Booklet 1

PHYSICAL QUANTITIES, SCALARS AND VECTORS

Specification:

1.1 Physical quantities

1.1.1 Describe all physical quantities as consisting of a numerical magnitude and unit;

1.1.2 State the base units of mass, length, time, current, temperature, and amount of substance and be able to express other quantities in terms of these units;

1.1.3 Recall and use the prefixes T, G, M, k, c, m, μ, n, p and f, and present these in standard form;

1.2 Scalars and vectors

1.2.1 Distinguish between and give examples of scalar and vector quantity;

1.2.2 Resolve a vector into two perpendicular components;

1.2.3 Calculate the resultant of two coplanar vectors by calculation or scale drawing, with calculations limited to two perpendicular vectors;

1.2.4 Solve problems that include two or three coplanar forces acting at a point, in the context of equilibrium;

Physical quantity

A Physical quantity is a *physical property* that can be *measured* or *calculated* from other physical property or properties. A particular value of a physical quantity is expressed as the product of a **numerical magnitude** and a **unit** and it is written as the product of a number and a unit abbreviation.

Physical quantity		
Mass	3	kg
Distance	50	km
Speed	20	km

Table 1: Examples of physical quantities and particular values of the physical quantity.

Base of physical quantities

All physical quantities can be expressed **only** in terms of 6[1] fundamental physical quantities. These 6 physical quantities are known as **base physical quantities**. In spite of the fact that we may select between different bases, a *general convention* is to use the following base physical quantities: **mass**, **length**, **time**, **electric current**, **temperature**, and **amount of substance**.

Example 1: Velocity in terms of base physical quantities.

$$\textbf{velocity} = \frac{\text{displacement}}{\text{time}} = \frac{\textbf{length}}{\textbf{time}}$$

Example 2: Acceleration in terms of base physical quantities.

$$\textbf{acceleration} = \frac{\text{velocity}}{\text{time}} = \frac{\text{displacement}}{\text{time}^2} = \frac{\textbf{length}}{\textbf{time}^2}$$

Example 3: Force in terms of base physical quantities.

$$\textbf{Force} = \text{mass} \times \text{acceleration} \times \text{displacement} = \frac{\textbf{mass} \times \textbf{length}}{\textbf{time}^2}$$

Example 4: Energy (Work) in terms of base physical quantities. (do it!)

$$\boxed{\textbf{Energy} = \qquad\qquad\qquad\qquad\qquad\qquad}$$

Base units

Once the base of physical quantities has been chosen, we must **scale** the base by assigning specific units to each quantity. These units are the **base units**. We could arbitrarily assign units to our base quantities but instead, we are going to embrace the general convention of using the

[1]There are in fact 7 physical quantities and therefore 7 base units. Candela is **not** considered by CCEA.

International System of Units (SI units). You must memorise the following table (SPEC. 1.1.2):

Base physical quantities & SI base units			
Physical quantity	**Symbol**	**SI units**	**SI unit name**
Mass	m	kg	Kilogram
Length	ℓ	m	Metre
Time	t	s	Second
Electric current	I	A	Ampere
Temperature	T	K	Kelvin
Amount of substance	n	mol	Mole

Table 2: Physical quantities, and their SI base units.

In some special occasions during A-level you will be using units out of the SI, for example in quantum physics you will consider energy in electron-volts instead of Joules, distance in Light years instead of metres in astrophysics and a few others.

Units of derived physical quantities

As stated before, we can express the units of **any physical quantity** in terms of the **base units**. To do so it is necessary to have an equation relating the derived physical quantity in terms of the base physical quantities.

- **Example 1: Derived quantity: Area**.
  Any equation for the calculation of an area can be used to derive the units. The simplest equation with dimensions of area is the area of a square,

$$[\text{Area}] = \underbrace{[\text{side}]}_{\text{m}} \times \underbrace{[\text{side}]}_{\text{m}} = \ \text{m} \times \ \text{m} = \ \text{m}^2$$

- Notice that **brackets** here should be read as units of the bracketed quantity. This is a standard notation. i.e. [Area] means units of area.

