Physics – Lecture 1

Dundas Valley Highschool Co-Op

Physics

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0. Who am I?

- My name is Brydon Eastman
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1. Introduction – What is Physics?

- Physics is the most fundamental science
- Has its origins in philosophy
- Math applied to the real world
- Full of assumptions and inaccuracies

1. Introduction – What is Physics?

1. Introduction – What is Physics? (cont'd)

- The study of physics can be divided into six main areas
  - Classical Mechanics
  - Relativity
  - Thermodynamics
  - Electromagnetism
  - Optics
  - Quantum Mechanics

1. Introduction – This Course

- We will mainly be focused on classical mechanics
  - Kinematics (1-Dimensional and 2-Dimensional)
  - Forces (Newton's Laws)
  - Energy (Potential, Kinetic, Thermal, Power)
  - Waves and Sound (Time allowing)

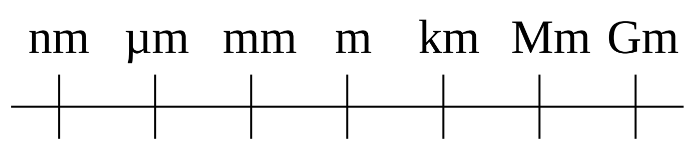
2. Setting Up - Units

- Physics is very dependent on units
  - Length (meters)
  - Mass (grams)
  - Time (seconds)
  - Temperature (Kelvin)

- Making sense of physics is a lot easier when you think about units!

2. Setting Up – Unit Prefixes

- Sometimes we use *prefixes* when talking about units
  - Eg: 1 km = 1000 meters
  - 1000 mL = 1 L
- There's a general scale we use



  - There are 1000 nm (nano-meters) in 1 µm (micro-meter)
  - There are 1000 µm (micro-meters) in 1 mm (milli-meter)
  - There are 1000 mm (milli-meters) in 1 m (meter)
  - There are 1000 m (meters) in 1 km (kilo-meter)
  - There are 1000 km (kilo-meters) in 1 Mm (mega-meter)
  - There are 1000 Mm (mega-meters) in 1 Gm (giga-meter)

2. Setting Up – Unit Switching

- Sometimes we need to switch between units
  - Example: Switching between units of length.
  - Jeph walked 3.5 miles, how many kilometers did he walk given 1 mile = 1.609 km?
    - 3.5 ~~miles~~ $\times \frac{1.609 \text{ km}}{1 \cancel{\text{ mile}}} = 5.6315 \text{ km}$
  - Sometimes we need to switch many units at once.
  - Sarah drove at a speed of 35 miles per hour, what is her speed in meters per second?
    - $\frac{35 \text{ miles}}{1 \text{ hour}} \times \frac{1.609 \text{ km}}{1 \text{ mile}} = 56.315 \, {}^{\text{km}}/_{\text{hour}}$ Step 1. ${}^{\text{miles}}/_{\text{hour}} \rightarrow {}^{\text{km}}/_{\text{hour}}$
    - $\frac{56.315 \text{ km}}{1 \text{ hour}} \times \frac{1000 \text{ m}}{1 \text{ km}} = 56315 \, {}^{\text{m}}/_{\text{hour}}$ Step 2. ${}^{\text{km}}/_{\text{hour}} \rightarrow {}^{\text{m}}/_{\text{hour}}$
    - $\frac{56315 \text{ m}}{1 \text{ hour}} \times \frac{1 \text{ hour}}{60 \text{ min}} = 938.533 \, {}^{\text{m}}/_{\text{min}}$ Step 3. ${}^{\text{m}}/_{\text{hour}} \rightarrow {}^{\text{m}}/_{\text{min}}$
    - $\frac{938.533 \text{ m}}{1 \text{ min}} \times \frac{1 \text{ min}}{60 \text{ s}} = 15.643 \, {}^{\text{m}}/_{\text{s}}$ Step 4. ${}^{\text{m}}/_{\text{min}} \rightarrow {}^{\text{m}}/_{\text{s}}$

2. Setting Up – Significant Figures

- Physics is always an approximation – we can't measure perfectly
- Our results are only as good as our worst data!
- So we count “significant figures” to see how “good” data is

2. Setting Up – Significant Figures (cont'd)

- Trailing zeroes after the decimal count
  - 1.00 is 3 significant digits, 1.0 is 2 significant digits
- Trailing zeroes before the decimal *sometimes* count
  - 1000 is 1 signficant digit, 1200 is 2 signficant digits, 10.0 is 3 significant digits
- Leading zeroes don't
  - 023.4 is 3 significant digits

2. Setting Up – Significant Figures (example_

How many significant figures do the following numbers have?

