Principles of Physics

Lecture 1: Units and Dimensions

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References

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- Joel R. Hass, Christopher E. Heil, Maurice D. Weir. (2018) Thomas' Calculus, 14th edition, Pearson
- https://www.youtube.com/watch?v=KOKnWaLiL8w
- https://www.powershow.com/viewht/639099-MjM2Y/Halliday_Resnick_Walker_Fundamentals_of_Physics_8th_edition_powerpoint_ppt_presentation
- https://www.youtube.com/watch?v=8kcvyoHsXrw

Grades

Contact Hours					CH	Assessment Scheme		
LCT	TUT	LAB	Total	SWL		CW	MT	FE
2	1	1	4	120	3	40	20	40

LMS

- Course Materials: Lectures, tutorial and Lab
- Quizzes, sheets, Assignment.

Learning Outcomes

- Explain basic physics laws in mechanics and find solutions for one-dimensional and two -dimensional problems and communicate the results.
- Calculate the work related to kinetic energy, potential energy, and mechanical power to solve related problems and communicate the results orally/written in a team.
- Explain the concepts of modern physics and use basic knowledge of wave mechanics to solve problems.
- Review the various applications of semiconductors and P-N junction diode.
- Explain physical measurement equipment, perform experiments, interpret data, and draw results and conclusions.
- Write lab reports and present experimental results.

Calendar

- Week 2: Dimensions and Units.
- Week 3: Motion in one dimension, Position, and Displacement.
- Week 4: Equation of motion and Newton’s laws of motion.
- Week 5: Vectors and Scalars.
- Week 6: Elastic properties of solids.
- Week 7: Midterm

Calendar

- Week 8: Wave and Oscillations.
- Week 9: Wave and Oscillations (Simple pendulum).
- Week 10: Photoelectric effect.
- Week 11: Semiconductor physics.
- Week 12: Applications of Semiconductors.
- Week 13: Revision.
- Week 14: Practical Exam.
- Week 15: Final Exam.

Table of Contents

Base and Derived Units

Base and Derived Units

- In any system of units, the units for some physical quantities must be defined through a measurement process. These are called the **base quantities** for that system and their units are the system's **base units**. All other physical quantities can then be expressed as algebraic combinations of the base quantities. Each of these physical quantities is then known as a **derived quantity** and each unit is called a **derived unit**.

Base quantity

Base Quantity	SI units
Length, l	metres, m
Mass, m	kilogram, kg
Time, t	second, s
Temperature, T	Kelvin, k
Electrical current, I	Ampere, A

