Physics 101 P

General Physics I

Problem Sessions - Week 1

A.W. Jackura

William & Mary

General Info

Instructor: Andrew W. Jackura

Email: awjackura@wm.edu

Office: Small 326 B

Office hours: Wed, Fri – 1pm – 2pm
& by appointment
& open door policy

Website

ajackura.github.io/courses/phys101p_fall_2023.html

Participation

Be engaged!

- Show up to discussions
- Ask questions to instructor
- Answer questions from instructor
- Talk w/ neighbors about physics

⇒ 2% Engagement bonus

Problem Solving in Physics

Solving physics problems often requires using different fields of mathematics (e.g., algebra, trigonometry, calculus) as well physical intuition from our every day experiences.

Our goal in these discussions is to compliment the lectures by applying physics concepts to exercises.

Dimensions & Units

Physical quantities have two features

Dimensions - basic nature of
physical quantity

e.g., Time

Units - system of measurement
for physical quantity

e.g., seconds

three fundamental dimensions

- Time (T)
- Length (L)
- Mass (M)

Notation

For any physical quantity Q, the dimension of Q is denoted $[Q]$

e.g., $[\text{Distance}] = L$

$[\text{Speed}] = L/T$

$[\text{Density}] = M/L^3$

SI units

Système Internationale d' unités

Each dimension has an associate unit

Time — second (s)

Length — meter (m)

Mass — kilogram (kg)

Unit Prefixes

useful for working w/ large / small numbers

Tetra -	$\times 10^{12}$	T
Giga -	$\times 10^{9}$	G
Mega -	$\times 10^{6}$	M
kilo -	$\times 10^{3}$	k
centi -	$\times 10^{-2}$	c
milli -	$\times 10^{-3}$	m
micro -	$\times 10^{-6}$	μ
nano -	$\times 10^{-9}$	n
pico -	$\times 10^{-12}$	p
femto -	$\times 10^{-15}$	f

Any physical quantity can be multiplied by 1 without changing its value.

e.g., $1 \text{ min} = 60 \text{ s}$

$$\Rightarrow \quad 1 = \frac{60 \text{ s}}{1 \text{ min}}$$

$1 \text{ ft} = 12 \text{ in.}$

$$\Rightarrow \quad 1 = \frac{1 \text{ ft}}{12 \text{ in.}}$$

Example

Alice is driving at 55 mi/hr

What is her speed in meters per second?

Solution

Conversion factors:

$$1 \text{ mi} = 1609 \text{ m} \Rightarrow 1 = \frac{1609 \text{ m}}{1 \text{ mi}}$$

$$1 \text{ hr} = 3600 \text{ s} \Rightarrow 1 = \frac{1 \text{ hr}}{3600 \text{ s}}$$

mi to m

hr to s

$$\text{Speed} = 55 \frac{\text{mi}}{\text{hr}}$$

$$= 55 \frac{\text{mi}}{\text{hr}} \cdot 1 \cdot 1$$

$$= 55 \frac{\cancel{\text{mi}}}{\cancel{\text{hr}}} \cdot \left(\frac{1609 \text{ m}}{1 \cancel{\text{mi}}}\right) \cdot \left(\frac{1 \cancel{\text{hr}}}{3600 \text{ s}}\right)$$

$$\text{Speed} = \frac{55 \cdot 1609}{3600} \ \frac{m}{s}$$

$$= 24.581944\ldots \ m/s$$

Not all these digits are meaningful. Started w/ 2 sig. figs. (55 mi/hr) so, let's report 2 sig. figs.

$$\Rightarrow \boxed{\text{Speed} = 25 \ m/s}$$

Tip: Is this reasonable?
use power of 10 estimate

Lower bound → Round each number down to nearest power of 10.

Upper bound → Round each number up to nearest power of 10.

e.g.,

$$\text{speed}\Big|_{\text{lower}} \sim \frac{10 \cdot 1000}{1000} \frac{m}{s} \sim 10 \text{ m/s}$$

$$\text{speed}\Big|_{\text{upper}} \sim \frac{100 \cdot 10000}{10000} \frac{m}{s} \sim 100 \text{ m/s}$$

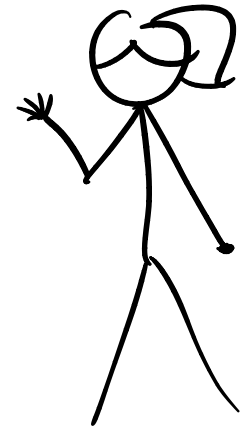
So, actual speed is bounded

$$10 \text{ m/s} < \text{speed} < 100 \text{ m/s}$$

We found speed $= 25$ m/s, so seems reasonable.

Example

Alice is 22 y old. How many seconds has she lived?



