CHAPTER

1 Units and Measurements

Section-A JEE Advanced/ IIT-JEE

A Fill in the Blanks

1. Planck's constant has dimension ________. *(1985 - 2 Marks)*

2. In the formula $X = 3YZ^2$, X and Z have dimensions of capacitance and magnetic induction respectively. The dimensions of Y in *MKSQ* sytem are _________, ________. *(1988 - 2 Marks)*

3. The equation of state for real gas is given by $\left(P+\frac{a}{V^2}\right)(V-b)=RT$. The dimensions of the constant a is _________. *(1997 - 2 Marks)*

C MCQs with One Correct Answer

1. The dimension of $\left(\frac{1}{2}\right)\varepsilon_0 E^2$ (ε_0 : permittivity of free space, E electric field) *(2000S)*
   (a) MLT^{-1} (b) ML^2T^{-2}
   (c) $ML^{-1}T^{-2}$ (d) ML^2T^{-1}

2. A quantity X is given by $\varepsilon_0 L\frac{\Delta V}{\Delta t}$ where ϵ_0 is the permittivity of the free space, L is a length, ΔV is a potential difference and Δt is a time interval. The dimensional formula for X is the same as that of *(2001S)*
   (a) resistance (b) charge
   (c) voltage (d) current

3. A cube has a side of length 1.2×10^{-2}m. Calculate its volume. *(2003S)*
   (a) $1.7 \times 10^{-6}\,m^3$ (b) $1.73 \times 10^{-6}\,m^3$
   (c) $1.70 \times 10^{-6}\,m^3$ (d) $1.732 \times 10^{-6}\,m^3$

4. Pressure depends on distance as, $P = \frac{\alpha}{\beta}\exp\left(-\frac{\alpha z}{k\theta}\right)$, where α, β are constants, z is distance, k is Boltzman's constant and θ is temperature. The dimension of β are *(2004S)*
   (a) $M^0L^0T^0$ (b) $M^{-1}L^{-1}T^{-1}$
   (c) $M^0L^2T^0$ (d) $M^{-1}L^1T^2$

5. A wire of length $\ell = 6 \pm 0.06$ cm and radius $r = 0.5 \pm 0.005$ cm and mass $m = 0.3 \pm 0.003$ gm. Maximum percentage error in density is *(2004S)*
   (a) 4 (b) 2
   (c) 1 (d) 6.8

6. Which of the following set have different dimensions? *(2005S)*
   (a) Pressure, Young's modulus , Stress
   (b) EMF, Potential difference, Electric potential
   (c) Heat, Work done, Energy
   (d) Dipole moment, Electric flux, Electric field

7. In a screw gauge, the zero of mainscale coincides with fifth division of circular scale in figure (i). The circular division of screw gauge are 50. It moves 0.5 mm on main scale in one rotation. The diameter of the ball in figure (ii) is *(2006 - 3M, –1)*

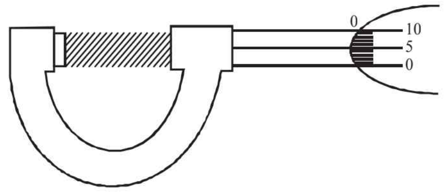


Figure (i)

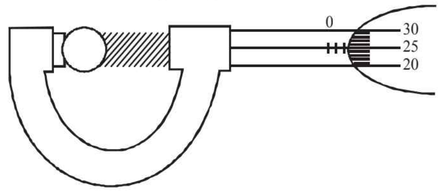


Figure (ii)

   (a) 2.25 mm (b) 2.20 mm
   (c) 1.20 mm (d) 1.25 mm

8. A student performs an experiment for determination of $g\left(=\frac{4\pi^2\ell}{T^2}\right)$. The error in length ℓ is $\Delta\ell$ and in time T is ΔT and n is number of times the reading is taken. The measurement of g is most accurate for *(2006 - 3M, –1)*

	$\Delta\ell$	ΔT	n
(a)	5mm	0.2 sec	10
(b)	5mm	0.2 sec	20
(c)	5mm	0.1 sec.	10
(d)	1mm	0.1 sec	50

9. A student performs an experiment to determine the Young's modulus of a wire, exactly 2 m long, by Searle's method. In a particular reading, the student measures the extension in the length of the wire to be 0.8 mm with an uncertainty of ± 0.05 mm at a load of exactly 1.0 kg. The student also

measures the diameter of the wire to be 0.4 mm with an uncertainty of ± 0.01 mm. Take $g = 9.8$ m/s^2 (exact). The Young's modulus obtained from the reading is *(2007)*

(a) $(2.0 \pm 0.3) \times 10^{11}$ N/m^2 (b) $(2.0 \pm 0.2) \times 10^{11}$ N/m^2

(c) $(2.0 \pm 0.1) \times 10^{11}$ N/m^2 (d) $(2.0 \pm 0.05) \times 10^{11}$ N/m^2

10. Students I, II and III perform an experiment for measuring the acceleration due to gravity (g) using a simple pendulum. They use different lengths of the pendulum and /or record time for different number of oscillations. The observations are shown in the table. *(2008)*

Least count for length = 0.1 cm

Least count for time = 0.1 s

Student	Length of the pendulum (cm)	No. of oscillations (n)	Total time for (n) oscillations (s)	Time period (s)
I	64.0	8	128.0	16.0
II	64.0	4	64.0	16.0
III	20.0	4	36.0	9.0

If E_I, E_{II} and E_{III} are the percentage errors in g, i.e., $\left(\frac{\Delta g}{g} \times 100\right)$ for students I, II and III, respectively, then

(a) $E_I = 0$ (b) E_I is minimum

(c) $E_I = E_{II}$ (d) E_{II} is maximum

11. A vernier calipers has 1 mm marks on the main scale. It has 20 equal divisions on the Vernier scale which match with 16 main scale divisions. For this Vernier calipers, the least count is *(2010)*

(a) 0.02 mm (b) 0.05 mm

(c) 0.1 mm (d) 0.2 mm

12. The density of a solid ball is to be determined in an experiment. The diameter of the ball is measured with a screw gauge, whose pitch is 0.5 mm and there are 50 divisions on the circular scale. The reading on the main scale is 2.5 mm and that on the circular scale is 20 divisions. If the measured mass of the ball has a relative error of 2 %, the relative percentage error in the density is *(2011)*

(a) 0.9 % (b) 2.4 %

(c) 3.1 % (d) 4.2 %

13. In the determination of Young's modulus $\left(Y = \frac{4MLg}{\pi l d^2}\right)$ by using Searle's method, a wire of length $L = 2$ m and diameter $d = 0.5$ mm is used. For a load $M = 2.5$ kg, an extension $l = 0.25$ mm in the length of the wire is observed. Quantities d and l are measured using a screw gauge and a micrometer, respectively. They have the same pitch of 0.5 mm. The number of divisions on their circular scale is 100. The contributions to the maximum probable error of the Y measurement *(2012)*

(a) due to the errors in the measurements of d and l are the same.

(b) due to the error in the measurement of d is twice that due to the error in the measurement of l.

(c) due to the error in the measurement of l is twice that due to the error in the measurement of d.

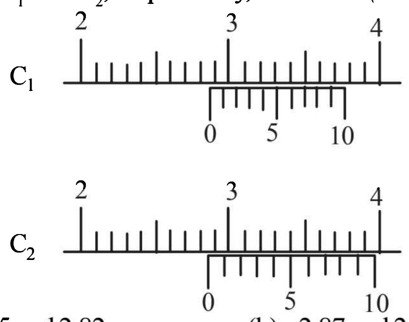
(d) due to the error in the measurement of d is four times that due to the error in the measurement of l.

