2. Physical Quantities and Units

Physics is a subject area built upon fundamental laws, theories, concepts and a few assumptions connected to matter and energy, able to explain natural phenomena and also on experimental results. When presenting these laws and theories it is necessary to make use of various qualities of systems. These qualities are known as physical quantities. A number of physical quantities are used when performing experiments and in most cases facts about certain physical quantities are revealed from the experimental results. A physical quantity has a magnitude. When this magnitude is obtained practically it is called a **measurement**. A measurement has a numerical value and a scale (or unit) corresponding to it. In order to determine the numerical value of a measurement, measuring instruments are used.

This unit deals with measurements in a long way. Also considered in this chapter as well as in chapter 3 are physical quantities representing various qualities of systems, their units and dimensions and equations and expressions obtained by combining some of them. In addition chapter 4 deals with several measuring instruments used in experiments coming under the G.C.E. (A.L.) syllabus.

Physical Quantities

If a certain quality possessed by a system can be measured directly or indirectly, that quality is referred to as a **Physical quantity.**

A physical quantity always has a magnitude. Mostly it has a unit and sometimes a direction too. Accordingly, physical quantities can be classified into three groups.

(a). Physical quantities having a magnitude, unit and direction. These are known as vector quantities. Velocity, force and acceleration are several examples.

(b). Physical quantities having a magnitude and unit only, but no specific direction. These are known as scalar quantities. Distance, speed and energy are several examples.

(c). Physical quantities having a magnitude only. Refractive index, strain and efficiency are several examples.

In addition physical quantities can be divided in to two groups, such as those which can be measured directly and those which can be measured indirectly.

Example

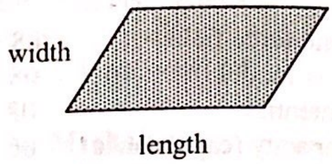

Figure 2.1

Figure 2.1 shows a rectangular shaped paper. Its length and width (which is also a length) can be measured directly by a meter ruler. Its mass can be measured directly by a balance. This length and mass are physical quantities which can be measured directly.

The area of the paper cannot be measured directly. It is a quantity obtained by multiplying length with width. This area can be mentioned as a physical quantity which can be obtained indirectly.

Example

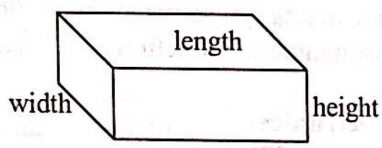

Figure 2.2

The Figure 2.2 shows a brick. Its length, width and height can be measured by a meter ruler and its mass by a balance directly. Width and height are all lengths and length and mass are quantities which can be measured directly.

By multiplying two of length, width and height together at a time the area of each face can be calculated. By multiplying all three quantities together, the volume of the brick can be calculated.

Scanned with CamScanner

Area (A_1) = length × width
Area (A_2) = length × height
Area (A_3) = width × height

Volume (V) = length × width × height

Accordingly, area and volume are two quantities which cannot be measured directly.

Since the density of the substance of the brick is found by dividing mass by volume, density too is a physical quantity which cannot be measured directly.

density = mass / volume

Example

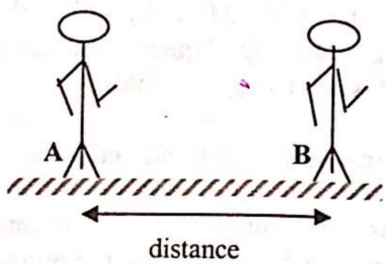

Figure 2.3

Figure 2.3 shows a boy running from a place A to a place B. The distance between these two places, which is the distance run by the boy, can be measured by a meter ruler while his time of running can be measured by a stop watch. Thus both distance and time are physical quantities which can be measured directly.

The speed with which the boy ran can be calculated by dividing distance by time.

speed = distance / time

This speed (or velocity) is a physical quantity which cannot be measured directly.

Fundamental Physical Quantities

Physical quantities such as length (distance), mass and time mentioned above have been combined to drive other physical quantities. Furthermore, those three physical quantities can be measured directly most of the time. Hence these physical quantities are known as **fundamental physical quantities.** There are seven fundamental physical quantities as follows.