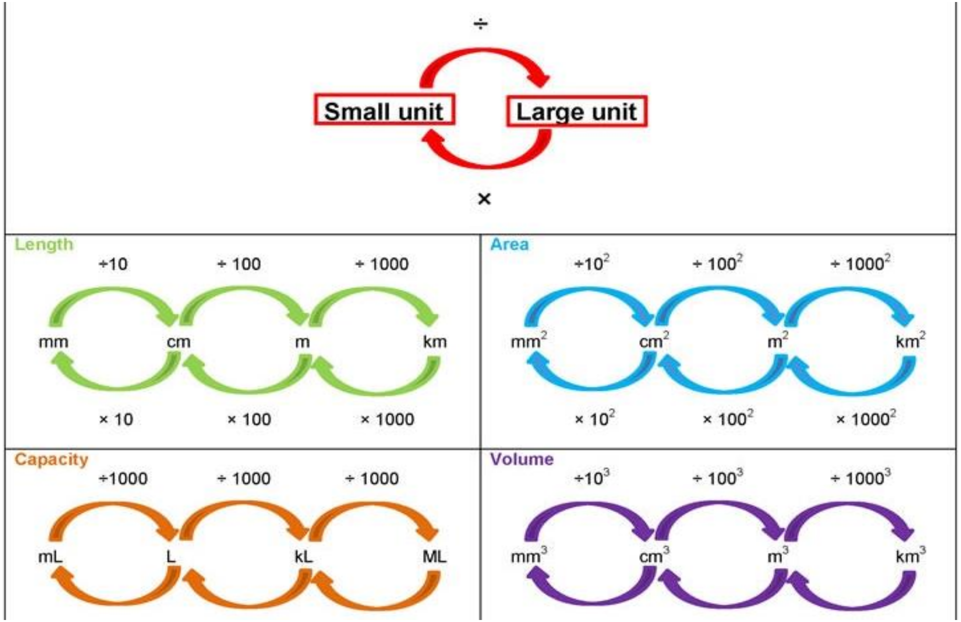
Derived quantity

Derived Quantity	Units
Volume, V	m^3
Density, ρ	kgm^{-3}
Velocity, v	ms^{-1}
Force, F	N
Acceleration, a	ms^{-2}

Units Conversion

Unit Conversion

- A conversion factor is an expression used to change from one unit to another.



Mass	1 kg = 10^3 g
	1 g = 10^{-3} kg
	1 u = 1.66×10^{-24} g = 1.66×10^{-27} kg
	1 slug = 14.6 kg
	1 metric ton = 1000 kg
Length	1 Å = 10^{-10} m
	1 nm = 10^{-9} m
	1 cm = 10^{-2} m = 0.394 in.
	1 yd = 3 ft
	1 m = 10^{-3} km = 3.281 ft = 39.4 in.
	1 km = 10^3 m = 0.621 mi
	1 in. = 2.54 cm = 2.54×10^{-2} m
	1 ft = 0.305 m = 30.5 cm
	1 mi = 5280 ft = 1609 m = 1.609 km
	1 ly (light year) = 9.46×10^{12} km
	1 pc (parsec) = 3.09×10^{13} km
Area	1 cm^2 = 10^{-4} m^2 = 0.1550 in.^{2}
	= 1.08×10^{-3} ft^2
	1 m^2 = 10^4 cm^2 = 10.76 ft^2 = 1550 in.^{2}
	1 in.^{2} = 6.94×10^{-3} ft^2 = 6.45 cm^2
	= 6.45×10^{-4} m^2
	1 ft^2 = 144 in.^{2} = 9.29×10^{-2} m^2 = 929 cm^2
Volume	1 cm^3 = 10^{-6} m^3 = 3.35×10^{-5} ft^3
	= 6.10×10^{-2} in.^{3}
	1 m^3 = 10^6 cm^3 = 10^3 L = 35.3 ft^3
	= 6.10×10^4 in.^{3} = 264 gal
	1 liter = 10^3 cm^3 = 10^{-3} m^3 = 1.056 qt
	= 0.264 gal
	1 in.^{3} = 5.79×10^{-4} ft^3 = 16.4 cm^3
	= 1.64×10^{-5} m^3
	1 ft^3 = 1728 in.^{3} = 7.48 gal = 0.0283 m^3
	= 28.3 L
	1 qt = 2 pt = 946 cm^3 = 0.946 L
	1 gal = 4 qt = 231 in.^{3} = 0.134 ft^3 = 3.785 L
Time	1 h = 60 min = 3600 s
	1 day = 24 h = 1440 min = 8.64×10^4 s
	1 y = 365 days = 8.76×10^3 h
	= 5.26×10^5 min = 3.16×10^7 s
Speed	1 m/s = 3.60 km/h = 3.28 ft/s
	= 2.24 mi/h
	1 km/h = 0.278 m/s = 0.621 mi/h
	= 0.911 ft/s
	1 ft/s = 0.682 mi/h = 0.305 m/s
	= 1.10 km/h
	1 mi/*h* = 1.467 ft/s = 1.609 km/h
	= 0.447 m/s
	60 mi/h = 88 ft/s
Force	1 N = 0.225 lb
	1 lb = 4.45 N
	Equivalent weight of a mass of 1 kg
	on Earth's surface = 2.2 lb = 9.8 N
	1 dyne = 10^{-5} N = 2.25×10^{-6} lb
Pressure	1 Pa = 1 N/m^2 = 1.45×10^{-4} lb/in.^{2}
	= 7.5×10^{-3} mm Hg
	1 mm Hg = 133 Pa
	= 0.02 lb/in.^{2} = 1 torr
	1 atm = 14.7 lb/in.^{2} = 101.3 kPa
	= 30 in. Hg = 760 mm Hg
	1 lb/in.^{2} = 6.89 kPa
	1 bar = 10^5 Pa = 100 kPa
	1 millibar = 10^2 Pa
Energy	1 J = 0.738 ft · lb = 0.239 cal
	= 9.48×10^{-4} Btu = 6.24×10^{18} eV
	1 kcal = 4186 J = 3.968 Btu
	1Btu = 1055 J = 778 ft · lb = 0.252 kcal
	1 cal = 4.186 J = 3.97×10^{-3} Btu
	= 3.09 ft · lb
	1 ft · lb = 1.36 J = 1.29×10^{-3} Btu
	1 eV = 1.60×10^{-19} J
	1 kWh = 3.6×10^6 J
	1 erg = 10^{-7} J = 7.38×10^{-6} ft · lb
Power	1 W = 1 J/s = 0.738 ft · lb/s
	= 1.34×10^{-3} hp = 3.41 Btu/h
	1 ft · lb/s = 1.36 W = 1.82×10^{-3} hp
	1 hp = 550 ft · lb/s = 745.7 W
	= 2545 Btu/h
Mass–Energy Equivalents	1 u = 1.66×10^{-27} kg $\leftrightarrow$ 931.5 MeV
	1 electron mass = 9.11×10^{-31} kg
	= 5.49×10^{-4} u $\leftrightarrow$ 0.511 MeV
	1 proton mass = 1.673×10^{-27} kg
	= 1.007 267 u $\leftrightarrow$ 938.28 MeV
	1 neutron mass = 1.675×10^{-27} kg
	= 1.008 665 u $\leftrightarrow$ 939.57 MeV
Temperature	$T_F = \frac{9}{5}T_C + 32$
	$T_C = \frac{5}{9}(T_F - 32)$
	$T_K = T_C + 273.15$
Angle	1 rad = 57.3°
	1° = 0.0175 rad; 60° = $\pi/3$ rad
	15° = $\pi/12$ rad; 90° = $\pi/2$ rad
	30° = $\pi/6$ rad; 180° = π rad
	45° = $\pi/4$ rad; 360° = 2π rad
	1 rev/min = $(\pi/30)$ rad/s = 0.1047 rad/s

