Theme 1
Introductory Material

Module T1M1:

The Predictable Universe

C01: In-class Quizzes & Homeworks

September

M	T	W	Th	F
	8	9	10	11
14	15	16	17 Q	18
21	22	23	24 Q	25
28	29	30		

October

M	T	W	Th	F
			1 Qh	2
5	6	7	8 Qh	9 MT1
12	13	14	15	16
19	20	21	22 Qh	23
26	27	28	29 Qh	30

November

M	T	W	Th	F
2	3	4	5 Qh	6
9	10 MT2	11	12 Qh	13
16	17	18	19 Qh	20
23	24	25	26 Qh	27
30				

December

M	T	W	Th	F
	1	2	3 Qh	4
7 h	8			

T1M1 – Learning Objectives

- Identify the approach taken by physicists to understanding complex phenomena.
- Recognize that measurements are really comparisons with a standard ***unit*** of measure, and that different standard units can be related to each other.
- Distinguish between the specific units of a measured quantity, and the more general statement of the ***dimensions*** of the quantity.
- Recognize that the dimensions of a quantity are helpful at predicting the relationships that govern a system.
- Understand the idea of ***proportionality*** to describe the specific way in which quantities are related.

Quantities

Base quantities

1. Length	metre (m)
2. Mass	kilogram (kg)
3. Time	second (s)
4. Electric current	Ampere (A)
5. Temperature	Kelvin (K)
6. Amount of substance	mole (mol)
7. Luminous intensity	candela (cd)

Making Quantitative Measurements

In order to make quantitative observations, we need to make measurements

Suppose are interested in learning about the height distribution of physics students?

- Our measurement of height
  - The quantity has both a numerical value (*magnitude*), as well as a **unit**
- It is important to have both a method of making measurements, and a system of units which allows us to
  - Measure accurately, consistently
  - Communicate with the scientific community
- There are many different units for a quantity
  - Need to be able to convert between different units
  - Good to have a standard system of units
  - We use SI units as our standard

OK, so lets measure the height of a student

Base units and compound units

Quantity	SI units	Quantity	SI units
time	seconds (s)	acceleration	m/s^2
distance	metres (m)	force	Newtons ($N = kg\ m/s^2$)
mass	kilograms (kg)	energy	Joules ($J = kg\ m^2/s^2$)
temperature	Kelvin (K)	power	Watts ($W = J/s$)
area	metres squared (m^2)	pressure	Pascals ($Pa = N/m^2$)
volume	metres cubed (m^3)	density	kg/m^3
speed	metres/second (m/s)		