14. The diameter of a cylinder is measured using a Vernier callipers with no zero error. It is found that the zero of the Vernier scale lies between 5.10 cm and 5.15 cm of the main scale. The Vernier scale has 50 divisions equivalent to 2.45 cm. The 24th division of the Vernier scale exactly coincides with one of the main scale divisions. The diameter of the cylinder is *(JEE Adv. 2013)*

(a) 5.112 cm (b) 5.124 cm

(c) 5.136 cm (d) 5.148 cm

15. There are two Vernier calipers both of which have 1 cm divided into 10 equal divisions on the main scale. The Vernier scale of one of the calipers (C_1) has 10 equal divisions that correspond to 9 main scale divisions. The Vernier scale of the other caliper (C_2) has 10 equal divisions that correspond to 11 main scale divisions. The readings of the two calipers are shown in the figure. The measured values (in cm) by calipers C_1 and C_2, respectively, are *(JEE Adv. 2016)*



(a) 2.85 and 2.82 (b) 2.87 and 2.83

(c) 2.87 and 2.86 (d) 2.87 and 2.87

D MCQs with One or More than One Correct

1. The dimensions of the quantities in one (or more) of the following pairs are the same. Identify the pair (s) *(1986 - 2 Marks)*

(a) Torque and Work

(b) Angular momentum and Work

(c) Energy and Young's modulus

(d) Light year and Wavelength

2. The pairs of physical quantities that have the same dimensions is (are) : *(1995S)*

(a) Reynolds number and coefficient of friction

(b) Curie and frequency of a light wave

(c) Latent heat and gravitational potential

(d) Planck's constant and torque

3. The *SI* unit of inductance, the henry can be written as *(1998 - 2 Marks)*

(a) weber/ampere (b) volt-sec/amp

(c) Joule/(ampere)^2 (d) ohm-second

4. Let $[\varepsilon_0]$ denote the dimensional formula of the permittivity of the vacuum, and $[\mu_0]$ that of the permeability of the vacuum. If M = mass, L = length, T = time and I = electric current, *(1998 - 2 Marks)*

(a) $[\varepsilon_0] = M^{-1}L^{-3}T^2I$ (b) $[\varepsilon_0] = M^{-1}L^{-3}T^4I^2$

(c) $[\mu_0] = MLT^{-2}I^{-2}$ (d) $[\mu_0] = ML^2T^{-1}I$

5. A student uses a simple pendulum of exactly 1m length to determine g, the acceleration due to gravity. He uses a stop watch with the least count of 1 sec for this and records 40 seconds for 20 oscillations. For this observation, which of the following statement(s) is (are) true? *(2010)*
(a) Error ΔT in measuring T, the time period, is 0.05 seconds
(b) Error ΔT in measuring T, the time period, is 1 second
(c) Percentage error in the determination of g is 5%
(d) Percentage error in the determination of g is 2.5%

6. Using the expression $2d \sin\theta = \lambda$, one calculates the values of d by measuring the corresponding angles θ in the range 0 to 90°. The wavelength λ is exactly known and the error in θ is constant for all values of θ. As θ increases from 0° *(JEE Adv. 2013)*
(a) The absolute error in d remains constant
(b) The absolute error in d increases
(c) The fractional error in d remains constant
(d) The fractional error in d decreases

7. Planck's constant h, speed of light c and gravitational constant G are used to form a unit of length L and a unit of mass M. Then the correct option(s) is(are) *(JEE Adv. 2015)*
(a) $M \propto \sqrt{c}$ (b) $M \propto \sqrt{G}$
(c) $L \propto \sqrt{h}$ (d) $L \propto \sqrt{G}$

8. Consider a Vernier callipers in which each 1 cm on the main scale is divided into 8 equal divisions and a screw gauge with 100 divisions on its circular scale. In the Vernier callipers, 5 divisions of the Vernier scale coincide with 4 divisions on the main scale and in the screw gauge, one complete rotation of the circular scale moves it by two divisions on the linear scale. Then : *(JEE Adv. 2015)*
(a) If the pitch of the screw gauge is twice the least count of the Vernier callipers, the least count of the screw gauge is 0.01 mm
(b) If the pitch of the screw gauge is twice the least count of the Vernier callipers, the least count of the screw gauge is 0.005 mm
(c) If the least count of the linear scale of the screw gauge is twice the least count of the Vernier callipers, the least count of the screw gauge is 0.01 mm
(d) If the least count of the linear scale of the screw gauge is twice the least count of the Vernier callipers, the least count of the screw gauge is 0.005 mm

9. In terms of potential difference V, electric current I, permittivity ε_0, permeability μ_0 and speed of light c, the dimensionally correct equation(s) is(are) *(JEE Adv. 2015)*
(a) $\mu_0 I^2 = \varepsilon_0 V^2$ (b) $\mu_0 I = \mu_0 V$
(c) $I = \varepsilon_0 cV$ (d) $\mu_0 cI = \varepsilon_0 V$

10. A length–scale (l) depends on the permittivity (ε) of a dielectric material. Boltzmann constant (k_B), the absolute temperature (T), the number per unit volume (n) of certain charged particles, and the charge (q) carried by each of the particles. Which of the following expression(s) for l is(are) dimensionally correct? *(JEE Adv. 2016)*

(a) $l = \sqrt{\left(\frac{nq^2}{\varepsilon k_B T}\right)}$ (b) $l = \sqrt{\left(\frac{\varepsilon k_B T}{nq^2}\right)}$

(c) $l = \sqrt{\left(\frac{q^2}{\varepsilon n^{2/3} k_B T}\right)}$ (d) $l = \sqrt{\left(\frac{q^2}{\varepsilon n^{1/3} k_B T}\right)}$

11. In an experiment to determine the acceleration due to gravity g, the formula used for the time period of a periodic motion is $T = 2\pi\sqrt{\frac{7(R-r)}{5g}}$. The values of R and r are measured to be (60 ± 1) mm and (10 ± 1) mm, respectively. In five successive measurements, the time period is found to be 0.52s, 0.56s, 0.57s, 0.54s and 0.59s. The least count of the watch used for the measurement of time period is 0.01s. Which of the following statement(s) is (are) true? *(JEE Adv. 2016)*
(a) The error in the measurement of r is 10%
(b) The error in the measurement of T is 3.75%
(c) The error in the measurement of T is 2%
(d) The error in the determined value of g is 11%

E Subjective Problems

1. Give the MKS units for each of the following quantities.
(i) Young's modulus *(1980)*
(ii) Magnetic Induction
(iii) Power of a lens

2. A gas bubble, from an explosion under water, oscillates with a period T proportional to $p^a d^b E^c$. Where 'P' is the static pressure, 'd' is the density of water and 'E' is the total energy of the explosion. Find the values of a, b and c. *(1981- 3 Marks)*

3. Write the dimensions of the following in terms of mass, time, length and charge *(1982 - 2 Marks)*
(i) magnetic flux
(ii) rigidity modulus

4. Match the physical quantities given in column I with dimensions expressed in terms of mass (M), length (L), time (T), and charge (Q) given in column II and write the correct answer against the matched quantity in a tabular form in your answer book. *(1983 - 6 Marks)*

Column I	Column II
Angular momentum	ML^2T^{-2}
Latent heat	ML^2Q^{-2}
Torque	ML^2T^{-1}
Capacitance	$ML^3T^{-1}Q^{-2}$
Inductance	$M^{-1}L^{-2}T^2Q^2$
Resistivity	L^2T^{-2}

5. Column-I gives three physical quantities. Select the appropriate units for the choices given in Column-II. Some of the physical quantities may have more than one choice correct : *(1990 - 3 Marks)*

Column I	Column II
Capacitance	(i) ohm-second
Inductance	(ii) coulomb^2–joule^{-1}
Magnetic Induction	(iii) coulomb (volt)$^{-1}$
	(iv) newton (amp-metre)$^{-1}$
	(v) volt-second (ampere)$^{-1}$