- 1.98
  - 3 significant figures
- 23000
  - 2 significant figures
- 2.3000
  - 5 significant figures
- 2003
  - 4 significant figures
- 2003.0
  - 5 significant figures

2. Setting Up – Significant Figures Example

- When we're done we have to make sure we represent our result with the correct amount of significant figures.
- Always present your answer with as many significant figures as your *worst* piece of data!
- Example:
  - A man walks 3.98 km in 1.7 hours. What was his average speed?
    - Average speed $= \frac{\text{distance}}{\text{time}}$
    - $= \frac{3.98\ \text{km}}{1.7\ \text{hours}}$
    - $= 2.341176470588235$ km/h
    - $= 2.3$ km/h

Questions?

3. One Dimensional Motion

- Everything in our universe is in motion

- What is motion?
  - Motion is a change in distance in a certain amount of time

- What are the units of motion?
  - $\frac{\text{length}}{\text{time}}$ Example: $\frac{\text{km}}{\text{hr}}$ or $\frac{\text{m}}{\text{s}}$

Figure 1 shows the motion of a car along a straight road. The images are taken at time intervals of 1.0 s. Describe the motion of the car using your vocabulary of motion.

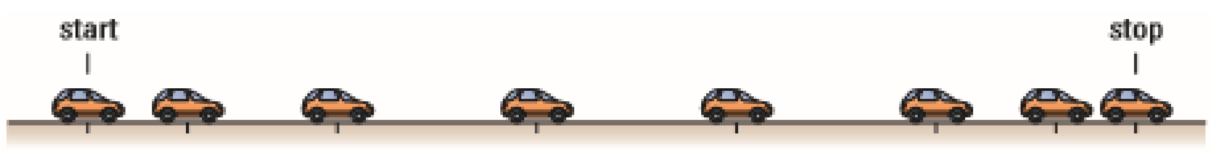


Figure 1

3. One Dimensional Motion - Speed

- Speeds we encounter in our lives are usually given in $\frac{\mathrm{km}}{\mathrm{hr}}$ or $\frac{\mathrm{m}}{\mathrm{s}}$
  - These are examples of *scalar* quantities