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Dimensional Analysis

Dimensional Analysis

- The dimension of any physical quantity expresses its dependence on the base quantities as a product of symbols representing the base quantities. This table lists the base quantities and the symbols used for their dimension.

Base Quantity	Symbol for Dimension
Mass	M
Length	L
Time	T

Dimensional Analysis

Chapter 1: Dimensional Analysis and Engineering units التحليل البُعدي والوحدات الهندسية

Derived Physical Quantities الكميات الفيزيائية المشتقة			
Quantity الكمية	Law القانون	Unit الوحدة	Dimension البعد
Distance المسافة	$d = l$	m	L
Area المساحة	$A = l^2$	m^2	L^2
Volume الحجم	$V = l^3$	m^3	L^3
Velocity السرعة	$v = l/t$	m/s	$L.T^{-1}$
Acceleration العجلة	$a = v/t = l/t^2$	m/s^2	$L.T^{-2}$
Momentum كمية الحركة	$P_m = m\,v$	$kg.m/s$	$M.L.T^{-1}$
Force القوة	$F = m\,a$	$kg.m/s^2$	$M.L.T^{-2}$
Impulse الدفع	$J = F\,t$	$kg.m/s$	$M.L.T^{-1}$
Energy or Work الطاقة أو الشغل	$W = F\,d$	$kg.m^2/s^2$	$M.L^2.T^{-2}$
Power القدرة	$p = E/t$	$kg.m^2/s^3$	$M.L^2.T^{-3}$
Density الكثافة	$\rho = m/V$	kg/m^3	$M.L^{-3}$
Pressure الضغط	$P = F/A$	$kg/m.s^2$	$M.L^{-1}.T^{-2}$