1. Length
2. Mass
3. Time
4. Thermodynamic temperature
5. Electric current
6. Amount of a substance
7. Luminous intensity

Units

As mentioned earlier a physical quantity has a magnitude and mostly a unit.

Examples

The length of a table is 2 m.
The distance from Colombo to Galle is 115 km.
A boy has a mass of 50 kg.
The average age of a student in the Advanced Level class is 17 yrs.

The magnitude of a physical quantity is represented relative to a certain reference standard. This reference standard is referred to as a **unit**.

For an example let us take the unit kilogram used to measure the mass. A kilogram is considered as the mass equal to the mass of a cylindrical international prototype made of platinum and iridium metals and placed at the International Bureau of weights and measures in the city of France. The magnitude of the mass of an object is obtained by comparing with the mass of this prototype. It is found how many times (X) the mass of the object is that of the prototype and the unit is noted as kg.

Mass of the object = X kg

Basic Units

Units used for fundamental physical quantities are known as fundamental units or basic units.

Various basic unit systems have been used in different countries during various periods of time. In Sri Lanka too various unit systems were used in the earlier decades. For instance, the British system of units was used in Sri Lanka during a certain era. In this system, the "foot" was used for length, the "pound" for mass and the "minute" for time. In the recent past the C.G.S. system was used here. In this system, the "centimeter" was used for length, the "gram" for mass and the "second" for time.

Due to the usage of different unit systems by different countries, many difficulties arose in the commercial activities as well as in the exchange of knowledge among countries. Hence it was decided at a convention held in Geneva in 1960, that a unique system of units should be used by all countries. This unit system came to be known as the system of international units (systeme international d'unite's) and is commonly referred to as SI unit system.

According to SI system of units seven SI basic units of seven fundamental physical quantities have been defined. Stated below are the definitions of these seven SI basic units (Memorization of these definitions is not required).

Definitions of SI basic units

Length – meter (m)

A meter is the length of 1,650,763.73 wave lengths in a vacuum of radiation corresponding to transference between the energy levels $2p^{10}$ and $5d^5$ of Krypton – 86 atom.

Mass – kilogram (kg)

The unit of measuring mass is the kilogram (kg). It is equal to the mass of the cylindrical international prototype made of Platinum and Iridium metals.

Time – second (s)

A second is the time taken for 9,192,631,770 oscillations (periods) of radiation corresponding to transference between two hyper fine levels in the ground state of Cesium – 133 atom.

Thermodynamic Temperature – Kelvin (K)

A Kelvin, the unit of thermodynamic temperature is $1/273.16^{th}$ of the temperature of the triple point of water.

Electric current – Ampere (A)

An ampere is that current when passes equally through two parallel 1 m apart straight infinitely long conductors of negligible circular cross - sections produces a mutual force of 2×10^7 Nm^{-1} between them.

Amount of matter – mole (mol)

Amole is the amount of matter containing the number of fundamental entities equal to the number of atoms in 0.012 kg of Carbon 12 isotope. (Important : fundamental entities should be specified when using the mole)

Luminous intensity – candela (cd)

A candela is the luminous intensity normally by 1/600000 m^2 of a black body at the temperature of Platinum freezing under a pressure of 101.325 Nm^{-2}.

SI Supplementary units

There are two supplementary units in the SI unit system. They are as follows.

Plane angle

The supplementary unit for measuring the plane angle is the radian and its symbol is **rad**.

Solid angle

The supplementary unit for measuring the solid angle is the steradian and its symbol is **sr**.

Derived Physical Quantities and Derived SI Units

Those quantities formed by combining a number of fundamental physical quantities are known as derived physical quantities.

Eg. 1 - volume = length × length × length
Eg. 2 - velocity = displacement / time
Eg. 3 - acceleration = velocity / time
Eg. 4 - force = mass × acceleration

Sometimes the derived unit is expressed by a single name. The names of a number of eminent scientists who have rendered yeoman services in the field of Physics are been used for many of these single names.

Eg. Unit of force is $kgms^{-2}$.
This unit is referred to as the "Newton" (N)

Given below are the SI derived units and their corresponding derived physical quantities. Also shown are the ways how the derived physical quantities are related to the fundamental physical quantities.