6. If n^{th} division of main scale coincides with $(n+1)^{th}$ divisions of vernier scale. Given one main scale division is equal to 'a' units. Find the least count of the vernier. *(2003 - 2 Marks)*

7. A screw gauge having 100 equal divisions and a pitch of length 1 mm is used to measure the diameter of a wire of length 5.6 cm. The main scale reading is 1 mm and 47th circular division coincides with the main scale. Find the curved surface area of wire in cm^2 to appropriate significant figure. (use $\pi = \frac{22}{7}$). *(2004 - 2 Marks)*

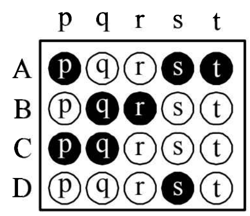
8. In Searle's experiment, which is used to find Young's Modulus of elasticity, the diameter of experimental wire is D = 0.05 cm (measured by a scale of least count 0.001 cm) and length is L = 110 cm (measured by a scale of least count 0.1 cm). A weight of 50 N causes an extension of X = 0.125 cm (measured by a micrometer of least count 0.001cm). Find maximum possible error in the values of Young's modulus. Screw gauge and meter scale are free from error. *(2004 - 2 Marks)*

9. The side of a cube is measured by vernier callipers (10 divisions of a vernier scale coincide with 9 divisions of main scale, where 1 division of main scale is 1 mm). The main scale reads 10 mm and first division of vernier scale coincides with the main scale. Mass of the cube is 2.736 g. Find the density of the cube in appropriate significant figures. *(2005 - 2 Marks)*

F Match the Following

DIRECTIONS (Q. No. 1) : *Each question contains statements given in two columns, which have to be matched. The statements in Column-I are labelled A, B, C and D, while the statements in Column-II are labelled p, q, r and s. Any given statement in Column-I can have correct matching with ONE OR MORE statement(s) in Column-II. The appropriate bubbles corresponding to the answers to these questions have to be darkened as illustrated in the following example :*

If the correct matches are A-p, s and t; B-q and r; C-p and q; and D-s then the correct darkening of bubbles will look like the given.



1. Some physical quantities are given in **Column I** and some possible SI units in which these quantities may be expressed are given in **Column II**. Match the physical quantities in **Column I** with the units in **Column II** and indicate your answer by darkening appropriate bubbles in the 4 × 4 matrix given in the *ORS*. *(2007)*

Column I	Column II
(A) GM_eM_s, G – universal gravitational constant, M_e – mass of the earth, M_s – mass of the Sun	(p) (volt) (coulomb)(metre)
(B) $\frac{3RT}{M}$, R – universal gas constant, T – absolute temperature, M – molar mass	(q) (kilogram) (metre)^3(second)$^{-2}$
(C) $\frac{F^2}{q^2B^2}$, F – Force, q – charge, B – magnetic field	(r) (metre)^2 (second)$^{-2}$
(D) $\frac{GM_e}{R_e}$, G – universal gravitational constant, M_e – mass of the earth, R_e – radius of the earth	(s) (farad) (volt)^2 (kg)$^{-1}$

DIRECTIONS (Q. No. 2) : *Following question has matching lists. The codes for the lists have choices (a), (b), (c) and (d) out of which ONLY ONE is correct.*

2. Match List I with List II and select the correct answer using the codes given below the lists: *(JEE Adv. 2013)*

List I	List II
P. Boltzmann constant	1. $[ML^2T^{-1}]$
Q. Coefficient of viscosity	2. $[ML^{-1}T^{-1}]$
R. Planck constant	3. $[MLT^{-3}K^{-1}]$
S. Thermal conductivity	4. $[ML^2T^{-2}K^{-1}]$

Codes:

	P	Q	R	S
(a)	3	1	2	4
(b)	3	2	1	4
(c)	4	2	1	3
(d)	4	1	2	3

G Comprehension Based Questions

PASSAGE

A dense collection of equal number of electrons and positive ions is called neutral plasma. Certain solids containing fixed positive ions surrounded by free electrons can be treated as neutral plasma. Let 'N' be the number density of free electrons, each of mass 'm'. When the electrons are subjected to an electric field, they are displaced relatively away from the heavy positive ions. If the electric field becomes zero, the electrons begin to oscillate about the positive ions with a natural angular frequency 'ω_p' which is called the plasma frequency. To sustain the oscillations, a time varying electric field needs to be applied that has an angular frequency ω, where a part of the energy is absorbed and a part of it is reflected. As ω approaches ω_p all the free electrons are set to resonance together and all the energy is reflected. This is the explanation of high reflectivity of metals. *(2011)*

1. Taking the electronic charge as 'e' and the permittivity as 'ε_0'. Use dimensional analysis to determine the correct expression for ω_p.

   (a) $\sqrt{\dfrac{Ne}{m\varepsilon_0}}$ (b) $\sqrt{\dfrac{m\varepsilon_0}{Ne}}$ (c) $\sqrt{\dfrac{Ne^2}{m\varepsilon_0}}$ (d) $\sqrt{\dfrac{Ne^2}{m\varepsilon_0}}$

2. Estimate the wavelength at which plasma reflection will occur for a metal having the density of electrons $N \approx 4 \times 10^{27}\,m^{-3}$. Taking $\varepsilon_0 = 10^{-11}$ and mass $m \approx 10^{-30}$, where these quantities are in proper SI units.

   (a) 800 nm (b) 600 nm
   (c) 300 nm (d) 200 nm

I Integer Value Correct Type

1. To find the distance *d* over which a signal can be seen clearly in foggy conditions, a railways-engineer uses dimensions and assumes that the distance depends on the mass density ρ of the fog, intensity (power/area) *S* of the light from the signal and its frequency *f*. The engineer finds that *d* is proportional to $S^{1/n}$. The value of *n* is *(JEE Adv. 2014)*

2. During Searle's experiment, zero of the Vernier scale lies between 3.20×10^{-2} m and 3.25×10^{-2} m of the main scale. The 20th division of the Vernier scale exactly coincides with one of the main scale divisions. When an additional load of 2 kg is applied to the wire, the zero of the Vernier scale still lies between 3.20×10^{-2} m and 3.25×10^{-2} m of the main scale but now the 45th division of Vernier scale coincides with one of the main scale divisions. The length of the thin metallic wire is 2 m and its cross-sectional area is $8 \times 10^{-7}\,m^2$. The least count of the Vernier scale is 1.0×10^{-5} m. The maximum percentage error in the Young's modulus of the wire is *(JEE Adv. 2014)*

3. The energy of a system as a function of time t is given as $E(t) = A^2 \exp(-\alpha t)$, where $\alpha = 0.2\,s^{-1}$. The measurement of *A* has an error of 1.25%. If the error in the measurement of time is 1.50%, the percentage error in the value of *E*(*t*) at *t* = 5 s is *(JEE Adv. 2015)*

Section-B JEE Main / AIEEE

1. Identify the pair whose dimensions are equal **[2002]**
   (a) torque and work (b) stress and energy
   (c) force and stress (d) force and work

2. Dimension of $\dfrac{1}{\mu_0\varepsilon_0}$, where symbols have their usual meaning, are **[2003]**
   (a) $[L^{-1}T]$ (b) $[L^{-2}T^2]$ (c) $[L^2T^{-2}]$ (d) $[LT^{-1}]$

3. The physical quantities not having same dimensions are **[2003]**
   (a) torque and work
   (b) momentum and planck's constant
   (c) stress and young's modulus
   (d) speed and $(\mu_0\varepsilon_0)^{-1/2}$

4. Which one of the following represents the correct dimensions of the coefficient of viscosity? **[2004]**
   (a) $ML^{-1}T^{-1}$ (b) MLT^{-1} (c) $ML^{-1}T^{-2}$ (d) $ML^{-2}T^{-2}$