Definition of Base Units

Base quantities

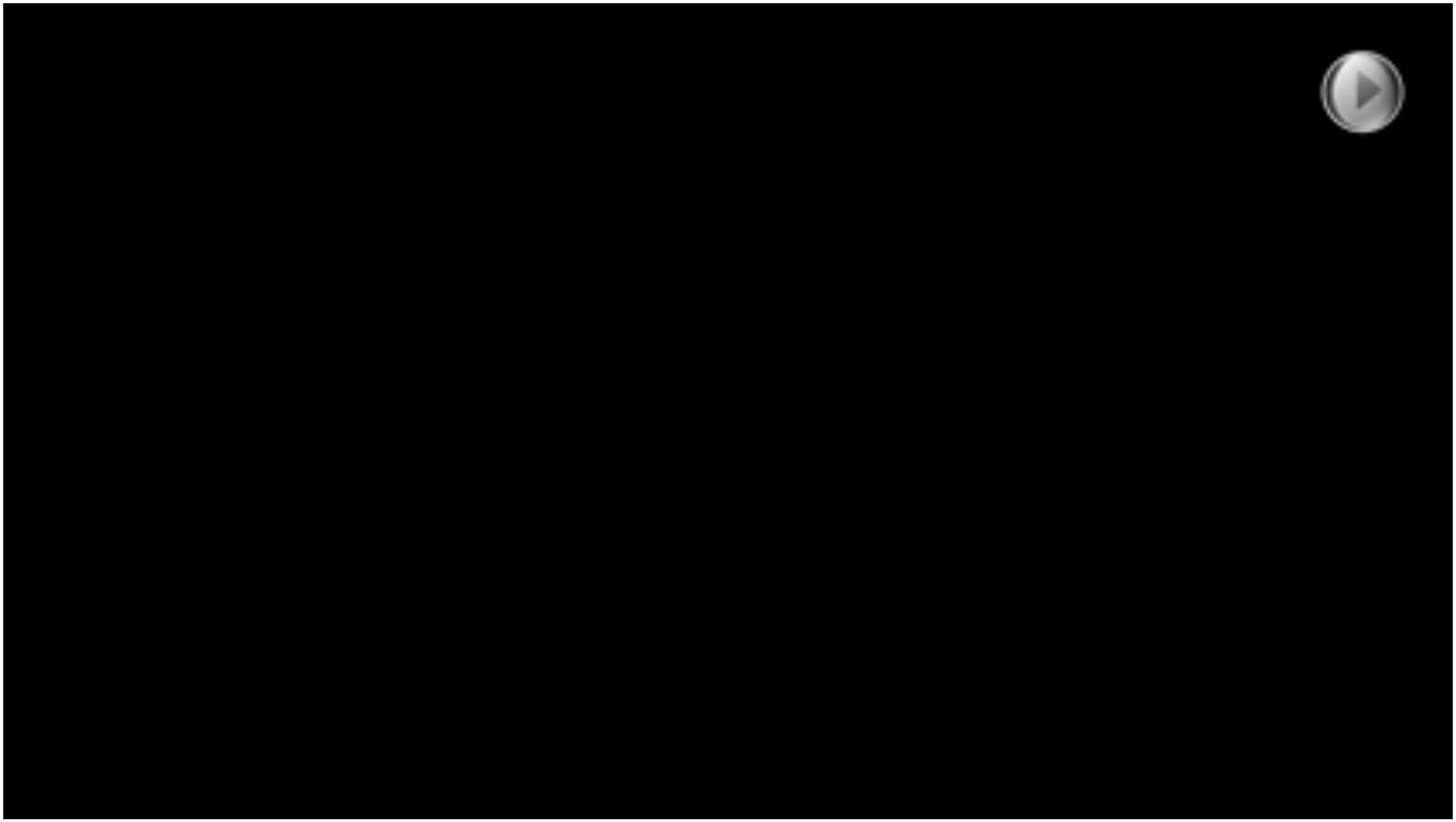
1. Length (m)
2. Mass (kg)
3. Time (s)
4. Electric current (A)
5. Temperature (K)
6. Amount of substance (mol)
7. Luminous intensity (cd)

the length of the path travelled by light in vacuum during a time interval of 1/299792458 of a second

1/273.16 of the thermodynamic temperature of the triple point of water

Veritasium

https://www.youtube.com/watch?v=ZMByI4s-D-Y



Units & Unit Conversions

- Physical quantities are meaningless without units

- Unit conversions essentially take a quantity and multiply it by 1 (in a creative way)

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

$$\boxed{\frac{2.54 \text{ cm}}{1 \text{ in}} = 1} \qquad \boxed{\frac{1 \text{ in}}{2.54 \text{ cm}} = 1}$$

$$17 \text{ in} = 17 \cancel{\text{in}} \times \frac{2.54 \text{ cm}}{1 \cancel{\text{in}}} \qquad 10 \text{ cm} = 10 \cancel{\text{cm}} \times \frac{1 \text{ in}}{2.54 \cancel{\text{cm}}}$$

$$= 43.2 \text{ cm} \qquad = 3.94 \text{ in}$$

Clicker Quiz

The blue whale is thought to be the largest animal ever to inhabit the Earth. The longest recorded blue whale had a length of 108 ft. If 1 ft = 30 cm, what is the length of this whale in meters?

A. 3.6 m
B. 32.4 m
C. 360 m
D. 3240 m

Answer

Conversion factors:

$$1\ ft = 30\ \ cm \qquad\qquad 1\ m = 100\ \ cm$$

$$1 = \frac{30\ \ cm}{1\ \ ft} \qquad\qquad 1 = \frac{1\ \ m}{100\ cm}$$

Calculate:

$$108\ ft = 108\ \cancel{ft} \times \frac{30\ \cancel{cm}}{1\ \ \cancel{ft}} \times \frac{1\,m}{100\,\cancel{cm}} \ \boxed{= 32.4\ m}$$

Clicker Quiz

- Volume conversion: How many cubic centimetres are there in one cubic metre?