SI derived units with special names

1. Force = mass × acceleration
   SI unit = $kg\ m\ s^{-2}$
   = N (Newton)

2. Pressure = force / area
   SI unit = $kg\ m^{-1}\ s^{-2}$
   = Pa (Pascal)

3. Work = force × displacement
   SI unit = $kg\ m^2\ s^{-2}$
   = J (Joule)

4. Power = work / time
   SI unit = $kg\ m^2\ s^{-3}$
   = W (Watt)

5. Frequency = 1 / periodic time
   SI unit = s^{-1}
   = Hz (Hertz)

6. Electric charge = electric current × time
   SI unit = A s
   = C (Coulomb)

7. Electric potential = work / charge
   SI unit = $kg\ m^2\ A^{-1}\ s^{-3}$
   = V (Volt)

8. Electric resistance = electric potential / current
   SI unit = $kg\ m^2\ A^{-2}\ s^{-3}$
   = Ω (Ohm)

9. Electric conductance = 1/electric resistance
   SI unit = $A^2\ s^3\ kg^{-1}\ m^{-2}$
   = S (Siemens)

10. Capacity (capacitance) = electric charge / electric potential
    SI unit = $s^4\ A^2\ kg^{-1}\ m^{-2}$
    = F (Farad)

11. Magnetic flux density = Force / (current × length)
    SI unit = $kg\ A^{-1}\ s^{-2}$
    = T (Tesla)

12. Magnetic flux = magnetic flux density × area
    SI unit = $kg\ m^2\ A^{-1}\ s^{-2}$
    = Wb (Weber)

13. Inductance = electric potential × time / current
    SI unit = $kg\ m^2\ s^{-2}\ A^{-2}$
    = H (Henry)

14. Luminous flu = luminous intensity × solid angle
    SI unit = cd sr
    = Lm (Lumen)

Shown below are those SI derived units which do not have special names and their corresponding physical quantities.

