly 9.8m/s^2 while riding a "free-fall" ride at the fair
c. A circus performer flying through the air, at the very top of their arc
[✓ d.] A space traveler accelerating at 6g (58.8m/s^2) beyond the edge of our solar system
e. The driver of a dragster, accelerating from 0-60mph in 0.4 seconds

15. Describe what something could be doing if it has positive acceleration and negative velocity.

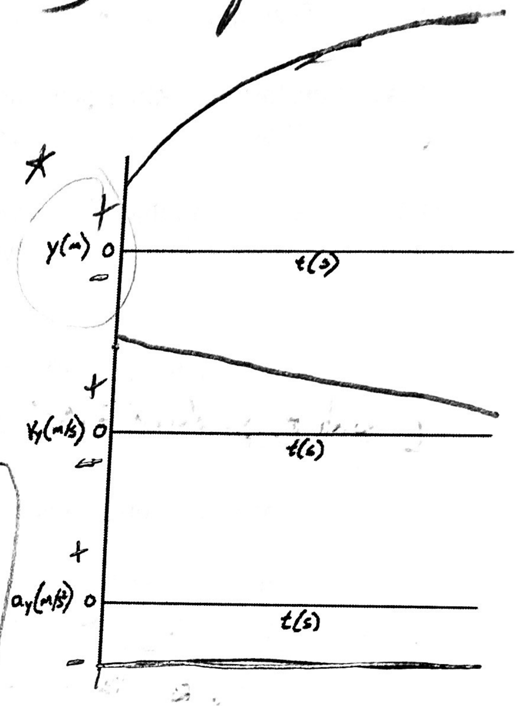
Moving leftward, slowing down

16. Describe what something could be doing if it has positive acceleration and zero velocity.

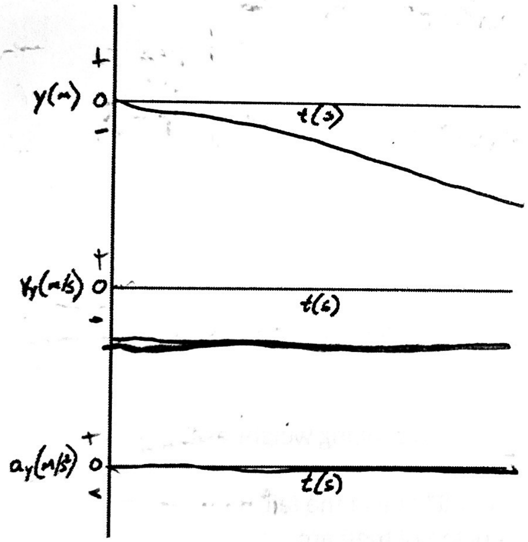
Not moving, but starting to speed up to the right.

17. Draw sets of position, velocity, and acceleration graphs for the situations described below. To keep things simple, assume that accelerations are constant.

a. The rocket is traveling upward and slowing down. [Use the graphs to the right.]

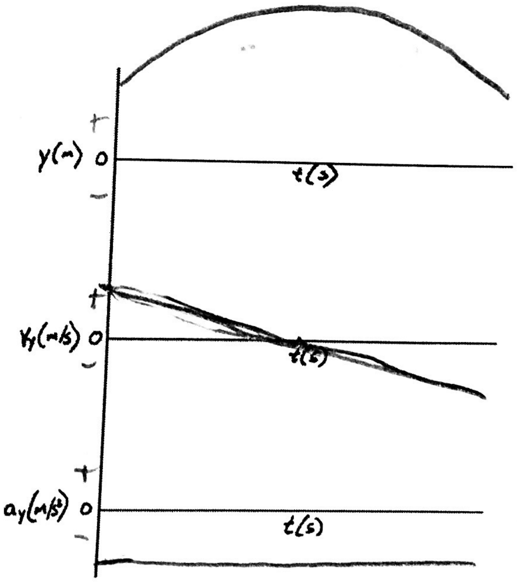


b. The rocket is falling at a constant velocity. [Use the graphs below.]



c. For this set of graphs, show the moments just before, during, and after it has reached its apogee (highest point). [Use the graphs to the right.]

* You can ignore air resistance here



18. According to Newton's 1st law, objects in motion sometimes "remain in motion in a straight line and at a constant speed."

a. When do water rockets do this?