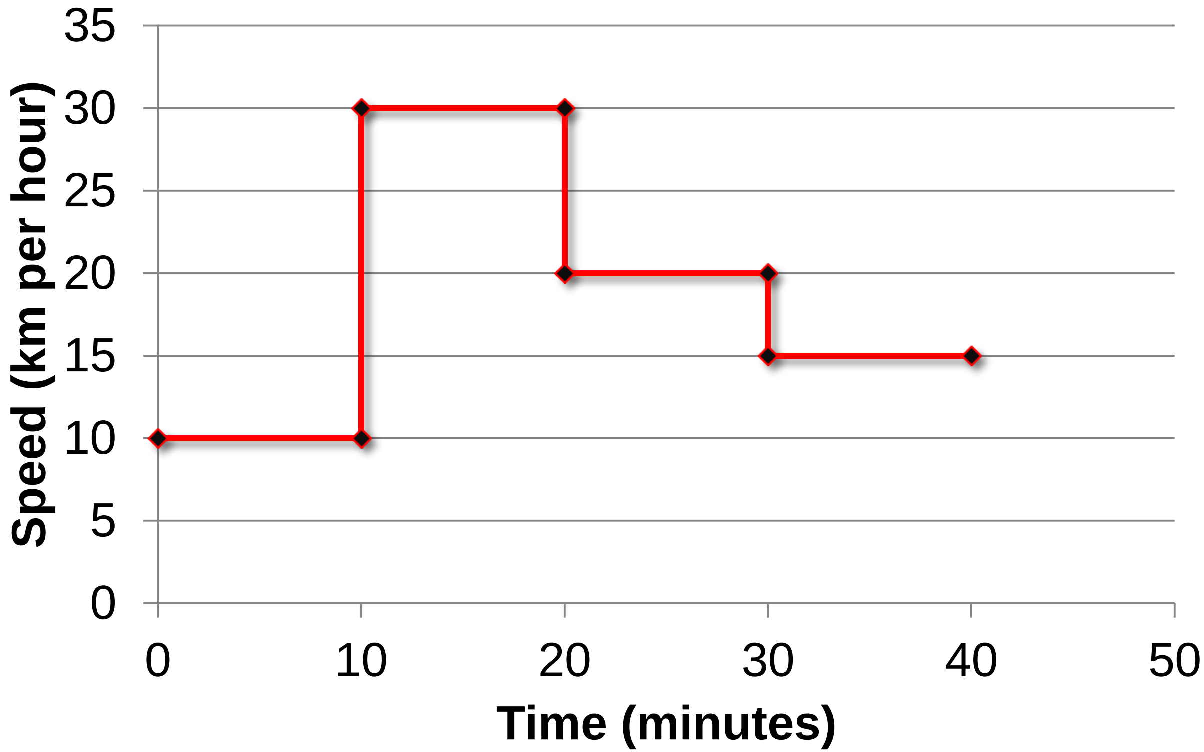
- We will talk about two kinds of speed *instantaneous speed* and *average speed*

- True or False:
  - The winner of a race reaches the highest instantaneous speed?
    - False
  - The winner of a race has the highest average speed?
    - True

3. One Dimensional Motion – Average Speed

A father is teaching his son to drive by slowly driving around an empty parking lot. There car travels 10 $^{\mathrm{km}}/_{\mathrm{hr}}$ for 10 minutes, 30 $^{\mathrm{km}}/_{\mathrm{hr}}$ for 10 minutes, 20 $^{\mathrm{km}}/_{\mathrm{hr}}$ for 10 minutes, and 15 $^{\mathrm{km}}/_{\mathrm{hr}}$ for another 10 minutes (illustrated in the graph below).

- What was their instantaneous speed after 25 minutes?
  - 20 $^{\mathrm{km}}/_{\mathrm{hr}}$
- What was their average speed for the whole lesson?
  - 18.75 $^{\mathrm{km}}/_{\mathrm{hr}}$



3. One Dimensional Motion – Average Speed

- The average speed is described as $\frac{\text{total distance}}{\text{total change in time}}$
- We can use the letter *d* to mean *distance* and the letter *t* to mean *time*
- We often use the Greek letter “delta” (Δ) to mean “total change in”
- For average speed we use the symbol v_{av}

$$v_{av} = \frac{d}{\Delta t}$$

- Now we have our first formula!
- Which brings me to the most important thing in the course…

3. Most Important Thing in the Course

- When we're trying to solve a problem we're looking to apply formulas
- We need a plan of attack!

G.A.R.F.S.S.E

1. **Write down the "givens" (include units!)**
2. **Write down what your "aim" is (include units!)**
3. **Write down "relevant formulas"**
4. **"Sketch" the problem and "Solve"!**
5. **Evaluate your answer**

- A track star, aiming for a world outdoor record, runs four laps of a circular track that has a radius of 15.9 m in 47.8 s. What is the runner's average speed for this motion?

r = 15.9m

$\Delta t = 47.8$ s

$v_{av} = ?\ {}^{m}/_{s}$

$$v_{av} = \frac{d}{\Delta t}$$

$$d = 4(2\pi r)$$

$$d = 4(2\pi r) = 4\big(2\pi(15.9m)\big) = 399.610\ m$$

$$v_{av} = \frac{d}{\Delta t} = \frac{399.610\ m}{47.8\ s} = 8.360054\ {}^{m}/_{s}$$

Therefore his average speed was 8.36 $\frac{m}{s}$

3. Applying G.A.R.F.S.S.E

G.A.R.F.S.S.E

1. **Write down the "givens" (include units!)**
2. **Write down what your "aim" is (include units!)**
3. **Write down "relevant formulas"**
4. **"Sketch" the problem and "Solve"!**
5. **"Evaluate" your answer**