SI derived units without special names

1. Area = length × length
   SI unit = m^2

2. Volume = length × length × length
   SI unit = m^3

3. Density = mass /volume
   SI unit = $kg\ m^{-3}$

4. Velocity = displacement / time
   SI unit = $m\ s^{-1}$

5. Acceleration = change in velocity / time
   SI unit = $m\ s^{-2}$

6. Moment of a force = force × perpendicular distance
   SI unit = $kg\ m^2\ s^{-2}$ = N m

7. Momentum = mass × velocity
SI unit = $kg\ m\ s^{-1}$

8. Impulse = force × time
SI unit = $kg\ m\ s^{-1} = N\ s$

9. Angular velocity = angle / time
SI unit = $rad\ s^{-1}$

10. Angular acceleration = angular velocity / time
SI unit = $rad\ s^{-2}$

11. Moment of Inertia = mass × distance^2
SI unit = $kg\ m^2$

12. Torque = moment of inertia × angular acceleration
SI unit = $kg\ m^2\ rad\ s^{-2}$

13. Angular momentum = moment of inertia × angular velocity
SI unit = $kg\ m^2\ rad\ s^{-1}$

14. Stress = force/ normal area
SI unit = $kg\ m^{-1} s^{-2}$

15. Strain = extension / initial length
SI unit = 1 (none)

16. Young's modulus = Stress / Strain
SI unit = $kg\ m^{-1}\ s^{-2}$

17. Tangential pressure = force /contact area
SI unit = $kg\ m^{-1}\ s^{-2}$

18. Velocity gradient = change in velocity / depth
SI unit = s^{-1}

19. Coefficient of viscosity = Tangential pressure / velocity gradient
SI unit = $kg\ m^{-1}\ s^{-1}$

20. Volume rate = volume / time
SI unit = $m^3\ s^{-1}$

21. Pressure gradient = pressure difference / length
SI unit = $kg\ m^{-2}\ s^{-2}$

22. Surface tension = force / length
SI unit = $kg\ s^{-2}$

23. Linear density = mass / length
SI unit = $kg\ m^{-1}$

24. Coefficient of expansion = expansion / (length × temperature difference)
SI unit = K^{-1}

25. Thermal capacity = heat energy / temperature difference
SI unit = $kg\ m^2\ s^{-2}\ K^{-1}$

26. Specific heat capacity = heat energy / (mass × temperature difference)
SI unit = $m^2\ s^{-2}\ K^{-1}$

27. Specific latent heat = heat energy / mass
SI unit = $m^2\ s^{-2}$

28. Rate of loss of heat = heat energy / time
SI unit = $kg\ m^2\ s^{-3}$

29. Rate of change of temperature = temperature difference / time
SI unit = $K\ s^{-1}$

30. Surface thermal emissivity = rate of loss of heat / (area × temperature difference)
SI unit = $kg\ K^{-1}\ s^{-3}$

31. Temperature gradient = temperature difference / length
SI unit = $K\ m^{-1}$

32. Thermal conductivity = rate of conduction of heat / (area × temperature gradient)
SI unit = $kg\ m\ K^{-1}\ s^{-3}$

33. Electric resistivity = resistance × area / length
SI unit = $kg\ m^3\ A^{-2}\ s^{-3}$

34. Electric current density = current / area
SI unit = $A\ m^{-2}$

35. Permittivity = capacitance × area / length
SI unit = $A^2\ s^4\ kg^{-1}\ m^{-3}$

36. Charge density = charge / area
SI unit = $A\ s\ m^{-2}$

37. Electric field intensity = force / charge
SI unit = $kg\ m\ A^{-1}\ s^{-3}$

38. Potential gradient = potential difference / distance
    SI unit = kg m A^{-1} s^{-3}

39. Permeability = flux density × length / current
    SI unit = kg m s^{-2} A^{-2}

40. Electric conductivity = 1 / resistivity
    SI unit = A^2 s^3 kg^{-1} m^{-3}

Note 2.1

Mentioned above are the units of all physical quantities included in the syllabus. Do not attempt to memorize writing of all these units right now. Remember only the units of those quantities you already know.

The magnitudes of physical quantities vary within very wide ranges from extremely low values to extremely high values. Shown below are some tables illustrating the variation of the quantities length, mass and time within wide ranges.

Distance or length	Order meters
Diameter of a proton	10^{-15}
Diameter of a heavy nucleus	10^{-14}
Wave length of gamma rays	10^{-12}
Average distance between atoms of a crystalline solid substance	10^{-10}
Distance between atoms of air in a room	10^{-8}
Wave length of visible light	10^{-7}
Diameter of a red corpuscle	10^{-5}
Thickness of a paper	10^{-4}
Thickness of a glass window pane	10^{-3}
Diameter of a pencil	10^{-2}
Length of a pencil	10^{-1}
Height of a boy	$10^{0} = 1$
Height of a three storied building	10^{1}
Length of a foot ball ground	10^{2}
Maximum depth of the ocean	10^{4}
Diameter of the Moon	10^{6}
Diameter of the Earth	10^{7}
Distance from the Earth to the Moon	10^{8}
Diameter of the Sun	10^{9}
Distance from the Sun to the Earth	10^{11}
Distance from the Sun to the Saturn	10^{12}
Distance to the nearest star	10^{17}
Observed end of the Universe	10^{27}

Measurement of mass are obtained within a large range.

Object	Order of mass (kg)
An electron	10^{-31}
A proton	10^{-27}
A heavy atom	10^{-25}
A corpuscle	10^{-22}
A simple live cell	10^{-10}
An apple	10^{-1}
A liter of water	$10^{0} = 1$
A dog	10^{1}
A man	10^{2}
An elephant	10^{6}
A large aero plane	10^{6}
The Moon	10^{22}
The Earth	10^{25}
The Sun	10^{30}
A star	$10^{32} - 10^{38}$
Galaxy	10^{41}

In measuring time too, measurements range from very small values to very large values. Shown below is such a table.