5. Out of the following pair , which one does NOT have identical dimensions is **[2005]**
   (a) impulse and momentum
   (b) angular momentum and planck's constant
   (c) work and torque
   (d) moment of inertia and moment of a force

(towards north-west)

6. The dimension of magnetic field in M, L, T and C (coulomb) is given as **[2008]**
   (a) $MLT^{-1}C^{-1}$ (b) MT^2C^{-2}
   (c) $MT^{-1}C^{-1}$ (d) $MT^{-2}C^{-1}$

7. A body of mass m = 3.513 kg is moving along the x-axis with a speed of 5.00 ms^{-1}. The magnitude of its momentum is recorded as **[2008]**
   (a) 17.6 kg ms^{-1} (b) 17.565 kg ms^{-1}
   (c) 17.56 kg ms^{-1} (d) 17.57 kg ms^{-1}

8. Two full turns of the circular scale of a screw gauge cover a distance of 1mm on its main scale. The total number of divisions on the circular scale is 50. Further, it is found that the screw gauge has a zero error of – 0.03 mm. While measuring the diameter of a thin wire, a student notes the main scale reading of 3 mm and the number of circular scale divisions in line with the main scale as 35. The diameter of the wire is **[2008]**
   (a) 3.32 mm (b) 3.73 mm
   (c) 3.67 mm (d) 3.38 mm

9. In an experiment the angles are required to be measured using an instrument, 29 divisions of the main scale exactly coincide with the 30 divisions of the vernier scale. If the smallest division of the main scale is half- a degree (= 0.5°), then the least count of the instrument is : **[2009]**
   (a) half minute (b) one degree
   (c) half degree (d) one minute

10. The respective number of significant figures for the numbers 23.023, 0.0003 and 2.1×10^{-3} are **[2010]**
(a) 5, 1, 2 (b) 5, 1, 5
(c) 5, 5, 2 (d) 4, 4, 2

11. A screw gauge gives the following reading when used to measure the diameter of a wire.
Main scale reading : 0 mm
Circular scale reading : 52 divisions
Given that 1mm on main scale corresponds to 100 divisions of the circular scale. The diameter of wire from the above data is: **[2011]**
(a) 0.052 cm (b) 0.026 cm
(c) 0.005 cm (d) 0.52 cm

12. Resistance of a given wire is obtained by measuring the current flowing in it and the voltage difference applied across it. If the percentage errors in the measurement of the current and the voltage difference are 3% each, then error in the value of resistance of the wire is : **[2012]**
(a) 6% (b) zero
(c) 1% (d) 3%

13. A spectrometer gives the following reading when used to measure the angle of a prism. **[2012]**
Main scale reading : 58.5 degree
Vernier scale reading : 09 divisions
Given that 1 division on main scale corresponds to 0.5 degree. Total divisions on the Vernier scale is 30 and match with 29 divisions of the main scale. The angle of the prism from the above data :
(a) 58.59 degree (b) 58.77 degree
(c) 58.65 degree (d) 59 degree

14. Let $[\epsilon_0]$ denote the dimensional formula of the permittivity of vacuum. If M = mass, L = length, T = time and A = electric current, then: **[JEE Main 2013]**
(a) $\epsilon_0 = [M^{-1} L^{-3} T^2 A]$ (b) $\epsilon_0 = [M^1 L^3 T^5 A^2]$
(c) $\epsilon_0 = [M^1 L^2 T^1 A^2]$ (d) $\epsilon_0 = [M^1 L^2 T^1 A]$

15. A student measured the length of a rod and wrote it as 3.50 cm. Which instrument did he use to measure it? **[JEE Main 2014]**
(a) A meter scale.
(b) A vernier calliper where the 10 divisions in vernier scale matches with 9 division in main scale and main scale has 10 divisions in 1 cm.
(c) A screw gauge having 100 divisions in the circular scale and pitch as 1 mm.
(d) A screw gauge having 50 divisions in the circular scale and pitch as 1 mm.

16. The period of oscillation of a simple pendulum is $T = 2\pi\sqrt{\frac{L}{g}}$.
Measured value of L is 20.0 cm known to 1 mm accuracy and time for 100 oscillations of the pendulum is found to be 90 s using a wrist watch of 1s resolution. The accuracy in the determination of g is : **[JEE Main 2015]**
(a) 1% (b) 5%
(c) 2% (d) 3%

17. A student measures the time period of 100 oscillations of a simple pendulum four times. The data set is 90 s, 91 s, 95 s, and 92 s. If the minimum division in the measuring clock is 1 s, then the reported mean time should be: **[JEE Main 2016]**
(a) 92 ± 1.8 s (b) 92 ± 3s
(c) 92 ± 2 s (d) 92 ± 5.0 s

18. A screw gauge with a pitch of 0.5 mm and a circular scale with 50 divisions is used to measure the thickness of a thin sheet of Aluminium. Before starting the measurement, it is found that wen the two jaws of the screw gauge are brought in contact, the 45th division coincides with the main scale line and the zero of the main scale is barely visible. What is the thickness of the sheet if the main scale reading is 0.5 mm and the 25th division coincides with the main scale line? **[JEE Main 2016]**
(a) 0.70 mm (b) 0.50 mm
(c) 0.75 mm (d) 0.80 mm

Solutions & Explanations

1 Units and Measurements

Section-A : JEE Advanced/ IIT-JEE

A 1. ML^2T^{-1} 2. $M^{-3}L^{-2}T^4Q^4$ 3. ML^5T^{-2}

C 1. (c) 2. (d) 3. (a) 4. (c) 5. (a) 6. (d)
7. (c) 8. (d) 9. (b) 10. (b) 11. (d) 12. (c)
13. (a) 14. (b) 15. (b)

D 1. (a, d) 2. (a, b, c) 3. (a, b, c, d) 4. (b, c) 5. (a, c) 6. (d)
7. (a,c,d) 8. (b, c) 9. (a, c) 10. (b, d) 11. (a, b, d)

E 1. (i) N/m^2; (ii) Tesla; (iii) Dioptre; 2. a = – 5/6, b = 1/2, c = 1/3 3. (i) $[M^1L^2T^{-1}Q^{-1}]$ (ii) $[ML^{-1}T^{-2}]$

4. Angular Momentum – $[ML^2T^{-1}]$; Latent heat – $[L^2T^{-2}]$; Torque – $[ML^2T^{-2}]$
Capacitance – $[M^{-1}L^{-2}T^2Q^2]$; Inductance – $[ML^2Q^{-2}]$; Resistivity – $[ML^3T^{-1}Q^{-2}]$

5. Capacitance — coulomb-volt^{-1}, coulomb^2-joule^{-1}
Inductance — ohm-sec, volt-second (ampere)$^{-1}$
Magnetic Induction — newton (ampere-metre)$^{-1}$

$\because$ (a) $q = CV;\ U = \frac{1}{2}CV^2$
(b) Refer to solution of Q. 3, type D
(c) $F = I\ell B$

6. $\frac{a}{n+1}$ units 7. 2.6 cm^2 8. $1.09 \times 10^{10}\ Nm^{-2}$ 9. 2.66 gm/cm^3

F 1. (A) → p, q ; (B) → r, s ; (C) → r, s ; (D) → r, s 2. (c)

G 1. (c) 2. (b)

I 1. (3) 2. (4) 3. (4)

Section-B : JEE Main/ AIEEE

1. (a) 2. (c) 3. (b) 4. (a) 5. (d) 6. (c)
7. (a) 8. (d) 9. (d) 10. (a) 11. (a) 12. (a)
13. (c) 14. (b) 15. (b) 16. (d) 17. (a) 18. (d)