- **Example 2: Derived quantity: Velocity**.
  The simplest equation with dimensions of area is the area of a square,

$$[\text{velocity}] = \frac{[\text{displacement}]}{[\text{time}]} = \frac{\text{m}}{\text{s}} = \ \text{m} \cdot \text{s}^{-1}$$

- Notice that instead of using the GCSE notation **m/s** we now also use $\mathbf{m{\cdot}s^{-1}}$ you must know this new form of writing the units. Remember:

$$x = x^1 \qquad 1/x = \frac{1}{x} = x^{-1} \qquad 1/x^2 = \frac{1}{x^2} = x^{-2}$$

- **Example 3: Derived quantity: Force**.

  $$[\text{Force}] = [\text{mass}]\times[\text{acceleration}] = [\text{mass}]\times\frac{[\text{velocity}]}{[\text{time}]} = [\text{mass}]\times\frac{[\text{displacement}]}{[\text{time}]^2} = \text{kg}\cdot\text{m}\cdot\text{s}^{-2}$$

  In this case we have a name for this derived unit, **Newton**.

  $$[F] = \text{N} = \text{kg}\cdot\text{m}\cdot\text{s}^{-2}$$

- **Example 4: Derived quantity: Energy**.
  Any energy equation can be used to derive the units of energy.

  $$[\text{Work}] = [\text{force}]\times[\text{displacement}] = \underbrace{\text{kg}\cdot\text{m}\cdot\text{s}^{-2}}_{\text{force}}\cdot\text{m} = \text{kg}\cdot\text{m}^2\cdot\text{s}^{-2}$$

  We could have used the equation for the kinetic energy and obtain the same

  $$[\text{Kinetic energy}] = \left[\frac{1}{2}\right]\times[\text{mass}]\times[\text{velocity}^2] = \text{kg}\times(\underbrace{\text{m}\cdot\text{s}^{-1}}_{\text{velocity}})^2 = \text{kg}\cdot\text{m}^2\cdot\text{s}^{-2}$$

- Notice that we ignore the term [1/2] because it is dimensionless i.e. **does not contribute** to the units.

- Notice that we obtain the same units following both methods.

- In this case we also have a name for this derived unit, **Joule**.

  $$[E] = \text{J} = \text{kg}\cdot\text{m}\cdot\text{s}^{-2}$$

Units of derived physical quantities questions/homework

(1) supertable

(2) Express the following derived units in terms of the SI base units. The first one has been done for you: [1] p. 3.

Derived Unit	**in Base Units**	**Power of each base unit**			
		m	s	kg	A
m s^{-2}	m s^{-2}	1	-2	0	0
J					
N					
C					
Ω					
Pa					
N C^{-1}					
V m^{-1}					

(3) *Find the units:* Determine the **SI unit** of each of the following quantities. Let $[a]=$ m s^{-2}, $[t]$=s, $[v]=$ m s^{-1}, and $[x]=$ m. [2]

(a) $\dfrac{v^2}{ax}$

Solution:

$$\boxed{\frac{[v]^2}{[a][x]} = \frac{\mathrm{m}^2 \cdot \mathrm{s}^{-2}}{\mathrm{m} \cdot \mathrm{s}^{-2} \cdot \mathrm{m}} = 1 \qquad \text{(dimensionless)}}$$

(b) $\dfrac{at^2}{2}$

Solution:

We can neglect the 2 dividing as it is dimensionless.

$$\boxed{[a] \cdot [t]^2 = \mathrm{m} \cdot \mathrm{s}^{-2} \cdot \mathrm{s}^2 = \mathrm{m}}$$

(c) $2\pi\sqrt{\dfrac{x}{a}}$

Solution:

We can neglect the factor 2π as it is dimensionless.

$$\boxed{\sqrt{\frac{[x]}{[a]}} = \sqrt{\frac{\cancel{\mathrm{m}}}{\cancel{\mathrm{m}} \cdot \mathrm{s}^{-2}}} = \mathrm{s}}$$

Definition of the SI base units

In 2019 the most fundamental of all the units, time, was redefined.