Phenomenon	Duration (s)
Traveling of light across the nucleus of an atom	10^{-24}
A proton makes one complete revolution inside the nucleus of an atom	10^{-22}
An electron makes one revolution along an internal orbit, around the nucleus of a heavy atom	10^{-20}
The electron of the hydrogen atom revolves around the proton	10^{-15}
Traveling of light cross a glass window pane	10^{-11}
Traveling of light across the class room	10^{-11}

One vibration of a high frequency sound note	10^{-4}
One revolution of an electric fan	10^{-2}
Flight of a rifle bullet across a foot ball ground	10^{-1}
Periodic time of a clock pendulum	$10^{0} = 1$
Running time for 100 m of a short distance runner	10^{1}
Time taken for light to travel from the Sun to the Earth	10^{3}
Periodic time of revolution of the Earth around the Sun (1 year)	10^{7}
Life period of man	10^{9}
Half life period of Radium	10^{10}
Time from the era of Christ up to the present	10^{11}
Time from the most ancient man up to the present	10^{13}
Period for one revolution of Sun around galaxy	10^{16}
Age of the oldest fossil	10^{17}
Expected life period of the Sun, considered as a normal star	10^{18}

It is not easy to write and read the value of physical quantity if it is extremely small or extremely large. In such instances the multiples or sub – multiples of SI units are represented by using prefixes. The following table shows the multiple factor name and symbol of several prefixes.

Multiple factor	Name of prefix	Symbol
10^{18}	exa	E
10^{15}	peta	P
10^{12}	tera	T
10^{9}	giga	G
10^{6}	mega	M
10^{3}	kilo	k
10^{2}	hecto	h
10^{1}	deca	da
10^{-1}	deci	d
10^{-2}	centi	c
10^{-3}	milli	m
10^{-6}	micro	μ
10^{-9}	nano	n
10^{-12}	pico	p
10^{-15}	femto	f
10^{-18}	atto	a

Note 2.2

When writing the value of a physical quantity with a prefix, the symbol of the prefix should be written in front of the SI symbol without leaving a gap between the two. No dots or commas should be marked between the prefix and the SI unit.

Examples

$$\frac{1}{1000}\,\text{s} = 1 \times 10^{-3}\,\text{s} = 1\ \text{ms}$$

$$\frac{1}{100}\,\text{m} = 1 \times 10^{-2}\,\text{m} = 1\ \text{cm}$$

$$1000\ \text{m} = 1 \times 10^{3}\,\text{m} = 1\ \text{km}$$

Note 2.3

The only difference in this system is that the basic unit of mass in the SI system has been confirmed as a term with a prefix.

Note 2.4

When denoting units of derived quantity, a gap is places between its basic units.

Example

meter second = m s

Other units which can be used along with SI units

There are units which are permitted for use as they do not belong to SI type. However these units are to be used without interfering with the SI units. Especially during calculations, the two types of units should not be allowed to mix. Some of these units which are shown below can be used along with SI units without obstructions. Some units are used only in special cases while the others can be used generally.

Quantity	Name	Symbol	Note
Time	Minute	min	
Time	Hour	h	
Time	Day	d	
Plane angle	degree		
Plane angle	Minute		
Mass	metric ton	Mt	can be used instead of mega gram
Volume	liter	l	used when measuring fluids in commercial activities
Energy	Electr-on volt	eV	confined to nuclear and atomic sciences
Mass	atomic mass unit	U	limited to Physics
Distance	Astron-omical unit	AU	limited to Astronomy
Distance	parcec	pc	limited to Astronomy
Speed	kilometers per hour	km/h	limited to express running speed
Distance	Nauti-cal miles		limited to sea and air travels
Speed	knot		limited to sea and air travels
Area	hectare	ha	limited to land measure-ments
Tempera-ture and tempera-ture intervals		^{0}C	used when thermod-ynamic temperatu-re (Kelvin) is not relevant
Rotational frequency	Revolu tion per minute	rpm	

Note 2.5

(i) Prefixes mega, hector, kilo and mili are used with unit liter.
(ii) Prefixes kilo, mega, giga and tera can be used with unit electron volt.
(iii) No prefixes should be used with any of the other units in the above table.
(iv) Consider "h" as the symbol for hour. This is an international symbol, which is used in all languages.

Note 2.6

The logarithm of a quantity or a combination of quantities can be considered only if it has no units. That is logarithm can be considered only of a number.

Examples

(a) log $[X]$
Quantity X should not have units.

(b) $\log\left[\dfrac{XY}{Z}\right]$
Quantity $\dfrac{XY}{Z}$ should not have units.