- In the human body, blood travels faster in the aorta, the largest blood vessel, than in any other blood vessel. Given an average speed of 28 cm/s, how far does blood travel in the aorta in 0.20 s?

$$v_{av} = 28\, {}^{cm}/_{s}$$
$$\Delta t = 0.20\ \mathrm{s}$$

$$d = ?\ \mathrm{cm}$$

$$v_{av} = \frac{d}{\Delta t}$$

$$v_{av} = \frac{d}{\Delta t} \rightarrow d = v_{av}\,\Delta t = 28\, {}^{cm}/_{s} \times\ 0.20\ s = 5.6\ cm$$

Therefore the blood traveled 5.6 cm.

3. More Complicated Average Speeds

- In Hawaii's 1999 Ironman Triathlon, the winning athlete swam 3.9 km, biked 180.2 km, and then ran 42.2 km, all in an astonishing 8 h 17 min 17 s. Determine the winner's average speed, in kilo- metres per hour and also in metres per second.

$$d = 3.9\ km + 180.2\ km + 42.2\ km = 226.3\ km = 226{,}300\ m$$
$$\Delta t = 8 \text{ hr } 17 \text{ min } 17 \text{ s}$$

$$\Delta t = 8 \text{ hr } 17 \text{ min } 17 \text{ s} = \left(8 \text{ hr} \times 60 \frac{min}{hr} \times 60 \frac{s}{min}\right) + \left(17 \text{ min } \times 60 \frac{s}{min}\right) + 17s$$
$$= 29{,}837s$$
$$= 29{,}837s \times \frac{1\ min}{60\ s} \times \frac{1\ hr}{60\ min} = 8.2880555\ hr$$

$$\Delta v_{av} = ?\ {}^{km}/_{h}$$
$$\Delta v_{av} = ?\ {}^{m}/_{s}$$
$$v_{av} = \frac{d}{\Delta t}$$

$$v_{av} = \frac{d}{\Delta t} = \frac{226.3\ km}{8.2880555\ hr} = 27.304353\ {}^{km}/_{hr}$$

$$v_{av} = \frac{d}{\Delta t} = \frac{226{,}300\ m}{29{,}837\ s} = 7.5845426819\ {}^{m}/_{s}$$

Therefore the winners average speed was 27 ${}^{km}/_{hr}$ or 7.6 ${}^{m}/_{s}$

4. Uniform Motion and Vector Quantities

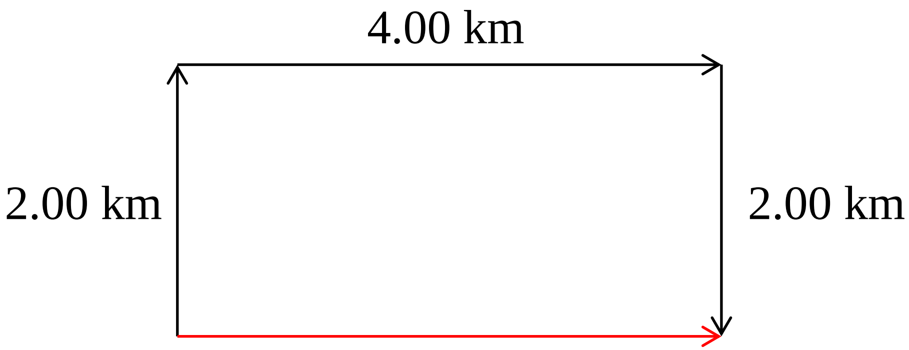
- Uniform motion is motion at a *constant speed* in a *straight line*.
- Recall 2.5 $\frac{km}{hr}$ is a *scalar quantity*.
- A 2.5 $\frac{km}{hr}$ [to the right] is a *vector quantity*
  - Vector quantities have a magnitude (the "2.5 $\frac{km}{hr}$" part) and a direction (the "to the right" part)
- *Velocity* is the "vector version" of speed
  - $v_{av} = 2.5\frac{km}{hr}$ - speed (scalar)
  - $\vec{v}_{av} = 2.5\frac{km}{hr}\ [\text{to the right}]$ – velocity (vector)
- *Displacement* is the "vector version" of distance
  - $d = 19\ km$ – distance (scalar)
  - $\Delta\vec{d} = 19\ km\ [\text{East}]$ – displacement (vector)

- Unfortunately there is no vector version of time (yet!) because (so far) we only travel one direction in time.