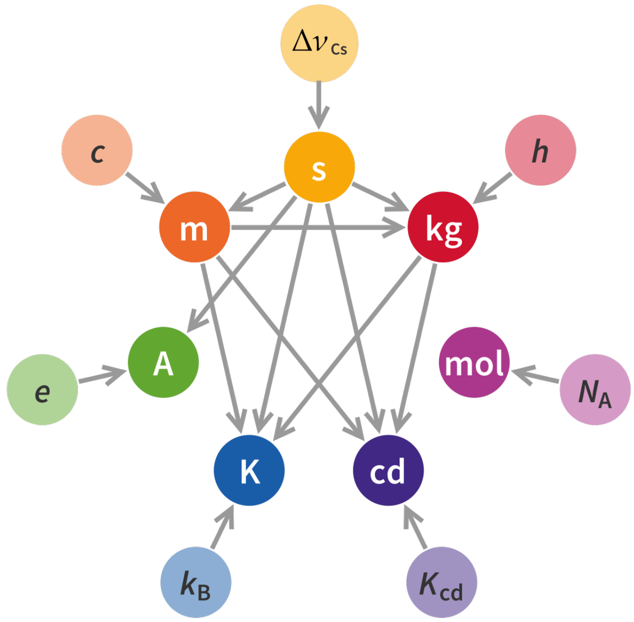

Figure 1: 2019 redefinition of the SI base units.

Importance of units

A wrong use of units can lead to disaster.

"Schoolkid blunder brought down Mars probe"

NASA lost his $125 million Mars Climate Orbiter spacecraft as a result of a mistake that would shame a first-year physics student, failing to convert Imperial units to metric.

"Gimli slider"

good practice can help you to,
detect if you are using a correct equation.
detect if all the units used in the equation are compatible.
This are very common mistakes that an A-Level physics student does.

Standard form & Metric prefixes

Big and small numbers are inconvenient to write down. Scientists and engineers use **standard form** to make things clearer.

$$\textbf{number in standard form} = \textbf{mantissa} \times \textbf{power of ten}$$

The **mantissa** is a number **bigger** than or equal to **1**, but **less** than **10**.

- **Example:** Two numbers written in both ways "normal form" and standard form.

Normal form		Standard form
450000	=	$\underbrace{4.5}_{\text{mantissa}} \times \underbrace{10^5}_{\text{power of ten}}$
0.000032	=	$\underbrace{3.2}_{\text{mantissa}} \times \underbrace{10^{-5}}_{\text{power of ten}}$

Metric prefixes are used **in front of the units** to change the magnitude. It is a quick way to re-scale the unit. You must memorise this metric prefixes (SPEC. 1.1.3):
YouTube video on Power of Ten (https://www.youtube.com/watch?v=bhofN1xX6u0)

Factor	Prefix	Symbol
10^3	kilo	k
10^6	mega	M
10^9	giga	G
10^{12}	tera	T

Factor	Prefix	Symbol
10^{-3}	mili	m
10^{-6}	micro	μ
10^{-9}	nano	n
10^{-12}	pico	p
10^{-15}	femto	f

- **Example 1: Newton to micro Newton.**
  0.00037 N $\longrightarrow$ x $\boldsymbol{\mu}$N

$$0.00037\,\cancel{\text{N}} \times \underbrace{\frac{1\ \mu\text{N}}{10^{-6}\ \cancel{\text{N}}}}_{\text{N}\rightarrow\ \mu\text{N}} = 370\ \mu\text{N} = 3.7 \times 10^2\ \mu\text{N}$$

- **Example 2: giga to mega square metre.**
  0.05 **G**m^2 $\longrightarrow$ x **M**m^2

$$0.05\,\cancel{\text{Gm}^2} \times \underbrace{\frac{10^9\ \cancel{\text{m}^2}}{1\ \cancel{\text{Gm}^2}}}_{\text{Gm}^2\ \rightarrow\ \text{m}^2} \times \underbrace{\frac{1\ \text{Mm}^2}{10^6\ \cancel{\text{m}^2}}}_{\text{m}^2\ \rightarrow\ \text{Mm}^2} = 50\ \text{Mm}^2 = 5.0 \times 10^1\ \text{Mm}^2$$