Dimensionless quantity

- All the numbers
- Some constant (such as $\pi = {}^{22}/_{7} = 3.14$)
- Ratios (Proportions)
- Non-algebraic Functions

such as: *Logarithmic functions* $\log(x)$, $\ln(x)$ – *Exponential Functions* e^x, a^x – *Trigonometric Functions* $\sin(x)$, $\cos(x)$, $\tan(x)$.

Dimension of a dimensionless quantities is 1

Important rules

قواعد هامة

١) يجب وضع اى كمية فيزيائية يطلب تحليل بعدى لها بدلالة الكميات الفيزيائية الثلاثة Mass (M) , Length (L) , Time (T).

٢) يفضل مراعاة الترتيب عند كتابة الـ Dimension لاى كمية فيزيائية بمعنى نكتب الـ Dimension كالاتى ($M \longrightarrow L \longrightarrow T$).

٣) يمكن ضرب او قسمة الـ Dimension بمعنى ($LT^{-1} \, x \, LT^{-1} = L^2T^{-2}$)

٤) لا يمكن جمع او طرح الـ Dimension بمعنى ($LT^{-1} + LT^{-1} = LT^{-1}$) الجمع والطرح هنا ليس جبريا.

٥) اذا كان هناك كميتين A & B لهم وحدات قياس مختلفة فانه لايمكن جمعهم أو طرحهم (لا يمكن ان نقول A + B أو A − B).

٦) اذا كان هناك كميتين A & B لهم وحدات قياس متشابهة فانه يمكن جمعهم أو طرحهم (يمكن ان نقول A + B أو A − B).

٧) اذا كان هناك كميتين A & B لهم وحدات قياس مختلفة او متشابهة فانه يمكن ضربهم او قسمتهم (يمكن ان نقول A x B أو A / B).

Problems

- Given, $F = G\frac{m_1 m_2}{r^2}$, Find the unit and the dimension of G?

Solution:

The unit

$$G = \frac{F \cdot r^2}{m_1 m_2} = \frac{N \cdot m^2}{Kg^2}$$

The dimensions

$$G = \frac{F \cdot r^2}{m_1 m_2} = \frac{MLT^{-2}L^2}{M^2} = M^{-1}L^3T^{-2}$$

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Uses of the dimensions

Uses of the dimensions

- <u>**Verify the validity of any equation التأكد من صحة أي معادلة**</u>
- Example: Verify the following equations:

$$1 - v = v_o + a\,t \qquad 2 - s = v_o\,t + \frac{1}{2}\,a\,t^2$$

$$3 - {v_f}^2 = {v_o}^2 + 2\,a\,s$$

Solution:

1

L.H.S	R.H.S
$[v] = L.T^{-1}$	$[v_0] = L.T^{-1}$
	$[a] * [t] = L.T^{-2} * T = L.T^{-1}$
	$[v_0] + [a] * [t] = L.T^{-1}$

$$\therefore\ [L.H.S] = [R.H.S]$$

Uses of the dimensions

$\boxed{2}$

L.H.S	R.H.S
$[s] = L$	$[v_0] * [t] = L.T^{-1} * T^{-1} = L$
	$[a] * [t^2] = L.T^{-2} * T^2 = L$
	$[v_0] * [t] + [a] * [t^2] = L$

$$\therefore \ [L.H.S] = [R.H.S]$$

$\boxed{3}$

L.H.S	R.H.S
$[v_f{}^2] = L^2.T^{-2}$	$[v_o{}^2] = L^2.T^{-2}$
	$[a] * [s] = L.T^{-2} * L = L^2.T^{-2}$
	$[v_o{}^2] + [a] * [s] = L^2.T^{-2}$

$$\therefore \ [L.H.S] = [R.H.S]$$

Uses of the dimensions

- **Deduce the law of any physical quantity إستنتاج القانون الخاص بأي كمية فيزيائية**