Section-A JEE Advanced/ IIT-JEE

A. Fill in the Blanks

1. $E = h\nu \qquad h = \frac{E}{\nu} = \frac{[ML^2T^{-2}]}{[T^{-1}]} = [ML^2T^{-1}]$

2. $[X] = [C] = [M^{-1}L^{-2}T^2Q^2]$
$[Z] = [B] = [MT^{-1}Q^{-1}]$

$\therefore\ [Y] = \frac{[M^{-1}L^{-2}T^2Q^2]}{[MT^{-1}Q^{-1}]^2} = [M^{-3}L^{-2}T^4Q^4]$

3. $[a] = [PV^2] = \frac{MLT^{-2}}{L^2}L^6 = ML^5T^{-2}$

C. MCQs with ONE Correct Answer

1. **(c)** **Note :** Here $\left(\frac{1}{2}\right)\varepsilon_0 E^2$ represents energy per unit volume.

$$[\varepsilon_0][E^2] = \frac{[\text{Energy}]}{[\text{Volume}]} = \frac{ML^2T^{-2}}{L^3} = ML^{-1}T^{-2}$$

2. **(d)** Dimensionally $\varepsilon_0 L$ = Capacitance (c)

$$\therefore\ \varepsilon_0 L\frac{\Delta V}{\Delta t} = \frac{C\Delta V}{\Delta t} = \frac{q}{\Delta t} = I$$

3. **(a)** $V = \ell^3 = (1.2 \times 10^{-2}\,m)^3 = 1.728 \times 10^{-6}\,m^3$
$\Rightarrow\ V = 1.7 \times 10^{-6}\,m^3$.

4. **(c)** Unit of k is joules per kelvin or dimensional formula of k is $[ML^2T^{-2}\theta^{-1}]$

Note : The power of an exponent is a number.

Therefore, dimensionally $\frac{\alpha z}{k\theta} = M^\circ L^\circ T^\circ$

$\therefore \quad \alpha = \frac{k\theta}{z}$

$\therefore \quad \alpha = \frac{[ML^2T^{-2}\theta^{-1}][\theta]}{[L]} = [MLT^{-2}]$

and dimensionally $P = \frac{\alpha}{\beta} \Rightarrow \beta = \frac{\alpha}{P}$

$\therefore \quad [\beta] = \frac{MLT^{-2}}{ML^{-1}T^{-2}} = M^0L^2T^0$

5. **(a)** $\rho = \frac{m}{\ell \pi r^2}$

$\frac{\Delta\rho}{\rho} = \frac{\Delta m}{m} + \frac{2\Delta r}{r} + \frac{\Delta\ell}{\ell}$

Putting the values

$\Delta\ell = 0.06$ cm, $\ell = 6$ cm; $\Delta r = 0.005$ cm; $r = 0.5$ cm, $m = 0.3$ gm; $\Delta m = 0.003$ gm

$\therefore \frac{\Delta\rho}{\rho} = \frac{4}{100} \qquad \therefore \frac{\Delta\rho}{\rho}\times 100 = 4\%.$

6. **(d)** Electric flux $\phi_E = \vec{E}.\vec{S}$

$\therefore$ Dimensionally $\phi_E \neq E$

7. **(c)** Least count $= \frac{0.5}{50} = 0.01$ mm

Zero error $= 5 \times L.C = 5 \times 0.01$ mm $= 0.05$ mm

Diameter of ball = [Reading on main scale] + [Reading on circular scale × L . C] – Zero error

$= 0.5 \times 2 + 25 \times 0.01 - 0.05 = 1.20$ mm

8. **(d)** $\frac{\Delta g}{g} = \frac{\Delta\ell}{\ell} + 2\frac{\Delta T}{T}$

$\Delta\ell$ and ΔT are least and number of readings are maximum in option (d), therefore the measurement of g is most accurate with data used in this option.

9. **(b)** $Y = \frac{4mgL}{\pi D^2\ell} = \frac{4\times1\times9.8\times2}{\pi(0.4\times10^{-3})^2\times(0.8\times10^{-3})}$

$= 2.0\times10^{11}$ N/m^2

Now $\frac{\Delta Y}{Y} = \frac{2\Delta D}{D} + \frac{\Delta\ell}{\ell}$

[$\because$ the value of m, g and L are exact]

$= 2\times\frac{0.01}{0.4} + \frac{0.05}{0.8} = 2\times0.025 + 0.0625$

$= 0.05 + 0.0625 = 0.1125$

$\Rightarrow \Delta Y = 2\times10^{11}\times0.1125 = 0.225\times10^{11}$

$= 0.2\times10^{11}$ N/m^2

Note: We can also take value of y from options given without calculating it as it is same in all options.

$\therefore \quad Y = (2\pm0.2)\times10^{11}$ N/m^2

10. **(b)** The time period of a simple pendulum is given by

$$T = 2\pi\sqrt{\frac{\ell}{g}} \therefore T^2 = 4\pi^2\frac{\ell}{g} \Rightarrow g = 4\pi^2\frac{\ell}{T^2}$$

$$\Rightarrow \frac{\Delta g}{g}\times100 = \frac{\Delta\ell}{\ell}\times100 + 2\frac{\Delta T}{T}\times100$$

Case (i)

$\Delta\ell = 0.1$ cm, $\ell = 64$cm, $\Delta T = 0.1$s, $T = 128$s

11. **(d)** 20 divisions on the vernier scale

= 16 divisions of main scale

$\therefore$ 1 division on the vernier scale

$= \frac{16}{20}$ divisions of main scale $= \frac{16}{20}\times 1$mm $= 0.8$ mm

We know that least count = 1MSD – 1VSD

= 1 mm – 0.8 mm = 0.2 mm

12. **(c)** Diameter D = M.S.R. + (C.S.R) × L.C.

$D = 2.5 + 20\times\frac{0.5}{50}$

D = 2.70 mm

The uncertainty in the measurement of diameter $\Delta D = 0.01$ mm.

We know that

$$\rho = \frac{\text{Mass}}{\text{Volume}} = \frac{M}{V} = \frac{M}{\frac{4}{3}\pi\left(\frac{D}{2}\right)^3}$$

$$\therefore \frac{\Delta\rho}{\rho}\times100 = \frac{\Delta M}{M}\times100 + 3\frac{\Delta D}{\Delta}\times100$$

$= 2 + 3\times\frac{0.01}{2.70}\times100 = 3.1\%$

13. **(a)** The maximum possible error in Y due to l and d are

$$\frac{\Delta Y}{Y} = \frac{\Delta l}{l} + \frac{2\Delta d}{d}$$

Least count $= \frac{\text{Pitch}}{\text{No. of divi on circular scale}}$

$= \frac{0.5}{100}$ mm $= 0.005$ mm

Error contribution of $l = \frac{\Delta l}{l} = \frac{0.005 \text{ mm}}{0.25 \text{ mm}} = \frac{1}{50}$

Error contribution of $d = \frac{2\Delta d}{d} = \frac{2\times0.005\text{ mm}}{0.5\text{ mm}} = \frac{1}{50}$

14. **(b)** Reading = M.S.R + No of division of V.S matching the main scale division (1MSD – 1VSD)

$= 5.10 + 24\left(0.05 - \frac{2.45}{50}\right)$

= 5.124 cm Option (b) is correct.