Note 2.7

A certain quantity or a combination of quantities can be used as the index of the exponential function or of any other quantity or a number only if they do not possess a unit. That is, only a number can be used as an index.

Examples

(a) e^X, A^X, 10^X
where X has no units and e is the exponential function.

(b) $e^{XY/Z}$, $A^{XY/Z}$, $10^{XY/Z}$
where $\dfrac{XY}{Z}$ combination has no units.

Physical quantities without units

Certain physical quantities are derived as ratios of two quantities having the same unit. Hence these physical quantities have no units.

Examples

1. Relative density (specific gravity)
2. Relative humidity
3. Relative permittivity (dielectric constant)
4. Coefficient of friction
5. Refractive index
6. Efficiency
7. Strain

A few past examination questions and solutions

1. 2000 – Physics 1 - Question no. 1

One of the following units measures a physical quantity that is different from the physical quantity measured by the others. This is
(1) eV (2) J s^{-1} (3) W s (4) kW hours
(5) MeV

Solution

All units eV, Ws, kW hour and MeV measure energy. Unit J s^{-1} measures power. **(Answer 2)**

2. 2001 – Physics 1 – Question no. 1

eV (electron volt) is a unit of
(1) power (2) energy (3) charge (4) voltage
(5) potential difference

Solution

An electron volt is the energy acquired by an electron under a potential difference of one volt.
(Answer 2)

3. 2003 - Physics I – Question No. 1

The unit of intensity level of a sound wave is
(1) Hz (2) W (3) J m^{-2} (4) Wm^{-2} (5) dB

Solution

The frequency of a sound wave is denoted Hz, power by W, energy density by Jm^{-2}, intensity by Wm^{-2} and intensity level by dB. **(Answer 5)**

4. 2005 - Physics I – Question No. 2

In the equation $C = \sqrt{\frac{k}{\rho}}$, C is speed and ρ is density. The units of k are
(1) kg m s^{-2} (2) $kg^{1/2}$ s (3) kg m s^{-1}
(4) kg m^{-1} s^{-2} (5) kg $m^{1/2}$ s

Solution

When k is subjected in the question, $k = C^2 \rho$. Thus,

units of k = units of C^2 x units of ρ
= $(m\ s^{-1})^2$ x kg m^{-3}
= kg m^{-1} s^{-2} **(Answer 4)**

5. 2006 - Physics I – Question No. 1

Which of the following is **not** an SI unit?
(1) kg (2) m (3) s (4) A (5) k

Solution

SI units are kg, m, s, A, K, mol, cd and not k. but Kelvin K. **(Answer 5)**

6. 2007 - Physics I – Question No. 1

SI unit of surface tension is
(1) N (2) N m^{-1} (3) N m (4) N m^{-2} (5) N m^2

Solution

Surface tension = force / length
Unit = N/m = N m^{-1} **(Answer 2)**

Exercise 2

1. 1 Gg is equal to
   (1) 10^9 kg (2) 10^6 kg (3) 10^6 g
   (4) 10^{-9} kg (5) 10^{-9} g

2. Which one is the following is a prefix with a multiple?
   (1) p (2) n (3) c (4) d (5) k

3. Which of the following ratios of magnitudes of two prefixes is not equal to 1000?
   (1) n/p (2) m/ μ (3) M/k
   (4) μ/n (5) G/T

4. The four prefixes centi (c), kilo (k), mega (M), and nano (n) are arranged in the ascending order of their magnitudes in,
(1) c,k,M,n (2) n,c,k,M (3) n,k,c,M
(4) M,k,c,n (5) M,k,n,c

5. Which one of the following quantities has derived units?
(1) mass (2) length (3) time
(4) charge (5) amount of matter

6. Which of the following choices consists of an SI basic unit and SI supplementary unit?
(1) A, mol (2) K, rad (3) J, strad
(4) m,W (5) g, rad

7. Which of the following is not an SI derived unit with a single name?
(1) N (2) T (3) C (4) F (5) K

8. Which following physical quantity has a unit?
(1) strain (2) coefficient of friction
(3) coefficient of expansion
(4) relative density (5) relative humidity