Alice

Solution

Let T = Alice's age

$= 22\ y$

Conversion factors:

$$1\ y = 365\ d \Rightarrow 1 = \frac{365\ d}{1\ y}$$

$$1\ d = 24\ hr \Rightarrow 1 = \frac{24\ hr}{1\ d}$$

$$1\ hr = 3600\ s \Rightarrow 1 = \frac{3600\ s}{1\ hr}$$

So,

$$T = 22\ y$$

y to d

d to hr

hr to s

$$= 22\ y \cdot 1 \cdot 1 \cdot 1$$

$$T = 22\,\cancel{y} \cdot \left(\frac{365\,\cancel{d}}{1\,\cancel{y}}\right) \cdot \left(\frac{24\,\cancel{h}}{1\,\cancel{d}}\right) \cdot \left(\frac{3600\,s}{1\,\cancel{h}}\right)$$

$$= (22 \cdot 365 \cdot 24 \cdot 3600)\,s$$

$$= 6.93792\ldots \times 10^{8}\ s$$

22 y ⇒ 2 sig. figs.

$$\Rightarrow \boxed{T = 6.9 \times 10^{8}\ s}$$

Is this sensible? check calculation

$$T\big|_{\text{Lower}} \sim 10 \cdot 100 \cdot 10 \cdot 1000 \sim 10^{7}\ s$$

$$T\big|_{\text{upper}} \sim 100 \cdot 1000 \cdot 100 \cdot 10000 \sim 10^{11}\ s$$

Not obviously wrong, $10^{7}\,s < 6.9 \times 10^{8}\,s < 10^{11}\,s$

N.B. Age of universe $\sim 5 \times 10^{17}\ s$!

Example

Bob's car holds 16 gallons of gas. What is the tank volume in cubic centimeters?

Solution

Let's say we know $1 \text{ gal} = 231 \text{ in.}^3$.

We also know $2.54 \text{ cm} = 1 \text{ in.}$

So, we have

$$\text{volume} = 16 \text{ gal}$$

gal to in^3

in^3 to cm^3

$$= 16 \text{ gal} \cdot 1 \cdot 1$$

$$= 16 \cancel{\text{gal}} \cdot \left(\frac{231 \cancel{\text{in.}^3}}{1 \cancel{\text{gal}}} \right) \cdot \left(\frac{2.54 \text{ cm}}{1 \cancel{\text{in}}} \right)^3$$

Need to include 3 copies of conversion

$$= \left(16 \cdot 231 \cdot (2.54)^3\right) \text{cm}^3$$

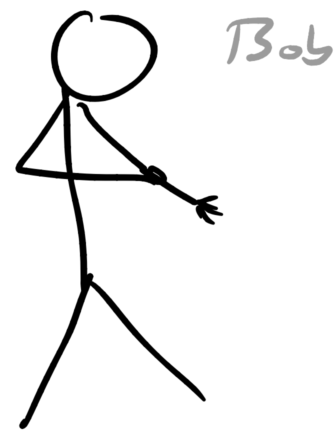
$$= 60566.588\ldots \text{ cm}^3$$

only 2 sig. figs

$$\boxed{\text{volume} = 6.1 \times 10^4 \text{ cm}^3}$$

Example

Bob's resting heart rate is 71.5 beats/min. How many times does Bob's heart beat per day?



Solution

Let R = Bob's heart rate

$= 71.5$ beats/min.

The number of beats is then

$$N = R \cdot T$$

heart rate

total time

$$T = 1 \text{ day} = 1\ \cancel{\text{day}} \cdot \left(\frac{24\ \cancel{\text{hr}}}{1\ \cancel{\text{day}}}\right) \cdot \left(\frac{60 \text{ min}}{1\ \cancel{\text{hr}}}\right)$$

$$= 24 \cdot 60 \text{ min}$$

$$= 1440 \text{ min}$$

So,

$$N = R \cdot T$$

$$= \left(71.5 \ \frac{\text{beats}}{\cancel{\text{min}}}\right) \cdot \left(1440 \ \cancel{\text{min}}\right)$$

$$= (71.5 \cdot 1440) \text{ beats}$$

$$= 102960 \text{ beats}$$

3 sig. figs. from 71.5

$$\Rightarrow \boxed{N = 1.03 \times 10^5 \text{ beats}}$$

Example

Alice wants to calculate the area of an 8.5 in. × 11 in. piece of paper. What is the area in cm^2?

Solution

$$1 \text{ in.} = 2.54 \text{ cm}$$

Let L = length = 11 in.
W = width = 8.5 in.

$$\Rightarrow \quad L = 11 \text{ in} \cdot \left(\frac{2.54 \text{ cm}}{1 \text{ in.}} \right)$$

$$= 27.9 \text{ cm}$$

$$W = 8.5 \text{ in.} \cdot \left(\frac{2.54 \text{ cm}}{1 \text{ in.}} \right)$$

$$= 21.6 \text{ cm}$$

Area of a rectangle

$$A = L \cdot W$$

So, $A = L \cdot W$

$$= (27.9 \text{ cm}) \cdot (21.6 \text{ cm})$$

$$= 602.64 \text{ cm}^2$$

round to 3 sig. figs.

$$\Rightarrow \boxed{A = 603 \text{ cm}^2}$$

Example

Bob wants to measure the thickness of an 8.5 in x 11 in piece of paper.

Bob measures 80 sheets and finds 1.27 cm.

What is the thickness?

Solution

Let D = thickness of 80 sheets

$= 1.27$ cm

Let d = thickness of single sheet.

N = Number of sheets $= 80$

So, $D = N \cdot d \Rightarrow d = \dfrac{D}{N}$

$$d = \frac{1.27\ \text{cm}}{80} = 0.015875\ \text{cm}$$

3 sig. figs

(N.B. NOT 2 since 80 is exact!)

$$\Rightarrow \boxed{d = 0.159\ \text{mm}}$$