15. **(b)** For C_1

L.C. = 1MSD – 1VSD

= 1mm – 0.9 mm = 0.1 mm = 0.01 cm [10 VSD = 9 mm]

Reading = MSR + L.C × Verni scale division coinciding the Main scale division = 2.8 + (0.01) × 7 = 2.87 cm

For C_2

$L.C = 1\,mm - 1.1\,mm \quad [10\,VSD = 11\,mm]$

$L.C = -0.1\,mm = -0.01\,cm$

$\text{Reading} = 2.8 + (10 - 7) \times 0.01 = 2.83\,cm$

D. MCQs with ONE or MORE THAN ONE Correct

1. **(a, d)** $\tau = F \times r \times \sin\theta$; $W = F \times d \times \cos\theta$

Dimensionally, light year = wavelength = $[L]$

2. **(a, b, c)**

Reynold's number

= Coefficient of friction = $[M^0L^0T^0]$

Note : Curie is the unit of radioactivity (number of atoms decaying per second) and frequency also has the unit per second.

Latent heat = $\frac{Q}{m}$ and Gravitation potential = $\frac{W}{m}$.

3. **(a, b, c, d)**

$$L = \frac{\phi}{I};\ L = -e\Big/\left(\frac{dI}{dt}\right);\ L = \frac{2U}{I^2};\ L = R \times t$$

$$L = \frac{\phi}{I} = \frac{\text{weber}}{\text{ampere}}$$

$$L = \frac{-e}{dI/dt} = \frac{\text{volt}}{\text{ampere/sec}} = \frac{\text{volt-sec}}{\text{ampere}}$$

$$L = \frac{2U}{I^2} = \frac{\text{joule}}{(\text{ampere})^2}$$

$$L = R \times t = \text{ohm} - \text{sec}$$

4. **(b, c)** By definition $F = \frac{Q_1Q_2}{(4\pi\varepsilon_0)r^2}$ and $\frac{F}{\ell} = \frac{\mu_0 I_1 I_2}{2\pi L}$

Hence, $[\varepsilon_0] = \frac{[Q]^2}{[F][r^2]} = \frac{I^2T^2}{MLT^{-2}.L^2} = M^{-1}L^{-3}T^4I^2$

$$[\mu_0] = \frac{[F]}{[I]^2} = \frac{MLT^{-2}}{I^2} = MLT^{-2}I^{-2}$$

5. **(a,c)** As the length of the string of simple pendulum is exactly 1 m (given), therefore the error in length $\Delta l = 0$.

Further the possibility of error in measuring time is 1 s in 40s.

$$\therefore \frac{\Delta t}{t} = \frac{\Delta T}{T} = \frac{1}{40}$$

The time period $T = \frac{40}{20} = 2$ seconds

$$\therefore \frac{\Delta T}{T} = \frac{1}{40} \Rightarrow \frac{\Delta T}{2} = \frac{1}{40} \Rightarrow \Delta T = 0.05\,sec$$

We know that $T = 2\pi\sqrt{\frac{l}{g}} \quad \Rightarrow T^2 = 4\pi^2\frac{l}{g}$

$$\therefore g = 4\pi^2\frac{1}{T^2}$$

$$\therefore \frac{\Delta g}{g} \times 100 = \frac{\Delta l}{l} \times 100 + 2\frac{\Delta T}{T} \times 100$$

$$\therefore \frac{\Delta g}{g} \times 100 = 0 + 2\left(\frac{1}{40}\right) \times 100 = 5$$

6. **(d)** Given $2d\sin\theta = \lambda \quad \therefore\ d = \frac{\lambda}{2}\text{cosec}\,\theta$ ... (i)

$$\therefore \frac{d(d)}{d\theta} = \frac{\lambda}{2}[-\text{cosec}\,\theta\cot\theta]$$

$$\therefore d(d) = -\frac{\lambda}{2}\text{cosec}\theta\cot\theta\,d\theta \quad \text{...(ii)}$$

on dividing (i) and (ii) we get

$$\therefore \left|\frac{d(d)}{d}\right| = \cot\theta\,d\theta$$

As θ increases from 0° to 90°, cot θ decreases and therefore $\left|\frac{d(d)}{d}\right|$ decreases option (d) is correct

From (ii) $|d(d)| = \frac{\lambda}{2}\frac{\cos\theta}{\sin^2\theta}$

This value of $\frac{\cos\theta}{\sin^2\theta}$ decreases as θ increases from 0° to 90°

9. **(a, c, d)**

$L \propto h^x c^y G^z$

Dimensionally

$$[M^0L^1T^0] = [ML^2T^{-1}]^x[LT^{-1}]^y[M^{-1}L^3T^{-2}]^z$$

$$M^0L^1T^0 = M^{x-z}L^{2x+y+3z}T^{-x-y-2z}$$

$\therefore\ x - z = 0 \quad \Rightarrow \quad x = z$

$\therefore\ 2x + y + 3z = 1$ and $-x - y - 2z = 0$

On solving we get

$$x = \frac{1}{2}, y = -\frac{3}{2}, z = \frac{1}{2}$$

$\therefore\ L \propto \sqrt{h}$

$L \propto \sqrt{G}$

C, D are correct options

$M \propto h^xc^yG^z$

$$M^1L^oT^o \propto [ML^2T^{-1}]^x[LT^{-1}]^y[M^{-1}L^3T^{-2}]^Z$$

$$\therefore\ M^1L^oT^o \propto M^{x-z}L^{2x+y+3z}T^{-x-y-2z}$$

$\therefore\ x - z = 1$

$2x + y + 3z = 0$

$-x - y - 2z = 0$

On solving we get

$$x = \frac{1}{2}, y = \frac{1}{2}, z = -\frac{1}{2}$$

$\therefore\ M \propto \sqrt{C}$

A is the correct option.

8. (b, c)

Vernier callipers

$1\text{ MSD} = \frac{1\text{cm}}{8} = 0.125\text{cm}$

$5\text{ VSD} = 4\text{MSD}$

$\therefore 5\text{VSD} = 4 \times \frac{1}{8}\text{cm} = 0.5\text{cm}$

$\therefore 1\text{ VSD} = 0.1\text{cm}$

$\text{L.C} = 1\text{MSD} - 1\text{VSD}$

$= 0.125\text{cm} - 0.1\text{cm}$

$= 0.025\text{cm}$

Screw gauge

One complete revolution = 2M.S.D

If the pitch of screw gauge is twice the L.C of vernier callipers then pitch = 2 × 0.025 = 0.05cm.

L.C of screw Gauge

$= \frac{\text{pitch}}{\text{Total no. of divisions of circular scale}}$

$= \frac{0.05}{100}\text{cm} = 0.0005\text{cm} = 0.005\text{ mm.}$

(b) is a correct option

Now if the least count of the linear scale of the screw gauge is twice the least count of venier callipers then.

L.C of linear scale of screw gauge = 2 × 0.025 = 0.05cm.

Then pitch = 2 × 0.05 = 0.1cm.

Then L.C of screw gauge $= \frac{0.1}{100}\text{cm} = 0.001\text{cm} = 0.01\text{mm.}$

(c) is a correct option.