When they're falling at terminal velocity

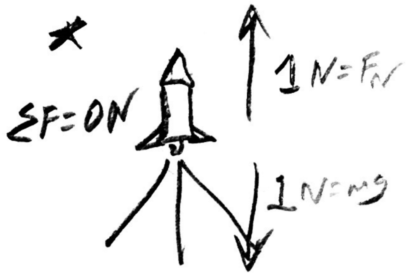
b. Why do they only do it then?

Their net force = 0N, because all forces (drag and weight) are balanced.

19. A rocket sits on its launcher, ready to launch. The rocket's weight pulls it down toward the launcher. The launcher's surface pushes up on the rocket with the same force.

a. How could you prove that these forces are not 3rd law pair?

Grab the launcher and lift it.



b. Explain how that constitutes proof?

The lifting of the rocket shows that the normal force can be stronger than the weight. If they're not equal, they can't be a 3rd Law pair

20. Describe one 3rd law pair of forces that is involved when a rocket is falling downward from the sky. Give the direction of each force, and tell what it acts on.

Drag: Air pushing rocket up; rocket pushing air down

Gravity: Earth pulling rocket down; Rocket pulling Earth up

25

Problems:

Δt

1. A rocket takes 3 seconds to reach its apogee after launching. If the y displacement is 60m, what is the rocket's average velocity during these 3 seconds?

$\bar{V}=?$ $\qquad$ Δy

$$\boxed{\bar{V}=\frac{\Delta y}{\Delta t}} \quad \bar{V}=\frac{60m}{3s}=\boxed{20 m/s}$$

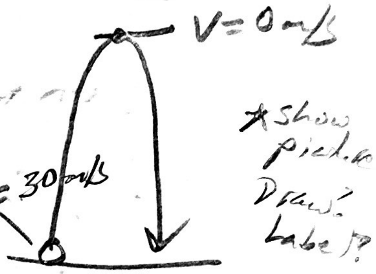
2. A ball is launched directly upward, in the absence of air resistance (so its acceleration is -9.8m/s²), with an initial velocity of 30m/s. $\bar{V}=30 m/s$

a

a. How long does it take the ball to reach its highest point?

$$\boxed{\Delta V = V-V_0} = 0-30m/s = -30m/s$$

$$\boxed{a=\frac{\Delta V}{\Delta t}} \Rightarrow -9.8m/s^2=\frac{-30m/s}{\Delta t} \Rightarrow \boxed{\Delta t = 3.06s}$$



*Show picture Draw? Label?

* b. What ~~is the ball's overall displacement for the entire round trip?~~ distance does the ball travel to its highest point?

$$\boxed{\bar{V}=\frac{V+V_0}{2}} = \frac{30m/s+0}{2} = 15 m/s$$

$$\boxed{\bar{V}=\frac{\Delta y}{\Delta t}} \Rightarrow 15m/s=\frac{\Delta y}{3.06s} \Rightarrow \boxed{\Delta y = 45.9 m}$$

* c. What is the overall ~~distance~~ displacement traveled by the ball during the entire round trip?

$$\boxed{\Delta y = 0m} \quad \text{Starts at } y=0, \text{ Ends at } y=0 \quad \boxed{\Delta y = y-y_0} = 0-0=0$$

d. What is the ball's average velocity for the entire trip?

$$\boxed{\bar{V}=\frac{\Delta y}{\Delta t}} = \frac{0}{3.06s} = \boxed{0 m/s}$$

e. What is the ball's average speed for the entire trip?

trip up $\qquad$ trip down

$$\boxed{\text{speed}=\frac{\text{distance}}{\text{time}}} = \frac{45.9m+45.9m}{3.06s+3.06s} = \boxed{15 m/s}$$

Trip up $\qquad$ trip down

26

3. A 20kg **rock** is hanging from a rope. If the tension in the rope is 120N, what is the acceleration of the rock?

Magnitude of acceleration: 3.8 m/s² Direction of Acceleration: down

$$\boxed{\begin{aligned}\Sigma F &= ma\\ \Sigma F &= T - mg\end{aligned}} \Rightarrow ma = T - mg$$

$$20kg(a) = 120N - 20kg(9.8m/s^2)$$

$$20kg(a) = -76N$$

$$\boxed{a = -3.8m/s^2}$$

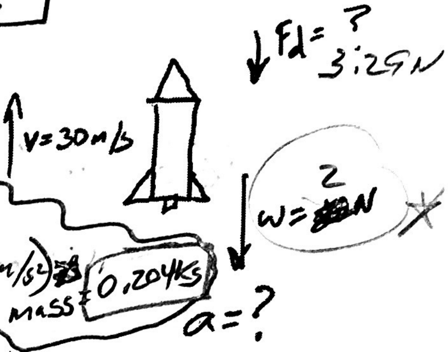
4. Consider the diagram on the right and the following information:

- The rocket's cross-sectional area is 0.01m²
- The density of the surrounding air is 1.22kg/m³
- ~~The rocket's drag coefficient is 0.3.~~
- The rocket's velocity and weight are shown in the diagram.

a. $\boxed{W = mg}$

$$2N = m(9.8m/s^2)$$

$$\text{MASS} = \boxed{0.204kg}$$



b. Find the force of drag acting on the rocket.

$$\boxed{Drag = 0.5 A \rho C_d V^2}$$

$$= 0.5(0.01m^2)1.22kg/m^3(0.3)(30m/s)^2 = \boxed{3.29N}$$

c. Calculate the rocket's acceleration.

$$\boxed{\begin{aligned}\Sigma F &= -Drag - Weight\\ \Sigma F &= ma\end{aligned}}$$

$$0.2kg(a) = -3.29N - 2N$$

$$\boxed{a = -26.5m/s^2}$$

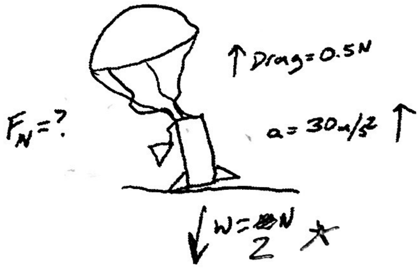
d. Assuming that this rocket has no parachute, what would its terminal velocity be if it fell from a very high elevation?

$$\boxed{@TV, \quad mg = 0.5 A_\rho C_d V^2} \Rightarrow 2N = 0.5(0.01m^2)(1.22kg/m^3)(0.3)V^2$$

$$\boxed{V = 33.1m/s}$$

5. The same rocket has just made contact with the ground, but it has not stopped moving downward. Find the normal force exerted on the rocket by the ground.

F_N = 7.62N



$$\boxed{\begin{aligned}\Sigma F &= ma\\ \Sigma F &= Drag + F_N - W\end{aligned}}$$

$$0.204kg(30m/s^2) = 0.5N - 2N + F_N$$

$$F_N = 7.62N$$

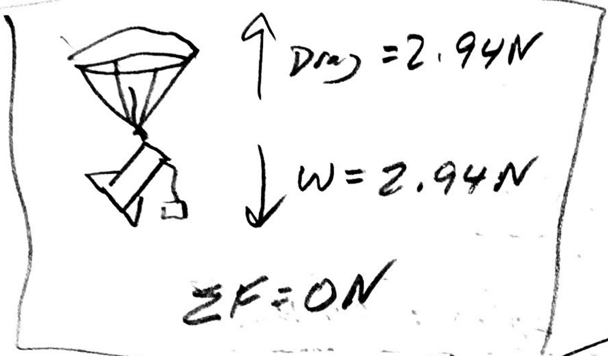
★ 0.3

Consider the flight of a water rocket that has **~~0.2~~kg of dry mass**. Before the launch, **0.5kg** of water is added to the rocket. All of this water comes out during the thrust phase. The rocket has a parachute, which deploys halfway through its descent. The rocket reaches terminal velocity before it lands.

★ Moments during the launch are described in terms of the rocket's velocity and acceleration at those points. First, mentally identify each moment. Then draw a diagram of the individual forces and net force acting on the rocket. Use arrows to show the directions of the forces. Label each force with its correct name and its magnitude.