- **Example 3: micro to giga Pascal.**
  5×10^{10} $\boldsymbol{\mu}$Pa $\longrightarrow$ x **G**Pa

$$5 \times 10^{10}\ \cancel{\mu\text{Pa}} \times \underbrace{\frac{10^{-6}\ \cancel{\text{Pa}}}{1\ \cancel{\mu\text{Pa}}}}_{\mu\text{Pa}\rightarrow\ \text{Pa}} \times \underbrace{\frac{1\ \text{GPa}}{10^9\ \cancel{\text{Pa}}}}_{\text{Pa}\rightarrow\ \text{GPa}} = 5 \times 10^{10} \times 10^{-15}\ \text{GPa} = 5.0 \times 10^{-5}\ \text{GPa}$$

Standard form & Metric prefixes questions/homework:

(1) *Prefix:* Complete the following puns based on the **SI** metric prefixes. [2]

(a) 1 **millionth** of a fish equals.

(b) 1 **trillion** pins equal.

(c) 1 **thousan** legs equal.

(d) 1 **billionth** of a chocolate bar equal.

(e) 1 **quadrillionth** of a boy equals.

(f) 1 **trillionth** of a door equals.

(g) 1 **billion** microphones equal.

(h) 1 **million** pains equal.

(i) 2000 mockingbirds equal.

(j) 1021 piccolos equal.

(1) Convert the following quantities to the given units or prefixes and unit.

Before	After
3 km (into m)	
76 g (into mg)	
4 m (into mm)	
5.5 kg (into μg)	
0.46 m (into nm)	
6.008 g (into kg)	
0.00809 km (into m)	
5.009 kg (into g)	
101325 Pa (into MPa)	
0.050508 J (into mJ)	

(2) *Tom Duff*, at Bell Labs is reported to have said that "π seconds is a nano-century". Show that he was more or less correct. [2]

(3) *J. V. Neumann sentence:* The mathematician John von Neumann is reputed to have said that a lecture should never last longer than a "microcentury". How long is this in more familiar time units? [2]

(4) *Nanoacres:* The nanoacre is a unit invented by computer engineers as a joke. It is said that one nanoacre of an integrated circuit (a computer chip) costs about the same to develop as an acre of real estate. Determine the length of the side of a square with an area of one nanoacre in. [2]

(a) inches

(b) millimeters

Change of units

In some occasions the units in a problem are not given in the SI system or you are requested to give an answer in units out of the SI system. In this cases you will need to change units. To change units you need to know how many times you can fit one unit in the other. This is known as **conversion factor**. Some examples of conversion factors are,

From	To	Conversion factor
meters	millimetres	$\frac{1000\,\text{mm}}{1\,\text{m}}$ (In one meter you can fit 1000 millimetres)
miles	kilometres	$\frac{1.61\,\text{km}}{1\,\text{mi}}$ (In one mile you can fit 1.61 kilometres)
minutes	seconds	$\frac{60\,\text{s}}{1\,\text{min}}$ (In one minute you can fit 60 seconds)

Table 3: Examples of conversion factors between different units.

The use of conversion factors is the most **systematic** and **safest** method to change units. Find some examples of this method below.

Example 1: Time: Base unit. 3 hours $\longrightarrow$ x seconds

$$3\text{ h} = 3\cancel{\text{h}} \times \underbrace{\frac{60\cancel{\text{ min}}}{1\cancel{\text{ h}}}}_{\text{h}\to\text{ min}} \times \underbrace{\frac{60\text{ s}}{1\cancel{\text{ min}}}}_{\text{min}\to\text{ sec}} = 10800\text{ s}$$

Example 2: Time: Base unit, reverse. 10800 s $\longrightarrow$ x h

$$10800\text{ s} = 10800\cancel{\text{s}} \times \underbrace{\frac{1\cancel{\text{ min}}}{60\cancel{\text{ s}}}}_{\text{s}\to\text{ min}} \times \underbrace{\frac{1\text{ h}}{60\cancel{\text{ min}}}}_{\text{min}\to\text{ h}} = 3\text{ h}$$