9. (a, c) We know that

$$C = \frac{1}{\sqrt{\mu_0 \varepsilon_0}} \text{ and } R = \sqrt{\frac{\mu_0}{\varepsilon_0}}$$

Now, $\mu_0 I^2 = \varepsilon_0 V^2$

$\therefore \frac{\mu_0}{\varepsilon_0} = \frac{V^2}{I^2} = R^2 \quad \Rightarrow$ Option A is correct

Now, $\varepsilon_0 I = \mu_0 V$

$\therefore \frac{\mu_0}{\varepsilon_0} = \frac{I}{V} = \frac{1}{R} \quad \Rightarrow$ Option B is incorrect

Now, $I = \varepsilon_0 C V$

$\therefore \frac{1}{\varepsilon_0 C} = \frac{V}{I} = R$

$\therefore \frac{1}{\varepsilon_0 \frac{1}{\sqrt{\mu_0 \varepsilon_0}}} = R$

$\therefore \sqrt{\frac{\mu_0}{\varepsilon_0}} = R \quad \Rightarrow$ Option C is correct

Now, $\mu_o C I = \varepsilon_0 V$

$\therefore \frac{\mu_0}{\varepsilon_0} = \frac{V}{I_C} = \frac{R}{C} = \sqrt{\frac{\mu_0}{\varepsilon_0}} \times \frac{1}{\frac{1}{\sqrt{\mu_0 \varepsilon_0}}} = \mu_0$

$\Rightarrow$ Option (d) is incorrect

10. (b, d)

We know that, dimensionally $\in = \frac{q^2}{\ell^2 F}$,

$k_B T = \frac{RT}{N_A} = PV = F \times \ell$

Now $\sqrt{\frac{\varepsilon k_B T}{n q^2}} = \left[\frac{q^2}{\ell^2 F} \times \frac{F \times \ell}{\ell^{-3} q^2}\right]^{1/2} = \ell$

Also $\sqrt{\frac{q^2}{\in n^{1/3} k_B T}} = \left[\frac{\ell^2 F \times q^2}{q^2 \ell^{-1} \times F \times \ell}\right]^{1/2} = \ell$

11. (a, b, d) % error in measurement of 'r' $= \frac{1}{10} \times 100 = 10\%$

$T_{mean} = \frac{0.52 + 0.56 + 0.57 + 0.54 + 0.59}{6} = 0.556 \approx 0.56\text{ S}$

$\Delta_T = \frac{0.04 + 0 + 0.01 + 0.02 + 0.03}{6} = 0.016 \approx 0.02\text{S}$

∴ % error in the measurement of 'T'

$= \frac{0.02}{0.56} \times 100 = 3.57\%$

% error in the value of g

$= 2\frac{\Delta T}{T} \times 100 + \left(\frac{\Delta R + \Delta r}{R - r}\right) \times 100$

$= 2(3.57) + \left(\frac{1+1}{60-10}\right) \times 100 \approx 11\%$

E. Subjective Problems

1. The M.K.S. unit of Young's modulus is Nm^{-2}.
   The M.K.S. unit of magnetic induction is Tesla.
   The M.K.S. unit of power of lens is Dioptre.
2. Given that $T \propto P^a d^b E^c$

   $\Rightarrow [M^0 L^0 T^1] = [ML^{-1}T^{-2}]^a [ML^{-3}]^b [ML^2T^{-2}]^c$

   $\therefore [M^0 L^0 T^1] = [M^{a+b+c} L^{-a-3b+2c} T^{-2a-2c}]$

   $\therefore a + b + c = 0, \; -a - 3b + 2c = 0$

   $-2a - 2c = 1$

   On solving, we get

   $a = -5/6, b = 1/2, c = 1/3$
3. Magnetic Flux = $[M^1 L^2 T^{-1} Q^{-1}]$
   Modulus of Rigidity = $[ML^{-1}T^{-2}]$
4.

Angular Momentum	$[ML^2T^{-1}]$
Latent heat	$[L^2T^{-2}]$
Torque	$[ML^2T^{-2}]$
Capacitance	$[M^{-1}L^{-2}T^2Q^2]$
Inductance	$[ML^2Q^{-2}]$
Resistivity	$[ML^3T^{-1}Q^{-2}]$

5.

Capacitance	coulomb-volt^{-1}, coulomb^2-joule^{-1}
Inductance	ohm-sec, volt-second (ampere)$^{-1}$
Magnetic Induction	newton (ampere-metre)$^{-1}$

$\because$ (a) $q = CV; U = \frac{1}{2}CV^2$

(b) Refer to solution of Q. 3, type D

(c) $F = I \ell B$

6. $(n+1)$ divisions of vernier scale = n divisions of main scale.

$\therefore$ One vernier division = $\frac{n}{n+1}$ main scale division

Least count = 1 M.S.D – 1VS.D = $\left(1-\frac{n}{n+1}\right)$ MSD

$= \frac{1}{n+1}$ M.S.D. = $\frac{a}{n+1}$ units [$\because$ 1 MSD = a units]

7. Least Count = $\frac{1\,mm}{100} = 0.01\,mm$

Diameter = $MSR + CSR \times$ (least count)

$= 1\,mm + 47 \times (0.01)\,mm = 1.47\,mm$

Surface Area = πDl

$= \frac{22}{7} \times 1.47 \times 56\,mm^2 = 2.58724\,cm^2$

$= 2.6\,cm^2$ (Rounding off to two significant figures)

8. $Y = \frac{W}{\frac{\pi D^2}{4}} \times \frac{L}{X}$

KEY CONCEPT : Maximum error in Y is given by

$$\left(\frac{\Delta Y}{Y}\right)_{max} = 2\left(\frac{\Delta D}{D}\right) + \frac{\Delta X}{X} + \frac{\Delta L}{L}$$

$$= 2\left(\frac{0.001}{0.05}\right) + \left(\frac{0.001}{0.125}\right) + \left(\frac{0.1}{110}\right) = 0.0489$$

It is given that $W = 50$ N; $D = 0.05$ cm $= 0.05 \times 10^{-2}$m;

$X = 0.125$ cm $= 0.125 \times 10^{-2}$m;

$L = 110$ cm $= 110 \times 10^{-2}$m

$$\therefore Y = \frac{50 \times 4 \times 110 \times 10^{-2}}{3.14(0.05\times10^{-2})\times(0.125\times10^{-2})} = 2.24 \times 10^{11} N/m^2$$

$\therefore$ Maximum possible error in the value of

$Y = \Delta Y = 0.0489 \times 2.24 \times 10^{11}$

$= 1.09 \times 10^{10}\ N/m^2$

F. Match the Following

1. **A : p→q**

Reason : Unit of $GM_eM_s = Fr^2 = Nm^2 = kg\frac{m}{s^2} \times m^2$

$= kg\ m^3s^{-2}$

Also (volt) (coulomb) (metre) = (joule) (metre)

$= (N\text{-}m)(m) = Nm^2 = kg\ m^3s^{-2}$

B : r → s

Reason : $v_{rms} = \sqrt{\frac{3RT}{M}} \Rightarrow v_{rms}^2 = \frac{3RT}{M}$

$\Rightarrow$ Unit of $\frac{3RT}{M}$ is $m^2 s^{-2}$

Also (farad) (volt)^2 (kg)$^{-1}$ = (joule) kg^{-1}

$=$ N-m kg^{-1} = kg ms^{-2} m kg^{-1} = m^{2}s^{-2}

C : r → s

Reason : $F = qvB \Rightarrow v^2 = \frac{F^2}{q^2B^2}$

$\therefore$ Unit of v^2 is m^2s^{-2} which is further equal to FV^2 kg^{-1}.

D : r → s

Reason : Escape velocity $v_e = \sqrt{\frac{2GM}{R}} \Rightarrow v_e^2 = \frac{2GM}{R}$

$\therefore$ The unit of $\frac{GM}{R}$ is m^2 s^{-2}.

2. (c) Boltzmannn constant $= \frac{R}{N} = \frac{PV}{nTN} = \frac{ML^{-1}T^{-2} \times L^3}{K}$

$= ML^2T^{-2}K^{-1}$

Coefficient of viscosity $= \frac{F}{6\pi rv} = \frac{MLT^{-2}}{L \times LT^{-1}} = ML^{-1}T^{-1}$

Planck constant $= \frac{E}{\nu} = \frac{ML^2T^{-2}}{T^{-1}} = ML^{-2}T^{-1}$

Thermal conductivity $= \frac{H\ell}{tA\Delta T} = \frac{ML^2T^{-2} \times L}{T \times L^2 \times K}$

$= MLT^{-3}K^{-1}$

(c) is the correct option.