Example : Prove that the period of oscillations of a simple pendulums is proportinal to its length (L) , the acceleration of garvity (g) & the mass of pendulum (m)

Solution

هنفرض ان زمن الاهتزازات يساوى دالة فى المتغيرات (طول البندول – عجلة الجاذبية – كتلة البندول)

$$let\ that \quad T_p = f(l, g, m)$$

$$T_p = k(l^a g^b m^c)$$ k : ثابت ليس له وحدة

take the dimension of both sides

$$[T_p] = [l^a][g^b][m^c]$$

$$T = M^c * L^a * L^b . T^{-2b} = M^c \ L^{a+b} \ T^{-2b}$$

بمساواة الاسس فى الطرفين

$$w.r.t\ (T) \rightarrow -2b = 1 \Longrightarrow b = -\frac{1}{2}$$

$$w.r.t\ (M) \rightarrow c = 0$$

$$w.r.t\ (L) \rightarrow a + b = 0 \Longrightarrow a = \frac{1}{2}$$

$$T = k\, l^{0.5} g^{-0.5} m^0 \Longrightarrow \boxed{T = k\sqrt{\frac{l}{g}}}$$

Problems

Example: Suppose we are told that the accelelration (a) of a particle moving with uniform speed (v) in a circle of radius (r) is proportional to some power of (r) , say (r^x) & some power of (v) , say (v^y). Determine the values of $(x \,\&\, y)$ and write the simplest form for the acceleration .

<u>Solution</u>

$a = k\,(r^x\, v^y)$ $\qquad$ k : ثابت ليس له وحدة

take the dimension of both sides

$[a] = [r^x]\,[v^y]$

$L\,.T^{-2} = L^x * (L.T^{-1})^y = L^{x+y}\,.T^{-y}$

بمساواة الاسس فى الطرفين

$$w.r.t\ (T) \quad \longrightarrow \quad -y = -2 \quad \Longrightarrow \quad y = 2$$
$$w.r.t\ (L) \quad \longrightarrow \quad x + y = 1 \quad \Longrightarrow \quad x = -1$$
$$a = k\,r^{-1}\,v^2$$

$$\boxed{a = k\frac{v^2}{r}}$$

Problems

- Assuming that the mass m of the largest stone that can be moved by a flowing river depends on the velocity V of the water, its density ρ, and the acceleration of gravity g. Show that m varies as the sixth power of the water velocity in the river.

Solution:

$$m \ \alpha \ \rho \, V \, g$$

$$m = k\, V^a \, \rho^b \, g^c \qquad \Rightarrow (1)$$

$$M = (L\,T^{-1})^a \ (M\,L^{-3})^b \ (L\,T^{-2})^c$$

$$M = L^a\,T^{-a} \ M^b\,L^{-3b} \ L^c\,T^{-2c}$$

$$M = L^{a-3b+c} \quad T^{-a-2c} \quad M^b$$

$$\text{For M: } b = 1 \qquad \Rightarrow (2)$$

$$\text{For L: } a - 3b + c = 0$$

$$a + c = 3 \qquad \Rightarrow (3)$$

$$\text{For T: } -a - 2c = 0 \qquad \Rightarrow (4)$$

Add (3) and (4):

$$c = -3 \qquad \Rightarrow (5)$$

Substitute from (5) in (3):

$$a = 6 \qquad \Rightarrow (6)$$

Substitute from (2), (5), and (6) in (1):

$$\therefore \mathbf{m} = \frac{\mathbf{k\ V^6\ \rho}}{\mathbf{g^3}}$$

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Thank You...