Example 3: Speed: 450 kn (knots=nautical mile/hour) $\longrightarrow$ x m/s

$$450\text{ kn} = 450\frac{\cancel{\text{NM}}}{\cancel{\text{h}}} \times \overbrace{\underbrace{\frac{1.852\cancel{\text{ km}}}{1\cancel{\text{ NM}}}}_{\text{NM}\to\text{ km}} \times \underbrace{\frac{1000\text{ m}}{1\cancel{\text{ km}}}}_{\text{km}\to\text{ m}}}^{\text{length conversion}} \times \overbrace{\underbrace{\frac{1\cancel{\text{ h}}}{60\cancel{\text{ min}}}}_{\text{h}^{-1}\to\text{ min}^{-1}} \times \underbrace{\frac{1\cancel{\text{ min}}}{60\text{ s}}}_{\text{min}\to\text{ sec}}}^{\text{time conversion}} = 232\text{ m}\cdot\text{s}^{-1}$$

Example 4: Density. 1 g/cm^3 $\longrightarrow$ kg/m^3

$$1\,\frac{\text{g}}{\text{cm}^3} = 1\,\frac{\cancel{\text{g}}}{\cancel{\text{cm}^3}} \times \underbrace{\frac{1\text{ kg}}{1000\cancel{\text{ g}}}}_{\text{g}\to\text{ kg}} \times \underbrace{\frac{(100\cancel{\text{ cm}})^3}{(1\text{ m})^3}}_{\text{cm}^{-3}\to\text{ m}^{-3}} = 1000\times\frac{\text{kg}}{\text{m}^3} = 1\,\frac{\text{Mg}}{\text{m}^3}$$

Dimensional analysis

Dimensional analysis is a powerful technique that can be applied to different situations We are going to cover the most likely situations where you need to apply dimensional analysis. Four typical applications of dimensional analysis in CCEA past paper problems:

1. Homogeneity of physics equations (validating equations)

Units must be **consistent** on both sides of the equal sign.

- **Example: Is this equation dimensionally correct?**

$$\frac{Ev}{a^3t^3} = 5m \qquad \text{where:} \qquad \begin{array}{ll} E = & \text{Energy} \\ v = & \text{velocity} \\ a = & \text{acceleration} \\ t = & \text{time} \\ m = & \text{mass} \end{array}$$

Substituting the physical quantities by its **SI base units** in the previous equation (on page 3 we wrote the energy (E) in terms of its SI base units):

$$\frac{\overbrace{(\mathrm{kg \cdot m^2 \cdot s^{-2}})}^{E} \cdot \overbrace{(\mathrm{m \cdot s^{-1}})}^{v}}{\underbrace{(\mathrm{m \cdot s^{-2}})^3}_{a^3} \; \underbrace{\mathrm{s^3}}_{t^3}} = 5 \; \overbrace{\mathrm{kg}}^{m}$$

The numbers dividing or multiplying the **units equation** do not affect the units and can be neglected.

$$\frac{(\mathrm{kg \cdot m^2 \cdot s^{-2}}) \cdot (\mathrm{m \cdot s^{-1}})}{(\mathrm{m \cdot s^{-2}})^3 \; \mathrm{s^3}} = \cancel{5} \; \mathrm{kg}$$

Simplifying the expression,

$$\frac{\mathrm{kg} \cdot \cancel{\mathrm{m}^3} \cdot \cancel{\mathrm{s}^{-3}}}{\cancel{\mathrm{m}^3} \cdot \cancel{\mathrm{s}^{-3}}} = \mathrm{kg} \Longrightarrow \boxed{\text{The equation is homogeneous}}$$

(but not necessarily meaningful)

2. Apply homogeneity to derive units of constants:

- **Example: What are the units of the unknown constant *G*?**

$$F = G\,\frac{m_1 \cdot m_2}{d^2} \qquad \text{where:} \qquad \begin{array}{ll} F = & \text{force} \\ m_1 = & \text{mass} \\ m_2 = & \text{mass} \\ d = & \text{distance} \end{array}$$

Solution:
Replace the known physical quantities by its **SI base units** in the previous equation (on page 3 we wrote the force (F) in terms of its SI base units,

$$\overbrace{(\mathrm{kg}\cdot\mathrm{m}\cdot\mathrm{s}^{-2})}^{F} = [G]\,\frac{\overbrace{\mathrm{kg}}^{m_1}\cdot\overbrace{\mathrm{kg}}^{m_2}}{\underbrace{\mathrm{m}^2}_{d^2}}$$

Solve the equation for the units of G represented as $[G]$ (do it!),

$$\boxed{[\boldsymbol{G}] = \qquad\qquad}$$

This is the equation used to calculate gravitational force and G is known as universal gravitational constant. This will be studied in A2.