3. L.C. = 1 MSD – 1 VSD

$= 1MSD - \frac{9}{10}MSD$

$= \left(1-\frac{9}{10}\right)MSD = \frac{1}{10}MSD = \left(\frac{1}{10}\times1\right)$ mm = 0.1 mm

The side of cube = 10 mm + 1 × 0.1 mm = 10.1 mm = 1.01 cm

Now, density $= \frac{mass}{volume} = \frac{2.736\,g}{(1.01)^3} = 2.66\,g/cm^3$

(Rounding off to 3 significant figures)

G. Comprehension Based Questions

1. (c) $e = [AT]$, $\omega = [T^{-1}]$

$N = [L^{-3}]$, $\in_o = [M^{-1}L^{-3}A^2T^4]$

We do not want Ampere [A] in the expression. This is only possible when $\in_0$ occurs as square. Therefore options a and b are incorrect.

$$\sqrt{\frac{Ne^2}{m\in_o}} = \sqrt{\frac{L^{-3}A^2T^2}{M\,M^{-1}L^{-3}A^2T^4}} = \sqrt{T^{-2}} = T^{-1}$$

2. (b) $\omega_p = \sqrt{\frac{Ne^2}{m\in_o}} = 2\pi\nu = 2\pi\frac{c}{\lambda}$; $\lambda = 2\pi c\sqrt{\frac{m\in_o}{Ne^2}}$

$$= 2\times\frac{22}{7}\times3\times10^8\sqrt{\frac{10^{-30}\times10^{-11}}{4\times10^{27}\times(1.6\times10^{-19})^2}} = 600\,nm$$

I. Integer Value Correct Type

1. (3) $d \propto \rho^x S^y f^z$

$M^0L^1T^0 = M^xL^{-3x}M^yT^{-y}T^{-z}$

$M^0L^1T^0 = M^{x+y}L^{-3x}T^{-y-z}$

$\therefore x + y = 0, -3x = 1$

$\therefore x = -\frac{1}{3}$ and $y = \frac{1}{3}$

$\therefore n = 3$

2. (4) $Y = \frac{FL}{a \times l}$

Here F, a and L are accurately known.

$$\frac{\Delta Y}{Y}\times100 = \frac{\Delta L}{l}\times100 = \frac{1.0\times10^{-5}}{25\times10^{-5}}\times100 = 4\%$$

3. (4) $E = A^2 e^{-0.2t}$

$\therefore$ $\log_e E = 2\log_e A - 0.2t$

On differentiating we get

$$\frac{dE}{E} = 2\frac{dA}{A} - 0.2\frac{dt}{t}\times t$$

As errors always add up therefore

$$\frac{dE}{E}\times 100 = 2\left(\frac{dA}{A}\times 100\right) + 0.2t\left(\frac{dt}{t}\times 100\right)$$

$$\therefore \frac{dE}{E}\times 100 = 2\times 1.25\% + 0.2\times 5\times 1.5\%$$

$$\therefore \frac{dE}{E}\times 100 = 4\%$$

Section-B JEE Main/ AIEEE

1. (a) $W = \vec{F}\cdot\vec{s} = Fs\cos\theta$

$= [MLT^{-2}][L] = [ML^2T^{-2}]$;

$\vec{\tau} = \vec{r}\times\vec{F} \Rightarrow \tau = rF\sin\theta$

$= [L][MLT^{-2}] = [ML^2T^{-2}]$

2. (c) We know that the velocity of light in vacuum is given by

$$c = \frac{1}{\sqrt{\mu_o\varepsilon_o}} \qquad \therefore \frac{1}{\mu_o\varepsilon_o} = c^2 = L^2T^{-2}$$

3. (b) Momentum $= mv = [MLT^{-1}]$

Planck's constant, $h = \dfrac{E}{\nu} = \dfrac{ML^2T^{-2}}{T^{-1}} = ML^2T^{-1}$

4. (a) From stokes law $F = 6\pi\eta rv \Rightarrow \eta = \dfrac{F}{6\pi rv}$

$$\therefore \eta = \frac{MLT^{-2}}{[L][LT^{-1}]} \Rightarrow \eta = [ML^{-1}T^{-1}]$$

5. (d) Moment of Inertia, $I = Mr^2$

$[I] = [ML^2]$

Moment of force, $\vec{\tau} = \vec{r}\times\vec{F}$

$[\vec{\tau}] = [L][MLT^{-2}] = [ML^2T^{-2}]$

6. (c) We know that $F = qvB$

$$\therefore B = \frac{F}{qv} = \frac{MLT^{-2}}{C\times LT^{-1}} = MT^{-1}C^{-1}$$

7. (a) Momentum, $p = m\times v$

$= (3.513)\times(5.00) = 17.565$ kg m/s

$= 17.6$ (Rounding off to get three significant figures)

8. (d) Least count of screw gauge $= \dfrac{0.5}{50}$ mm $= 0.01$mm

$\therefore$ Reading = [Main scale reading + circular scale reading × L.C] – (zero error)

$= [3 + 35\times 0.01] - (-0.03) = 3.38$ mm

9. (d) 30 Divisions of vernier scale coincide with 29 divisions of main scales

Therefore 1 V.S.D $= \dfrac{29}{30}$ MSD

Least count = 1 MSD – 1VSD = 1 MSD $- \dfrac{29}{30}$ MSD

$$= \frac{1}{30}\text{MSD} = \frac{1}{30}\times 0.5° = 1 \text{ minute.}$$

10. (a) Number of significant figures in 23.023 = 5

Number of significant figures in 0.0003 = 1

Number of significant figures in $2.1\times 10^{-3} = 2$

11. (a) L.C. $= \dfrac{1}{100}$ mm

Diameter of wire $= MSR + CSR\times L.C. = 0 + \dfrac{1}{100}\times 52$

$= 0.52$ mm $= 0.052$ cm

12. (a) $R = \dfrac{V}{I}$

$$\frac{\Delta R}{R}\times 100 = \frac{\Delta V}{V}\times 100 + \frac{\Delta I}{I}\times 100 = 3 + 3 = 6\%$$

13. (c) $\because$ Reading of Vernier = Main scale reading + Vernier scale reading × least count.

Main scale reading = 58.5

Vernier scale reading = 09 division

least count of Vernier = 0.5°/30

Thus $R = 58.5° + 9\times\dfrac{0.5°}{30}$

$R = 58.65$

14. (b) As we know, $F = \dfrac{1}{4\pi\varepsilon_0}\dfrac{q_1q_2}{R^2} \Rightarrow \varepsilon_0 = \dfrac{q_1q_2}{4\pi FR^2}$

Hence, $\varepsilon_0 = \dfrac{[AT]^2}{MLT^{-2}.L^2} = [M^{-2}L^{-3}T^4A^2]$

15. (b) Measured length of rod = 3.50 cm

For vernier scale with 1 Main Scale Division = 1 mm

9 Main Scale Division = 10 Vernier Scale Division,

Least count = 1 MSD – 1 VSD

= 0.1 mm

16. (d) As, $g = 4\pi^2\dfrac{l}{T^2}$

So, $\dfrac{\Delta g}{g}\times 100 = \dfrac{\Delta l}{l}\times 100 + 2\dfrac{\Delta T}{T}\times 100$

$= \dfrac{0.1}{20}\times 100 + 2\times\dfrac{1}{90}\times 100 = 2.72 \simeq 3\%$

17. (a) $\Delta T = \dfrac{|\Delta T_1| + |\Delta T_2| + |\Delta T_3| + |\Delta T_4|}{4}$

$= \dfrac{2+1+3+0}{4} = 1.5$

As the resolution of measuring clock is 1.5 therefore the mean time should be 92 ± 1.5

18. (d) L.C. $= \dfrac{0.5}{50} = 0.01$ mm

Zero error $= 5\times 0.01 = 0.05$ mm (Negative)

Reading $= (0.5 + 25\times 0.01) + 0.05 = 0.80$ mm