$m = 0.3kg$ • Rocket is falling at terminal velocity

6. Negative velocity (-4m/s) and zero acceleration

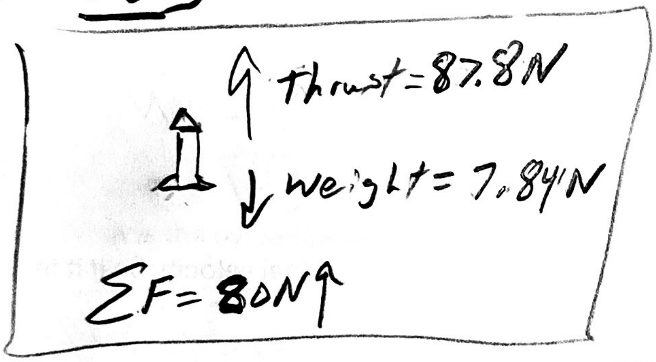


$W = 0.3kg(9.8m/s^2) = 2.94N$

• Rocket is just starting to launch

★ 7. 0 velocity and positive (+100 ~~10~~m/s²) acceleration

$m = 0.8kg$



$W = 0.8kg(9.8m/s^2) = 7.84N$

$\Sigma F = ma = 0.8kg(100m/s^2) = 80N$

$\Sigma F = Thrust - weight$

$80N = Thrust - 7.84N$

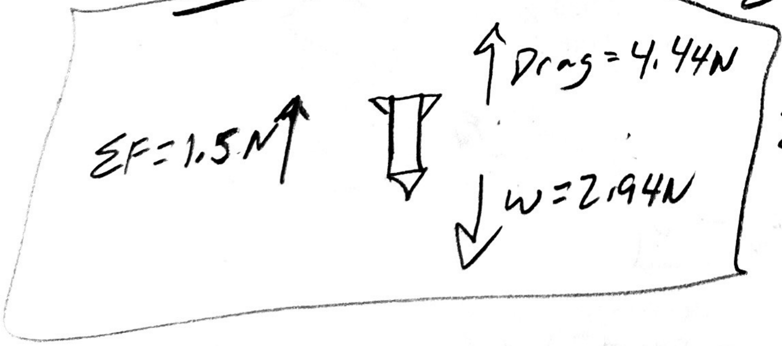
$Thrust = \boxed{87.8N}$

• Rocket is falling, before parachute deployment.

8. Negative velocity (-15m/s) and positive acceleration (+5m/s²)

$m = 0.3kg$

$\Sigma F = ma = 0.3kg(5m/s^2) = \boxed{1.5N}$

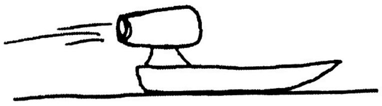


$\Sigma F = Drag - W$

$1.5N = Drag - 2.94$

$Drag = 4.44$

9. A rocket sled and its driver (total mass = 2,000kg) accelerate horizontally from 0mph to 60mph in 4.4 seconds.



a. Convert 60mph to m/s.

$$60mph\left(\frac{1\ m/s}{2.24mph}\right) = 26.8\ m/s$$

b. What is the sled's average acceleration?

$$\boxed{a = \frac{\Delta V}{\Delta t}}$$

$$\boxed{\Delta V = V - V_0} = 26.8m/s - 0m/s = 26.8m/s$$

$$a = \frac{26.8m/s}{4.4s} = \boxed{6.1\ m/s^2}$$

c. How far does the sled travel during this time?

$$\boxed{\bar{V} = \frac{\Delta X}{\Delta t}}$$

$$\boxed{\bar{V} = \frac{V + V_0}{2}}$$

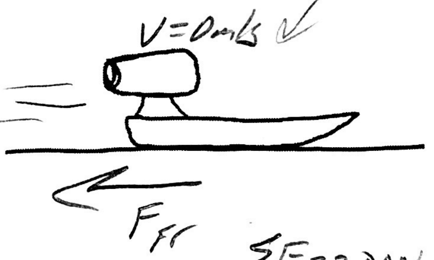
$$\bar{V} = \frac{0 + 26.8m/s}{2} = 13.4m/s$$

$$13.4m/s = \frac{\Delta X}{4.4m/s} \Rightarrow \boxed{\Delta X = 59.0m}$$

✗ d. ~~What is the sled's weight?~~

10. When the rocket sled's rocket engine is turned off, there is no more thrust. At this point, friction slows the sled down, bringing it to a stop in a time of 7 seconds.

\# better pic



$V = 0m/s$ a. What force of friction is acting on the sled as it slows down?

More +space

$$\boxed{\begin{aligned}\Sigma F &= F_{fr}\\ \Sigma F &= ma\end{aligned}}$$

$$\Delta V = V - V_0 = 0 - 26.8m/s = -26.8m/s$$

$$a = \frac{\Delta V}{\Delta t} = \frac{-26.8m/s}{7s} = -3.83m/s^2$$

$$\Sigma F = 2000kg(-3.83m/s^2)$$

$$\boxed{\Sigma F = -7660N}$$

$$\Sigma F = F_{fr} = ?$$

$$\boxed{-7660N}$$

11. b. If we assume that this force of friction was the same when the sled was speeding up and slowing down, what was the magnitude of the rocket sled's thrust?

$$\boxed{\begin{aligned}\Sigma F &= ma\\ \Sigma F &= Thrust - F_{fr}\end{aligned}}$$

$$2000kg(6.1m/s^2) = Thrust - 7660N$$

$$\boxed{Thrust = 19,860N}$$