3. Dimensionless argument of some functions.

The **argument** of a **trigonometric**, **logarithmic**, or **exponential** function **must** be always **dimensionless**.

- **Example 1: Derive the units of ω for the displacement of a pendulum,**

$$\boldsymbol{x(t) = A\cos(\omega\, t)} \qquad \text{where } A \text{ represents amplitude and } t \text{ time}$$

The argument of the trigonometric function cos, in this case ωt, must be dimensionless, therefore,

$$[\omega]\cdot[t] = \underbrace{1}_{\text{no units}} \Longrightarrow [\omega]\cdot\ \mathrm{s} = 1 \Longrightarrow \boxed{[\omega] = \mathrm{s}^{-1}}$$

- Comment: ω is known as angular velocity.

4. Change of base units.

This type of theoretical exercise it is *rarely* required by CCEA, but it has appeared.

- **Example: Imagine that you want to use Newton and Hertz as base units instead of kilogram and second. What would be the units of energy in this new base?**

Method 1: Intuitive.
From the definition of work as force times displacement we can directly write the units of energy as Newton times metre that is a direct way of writing the energy in the new base.

$$\boxed{[E] = \ \mathrm{N}\cdot\mathrm{m}}$$

Method 2: systematic.
The new units of energy will be a combination of the new base (N,m,Hz,A,K,mol).

$$\text{units of energy} = [E] = \ \mathrm{N}^x m^y \ \mathrm{Hz}^z$$

we do not assume dependence in current, temperature or mole. x, y, and z are the three exponents to be determined to obtain the dependence of the energy on the new base.

Writing the new base in terms of the old one,

$$\underbrace{\mathrm{kg}\cdot\mathrm{m}^2\cdot\mathrm{s}^{-2}}_{\text{energy}} = (\underbrace{\mathrm{kg}\cdot\mathrm{m}\cdot\mathrm{s}^{-2}}_{\mathrm{N}})^x m^y (\underbrace{\mathrm{s}^{-1}}_{\mathrm{Hz}})^z$$

we can write an equation for each unit,

$$\begin{aligned} \mathrm{kg}^1 &= \ \mathrm{kg}^x \\ \mathrm{m}^2 &= \ \mathrm{m}^x \ \mathrm{m}^y \\ \mathrm{s}^{-2} &= \ \mathrm{s}^{-2x} \ \mathrm{s}^{-z} \end{aligned}$$

solving the equations, we obtain $x = 1$, $y = 1$, and $z = 0$, therefore,

$$\boxed{[E] = \ \mathrm{N}\cdot\mathrm{m}}$$

What would be the units of **speed** in this new base? (do it!)

$$\boxed{[v] = \qquad\qquad}$$

5. Guessing equations from parameters of a system.

In some occasions (not always!) one can use dimensional analysis to derive the equations of a particular physical system.

Example: Derive the equation for the period T of a pendulum just considering its main parameters: Length ℓ, mass m and gravity g. You can consider the following functional dependence.

$$T = \ell^x \, g^y \, m^z$$

Solution:
In this case let us replace the quantities by the base dimensions,

$$\underbrace{T^1\cdot L^0\cdot M^0}_{\text{period}} = (\underbrace{L}_{\text{length}})^x \, (\underbrace{L\cdot T^{-2}}_{\text{gravity}})^y \, (\underbrace{M}_{\text{mass}})^z$$

this equation must be true for every dimension,

for time dimension: $T^1 = T^{-2y} \Longrightarrow 1 = -2y \Longrightarrow y = -1/2$

for length dimension: $L^0 = L^x \cdot L^{-\frac{1}{2}} \Longrightarrow 0 = x - 1/2 \Longrightarrow x = 1/2$

for mass dimension: $M^0 = M^z \Longrightarrow z = 0$ (does not depend on mass!)