9. Which of the following choices does not mention the fundamental physical quantity and its relevant SI basic unit?
(1) length - m (2) luminous intensity - cd
(3) amount of matter - mol
(4) electric current - A
(5) mass - g

10. Density of water is 1000 kg m^{-3}. This value when expressed as a gcm^{-3} unit is
(1) 1000 (2) 100 (3) 1 (4) 0.1 (5) 0.01

11. The unit kilowatt – hour (kWh) measures
(1) current (2) charge (3) power
(4) potential difference (5) energy

12. Consider the following physical quantities
a. force b. momentum c. impulse
Which following physical quantity has the unit N s?
(1) a only. (2) a only. (3) a and b only.
(4) b and c only. (5) all a, b and c

13. Which of the following unit cannot measure pressure?
(1) kg m s^{-2} (2) Pa (3) atmospheres
(4) cm of mercury (5) N m^{-2}

14. Given below are the five units used to measure distance.
a. millimeter b. micrometer c. angstrom
d. light year e. kilometer
The largest and the smallest units respectively of the above units are
(1) a and e (2) b and d (3) c and d
(4) c and e (5) b and d

15. The following expression is used to calculate a certain physical quantity.

$$\frac{\pi}{3}\left(a^2 - b^2\right)h$$

Where a, b and h are lengths and π is a numerical constant. This physical quantity calculated is
(1) velocity (2) acceleration (3) force
(4) area (5) volume

16. $F = G\frac{M_1 M_2}{d^2}$ is the equation expressing Newton's law of gravitation, where M_1 and M_2 are masses of two bodies and d the distance between their centers of mass. F is the mutual gravitational force between the two bodies. The unit of the universal gravitational constant (G) is
(1) m s^{-2} (2) N m kg^{-1} (3) m^3 kg^{-1} s^{-2}
(4) m^2 kg^{-2} (5) N m^2 kg^{-2}

17. The value of a certain quantity can be written as x kg m^{-2} s^{-2}. If this value is given as y g cm^{-2} s^{-2}, the relation between x and y is,
(1) $x = 10^{-2}\,y$ (2) $x = 10^{-1}\,y$ (3) $x = 10\,y$
(4) $x = 10^{2}\,y$ (5) $x = 10^{7}\,y$

18. The following equation expresses the magnitude of the electrostatic force between two charged particles of magnitudes Q_1 and Q_2 at a distance d apart.

$$F = \frac{1}{4\pi\xi}\frac{Q_1 Q_2}{d^2}$$

The units of the permittivity ξ of the medium in which the two charged particles are placed is
(1) C N^{-1} m^{-2} (2) C^2 N^{-1} m^{-2} (3) C^2 N m^{-2}
(4) C N m^{-2} (5) C N m^2

19. In the following equation V_1 and V_2 represent voltages and I_1 the electric current

$$V_1 = k_1 I_1 + k_2 V_2$$

Which of the following quantities has the unit of ratio k_1 / k_2?

(1) resistance (2) current (3) energy
(4) power (5) voltage

20. The velocity of sound in air is calculated using the equation,

$$V = k\sqrt{\frac{\gamma P}{\rho}}$$

Where γ is the ratio between the two principal specific heat capacities of air, P is the pressure of air and ρ is the density of air. When all quantities in the equation are measured in SI units, $k = 1$. When pressure is measured in $g\ cm^{-1}\ s^{-2}$ and density in, $g\ cm^{-3}$ in order to maintain $k = 1$ the unit by which the speed of sound should be measured is

(1) $km\ s^{-1}$ (2) $cm\ s^{-1}$ (3) $mm\ s^{-1}$
(4) $\mu m\ s^{-1}$ (5) $km\ ms^{-1}$

21. In equation

$$X = B\left[\frac{BLV}{R}\right]L$$

B, L, V and R are magnetic flux density, length, speed and resistance respectively. The quantity represented by X is

(1) potential difference
(2) electric current
(3) force
(4) power
(5) energy

(1) 2 (2) 5 (3) 5 (4) 2 (5) 4 (6) 2 (7) 5 (8) 3
(9) 5 (10) 3 (11) 5 (12) 4 (13) 1 (14) 3 (15) 5
(16) 5 (17) 3 (18) 2 (19) 1 (20) 2 (21) 3