4. Displacement vs. Distance

- Displacement is a little trickier than distance

- You want to bike to your friends house. You get on your bike and bike 2.00 km north, 4.00 km east, and 2.00 km south. After you have reached your friends house what is your distance? What is your displacement?



- The distance is trivial (8.00 km)

- The displacement is $\Delta\vec{d}$ which is the *change* in position. So we would say that $\Delta\vec{d} = 4.00\ km$ [East]

4. Displacement

- If you left your desk, walked all the way around the world, then sat back down in your desk what would your displacement be?
- We can take our average speed formula and change it into an average velocity formula
- $\vec{v}_{av} = \frac{\Delta\vec{d}}{\Delta t}$ and using it isn't that different
- The world's fastest coconut tree climber takes only 4.88 s to climb barefoot 8.99 m up a coconut tree. Calculate the climber's average velocity for this motion, assuming that the climb was vertically upward.

$\Delta\vec{d} = 8.99\ \mathrm{m}\ [\mathrm{up}]$
$\Delta t = 4.88\ \mathrm{s}$

$\vec{v}_{av} = ?\ \frac{\mathrm{m}}{\mathrm{s}}$

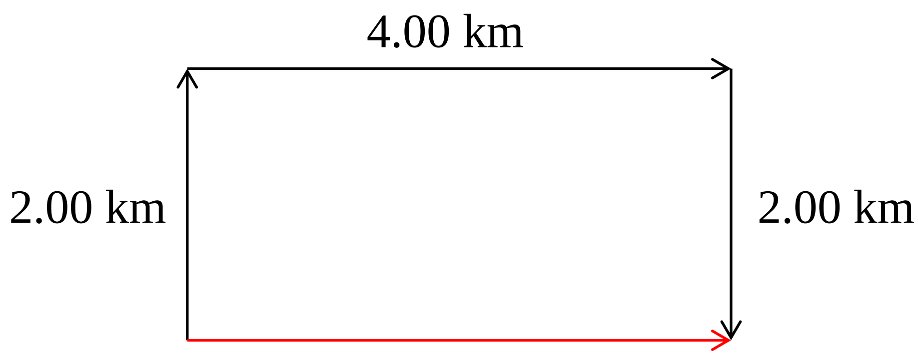
$$\vec{v}_{av} = \frac{\Delta\vec{d}}{\Delta t}$$

$$\vec{v}_{av} = \frac{\Delta\vec{d}}{\Delta t} = \frac{8.99\ \mathrm{m}\ [\mathrm{up}]}{4.88\ s} = 1.842213114\frac{\mathrm{m}}{\mathrm{s}}\ [\mathrm{up}]$$

Therefore the climber had an average velocity of $1.84\ \frac{\mathrm{m}}{\mathrm{s}}$ [up]

4. Displacement vs. Distance

- You want to bike to your friends house. You get on your bike and bike 2.00 km north, 4.00 km east, and 2.00 km south. If the total trip took you 1725 s After you have reached your friends house what is you are average velocity (in m/s)?



$$\Delta\vec{d} = 4.00\ km\ \text{[East]}$$

$$\Delta\vec{d} = 4000\ \text{m [East]}$$
$$\Delta t = 165\ \text{s}$$
$$\vec{v}_{av} = ?\ \frac{\text{m}}{\text{s}}$$

$$\vec{v}_{av} = \frac{\Delta\vec{d}}{\Delta t}$$

$$\vec{v}_{av} = \frac{\Delta\vec{d}}{\Delta t} = \frac{4000\ \text{m [up]}}{1725\ s} = 2.318840579710145\ \frac{\text{m}}{\text{s}}\ \text{[East]}$$

Therefore you biked with an average velocity of 2.32 $\frac{\text{m}}{\text{s}}$ [East]