Therefore, the period of a pendulum has the following dependence on the length and gravity:

$$\boxed{T \sim \sqrt{\frac{\ell}{g}}}$$

(there is a prefactor 2π that can't be obtained with this analysis)

Dimensional analysis questions/homework:

(1) A simple pendulum consists of a mass on the end of a length of string. If the length of the string is $\boldsymbol{\ell}$ and $\boldsymbol{g}$ is the acceleration of free fall, then the time to complete one oscillation, called the period, is $\boldsymbol{T}$, where: [3] p. 7 pb. 3.

$$T = 2\pi\sqrt{\frac{\ell}{g}}$$

Show that the **base units** of both sides of the equation are identical.

(2) A mass attached to a spring will oscillate up and down when disturbed. The period $\boldsymbol{T}$ of such oscillations is given by: [3] p. 7 pb. 4.

$$T = 2\pi\sqrt{\frac{m}{k}}$$

The mass is m and k is the spring constant, ie the force needed to stretch the spring by 1 m. The units of k are Nm^{-1}. Show that the equation is **homogeneous** in terms of the **base units** on each side.

(3) *Dimensional consistency:* Determine which of the following expressions are dimensionally consistent. Let [a]= $\mathrm{m/s^2}$, [t]=s, [v]= m/s, and [x]= m. [2]

(a) $v^2 = 2ax$ **(b)** $x = v\,t + \frac{1}{2}a\,t^3$ **(c)** $\tan\theta = \frac{v}{x}$

(d) $v = x\,t$ **(e)** $x = a\,t^{\frac{2}{3}}$ **(f)** $t = \sqrt{\frac{v^2}{ax}}$

(4) *Determine* which of the following expressions are dimensionally consistent. Let [a]= $\mathrm{m/s^2}$, [t]=s, [v]= m/s, and [x]= m. [2]

(a) $v = xt$

(b) $x = vt$

(c) $t = vx$

(d) $x = at + \frac{1}{2}at^2$

(e) $x = vt + \frac{1}{2}at^3$

(f) $v^2 = 2ax^2$

(g) $x = \sqrt{\frac{2a}{t}}$

(h) $t = \sqrt{\dfrac{2x}{a}}$

(i) $t = \sqrt{\dfrac{v^2}{ax}}$

(j) $\tan(\theta) = \dfrac{x}{y}$

(k) $\log(\theta) = \dfrac{y}{x}$

(l) $\cos(\theta) = \dfrac{v}{at}$

(5) *Constants dimensions:* Determine the SI units of the constants C_1 and C_2 so that the following expressions are dimensionally correct. [2]

(a) $x = C_1 + C_2\, t$

(b) $x = C_1\, t + \dfrac{1}{2} C_2\, t^2$

(c) $v = C_1\, t + C_2\, t^2$

(d) $x = C_1\, \sin(2\pi C_2\, t)$

(d) $v = \dfrac{1}{2} C_1\, e^{-C_2\, t}$

(6) *Coupled derivation:* Derive the unit for the quantity P given the following equations. [2]

$$\begin{aligned} v &= \frac{x}{t} \\ a &= \frac{v}{t} \\ F &= ma \\ W &= Fx \\ P &= \frac{W}{t} \end{aligned}$$

(7) In the formula below the symbol U is measured in kg $\mathrm{m}^2/\mathrm{s}^2$ (i.e. energy units, Joules) and x stands for length. What are the units of k?

$$U = \frac{1}{2} k\, x^2$$

(8) *Superman's land:* On the planet Krypton the same laws of Physics apply as on the Earth. However, the inhabitants of Krypton have decided to use **force** (F), **acceleration** (a) and **time** (t) as their **base units** (instead of Mass (m), Length (l), and time (t)).
What are the base units of **energy** on the planet Krypton? [3] p. 7 pb. 2.

Scalars and vectors

Graphical addition/subtraction of vectors

References

[1] A. Machacek, J. Crowter, and L. Jardine−Wright, Mastering Essential pre-university PHYSICS. 2018.

[2] G. Elert, “The physics hyper textbook.”

[3] P. Carson and R. White, Physics for CCEA AS Level. 2016.