A. 10

B. 100

C. 1000

D. 10^4

E. 10^6

$$
\begin{aligned}
1\ \mathrm{m}^3 &= \overset{\left(\frac{100\ \mathrm{cm}}{1\ \mathrm{m}}\right)}{1\ \cancel{\mathrm{m}}} \times \overset{\left(\frac{100\ \mathrm{cm}}{1\ \mathrm{m}}\right)}{1\ \cancel{\mathrm{m}}} \times \overset{\left(\frac{100\ \mathrm{cm}}{1\ \mathrm{m}}\right)}{1\ \cancel{\mathrm{m}}} \times \left(\frac{100\ \mathrm{cm}}{1\ \cancel{\mathrm{m}}}\right)^3 \\
&= (100\ \mathrm{cm})^3 \\
&= 10^6\ \mathrm{cm}^3
\end{aligned}
$$

The cost of Living

- **Being comfortable with unit conversions allows you to better process/interpret information:**
- What is a typical value for daily consumption (in Calories)?
  - **2000 Cal**
- Convert this to SI units of energy (Joules), given that there are 0.239 Calories in 1 kJ.

$$0.239\,Cal = 1\,kJ \longrightarrow 1 = \frac{1\ kJ}{0.239\ Cal}$$

$$2000\,Cal = 2000\,\cancel{Cal} \times \frac{1\ \cancel{kJ}}{0.239\ \cancel{Cal}} \times \frac{1000\ J}{1\ \cancel{kJ}} = 8.4\times 10^{6}\ J$$

The cost of Living

- Does anybody know the SI units of Power (rate of energy consumption)?
  - **Watts [1 W = 1J/s]**
- Since we require 8.4 million Joules each day, on average we burn through energy at a rate of:

$$\frac{8.4\times 10^{6}\ J}{24\ hr}\times\frac{1\ hr}{3600\ s}=97\,J/s=97\ Watts\,!!$$

- So, the power we expend is about 100 Watts, remind you of anything?

Dimensions

- "Dimension" refers to a basic ***type*** of quantity

  Example: Regardless of whether you measure your height in cm, inches or feet (or TP-rolls!), your height is a <u>length</u> quantity

We identify dimensions using square brackets

- Your height (length) → dimensions [L]
- Your age (time) → dimensions [T]
- How much of you there is
  - (mass) → dimensions [M]
  - (volume) → dimensions [L^3]
  - (as a food source - energy) → dimensions [ML^2/T^2]

Dimensions

- Dimensions of some common physical quantities

Quantity	Symbol	Dimension
Area	A	$[L^2]$
Volume	V	$[L^3]$
Speed	v	$[L/T]$
Acceleration	a	$[L/T^2]$
Force	F	$[ML/T^2]$
Pressure (F/A)	p	$[M/LT^2]$
Density (M/V)	ρ	$[M/L^3]$
Energy	E	$[ML^2/T^2]$
Power (E/t)	P	$[ML^2/T^3]$

Clicker Quiz

- Which of the following equations is *dimensionally correct*?

- A $t = \dfrac{x \times a}{v^2}$

- B $v = v_0 + x \times t$

- C $x = x_0 + a \times t^2$

- D $\text{pie} = \text{crust} + \text{filling}$

Clicker Quiz

- Which of the following equations is *dimensionally correct*?

- A $t = \dfrac{x \times a}{v^2}$ $\qquad [T] = \dfrac{[L] \times [L/T^2]}{[L/T]^2}$

- B $v = v_0 + x \times t$ $\qquad [L/T] = [L/T] + [L] \times [T]$

- C $x = x_0 + a \times t^2$ $\qquad [L] = [L] + [L/T^2] \times [T^2]$

- D $\text{pie} = \text{crust} + \text{filling}$ $\qquad \boxed{\text{nonsense}}$

Clicker Quiz

- Ideal gas law: physicists often write this as: $PV = Nk_BT$

where N is the number of particles and k_B is a constant. What are the dimensions of k_B ?

(Note: K determines the dimension of temperature)

a) $\left[\dfrac{ML^2}{T^2K)}\right]$

b) $\left[\dfrac{FL}{K}\right]$

c) $\left[\dfrac{ML^2}{NT^2K}\right]$

d) $\left[\dfrac{ML}{KT}\right]$

Clicker Quiz

- Ideal gas law: physicists often write this as: $PV = Nk_BT$

where N is the number of particles and k_B is a constant.

What are the dimensions of k_B ?

(Note: K determines the dimension of temperature)

Answer:

Pressure is a force per unit area.
Force is a mass times acceleration.
N is a number, numbers are dimensionless

$$k_B = \frac{PV}{NT} \quad \rightarrow \frac{\left[\frac{ML}{L^2T^2}\right] \times [L^3]}{K} = \left[\frac{ML^2}{T^2K}\right]$$