

Experiments & Errors

Experiments & Errors	Chapter – 22
Level - 1	JEE Main Pattern

1.(A) We know that
$$[Voltage] = \frac{[Work]}{[Charge]} = \frac{[ML^2T^{-2}]}{[AT]} = [ML^2T^{-3}A^{-1}]$$

and,
$$[Resistance] = \frac{[Voltage]}{[Current]} = \frac{[ML^2T^{-3}A^{-1}]}{[A]} = [ML^2T^{-3}A^{-2}]$$

2.(B) We know that the magnetic energy stored in a coil of inductance L carrying a current I ,

$$U = \frac{1}{2}LI^2$$

Therefore,
$$[Inductance] = \frac{[Energy]}{[Current]^2} = \frac{[ML^2T^{-2}]}{[A^2]} = [ML^2T^{-2}A^{-2}]$$

3.(A) Bulk modulus,
$$K = -\frac{\Delta P}{\left(\frac{\Delta V}{V}\right)}$$

Therefore,
$$[K] = [P] = [ML^{-1}T^{-2}]$$

4.(B)
$$[Angular\ acceleration] = \frac{[Angle]}{[Time]^2}$$

We know that angles are dimensionless quantities.

Therefore,
$$[\alpha] = [T^{-2}]$$

5.(D) Coulomb's Law:
$$F = \frac{q_1q_2}{4\pi\epsilon_0r^2}$$

Therefore,
$$[\epsilon_0] = \frac{[Charge]^2}{[Force][Distance]^2} = \frac{[AT]^2}{[MLT^{-2}][L]^2} = [M^{-1}L^{-3}T^4A^2]$$

6.(C) We know that heat current (i.e. the amount of heat passing through a cross-section per unit time) in a slab of length L and area of cross-section A ,

$$H = \frac{KA(\Delta\theta)}{L}$$

Therefore,
$$[K] = \frac{[H][L]}{[A][\Delta\theta]} = \frac{[ML^2T^{-3}][L]}{[L^2][\theta]} = [MLT^{-3}\theta^{-1}]$$

7.(D) Let us rewrite the given quantity as:

$$\begin{aligned} \left[\frac{\sigma^2 r^3}{\epsilon_0}\right] &= \left[\frac{\sigma}{\epsilon_0}\right][\sigma r^2][r] = [Electric\ field][Charge][Distance] \\ &= [Force][Distance] = [Torque] \end{aligned}$$

$$8.(C) \quad \text{Unit of } X = \sqrt{\frac{\text{Unit of } Y}{\text{Unit of } Z}} = \sqrt{\frac{10^{-3} \text{ J}}{10^{-3} \text{ kg}}} = 1 \text{ m/s}$$

$$9.(C) \quad \text{Resistance} = \frac{\text{Potential difference}}{\text{Current}} = \frac{97.52}{2.50} = 39.008 \approx 39.0 \Omega$$

$$10.(B) \quad 0.095 + 23.02 - 8.734 = 14.381 \approx 14.38 \quad 11.(D) \quad \text{Speed} = \frac{\text{Distance}}{\text{Time}} = \frac{9.86}{2.0} = 4.93 \approx 4.9 \text{ m/s}$$

$$12.(D) \quad \frac{14.28}{0.714} = 20.0$$

$$13.(B) \quad x = 0.72 + 0.8 + 3.87 - 1.089 = 2.781 \approx 2.8$$

$$14.(C) \quad (1.45)(2.2) = 3.19 \approx 3.2$$

$$15.(A) \quad (2.9)^2 - 1.06 = 8.41 - 1.06 = 7.35 \approx 7.4$$

$$16.(D) \quad \text{Least count of a screw gauge} = \frac{\text{Pitch}}{\text{Number of divisions on the circular scale}}$$

$$17.(C) \quad \text{Least count} = (1 \text{ mm}) \left(1 - \frac{49}{50} \right) = 0.02 \text{ mm}$$

$$18.(B) \quad \text{Least count of Vernier callipers} = (1 \text{ mm}) \left(1 - \frac{19}{20} \right) = 0.05 \text{ mm}$$

$$\text{Least count of a screw gauge} = \frac{\text{Pitch}}{\text{Number of divisions on the circular scale}} = \frac{P}{N}$$

$$19.(B) \quad \text{Mean value of all readings} = \frac{12.35 + 12.61 + 12.42 + 12.29 + 12.44}{5} = 12.42 ; \quad \text{Sum of all}$$

$$\text{deviations} = |12.35 - 12.42| + |12.61 - 12.42| + |12.42 - 12.42| + |12.29 - 12.42| + |12.44 - 12.42| = 0.41$$

$$\text{Therefore, the mean error} = \frac{0.41}{5} = 0.08$$

$$\text{So, the diameter of the cylinder is } (12.42 \pm 0.08) \text{ mm}$$

$$20.(A) \quad \text{We are given that} \quad z = \frac{1}{x+y}$$

$$\text{Differentiating,} \quad dz = -\frac{(dx+dy)}{(x+y)^2} \quad \Rightarrow \quad \Delta z = \frac{\Delta x + \Delta y}{(x+y)^2}$$

$$21.(C) \quad \text{We are given that} \quad z = x - y$$

$$\text{Differentiating,} \quad dz = dx - dy$$

$$\text{Therefore,} \quad \Delta z = \Delta x + \Delta y$$

$$\text{So, the fractional error in } z, \quad \frac{\Delta z}{z} = \frac{\Delta x + \Delta y}{x - y}$$

$$22.(C) \quad \text{We know that} \quad \rho = \frac{M}{\frac{4\pi}{3}R^3} = \frac{3M}{4\pi R^3}$$

$$\text{Therefore,} \quad \frac{\Delta \rho}{\rho} = \frac{\Delta M}{M} + 3 \left(\frac{\Delta R}{R} \right) = 1\% + 3(0.5\%) = 2.5\%$$

$$23.(B) \quad \text{Both measurements are made using the same scale. Therefore, the absolute error in the measurement of } a \text{ and } L \text{ are equal, i.e. } \Delta a = \Delta L$$

$$\text{In method 1,} \quad f_1 = \left(\frac{\Delta A}{A} \right)_1 = 2 \left(\frac{\Delta a}{a} \right)$$

$$\text{In method 2,} \quad f_2 = \left(\frac{\Delta A}{A} \right)_2 = 2 \left(\frac{\Delta L}{L} \right)$$

So, since $\Delta a = \Delta L$ and $L = \sqrt{2}a$,

$$f_2 = \frac{1}{\sqrt{2}} f_1$$

24.(A) Mirror formula: $\frac{1}{f} = \frac{1}{u} + \frac{1}{v} \Rightarrow \frac{1}{f} = \frac{1}{(-40)} + \frac{1}{(-40)} \Rightarrow |f| = 20 \text{ cm}$

Differentiating the mirror equation,

$$\frac{df}{f^2} = -\frac{du}{u^2} - \frac{dv}{v^2}$$

$$\Rightarrow \frac{\Delta f}{f^2} = \frac{\Delta u}{u^2} + \frac{\Delta v}{v^2} \Rightarrow \frac{\Delta f}{f^2} = \frac{(0.1)}{(40)^2} + \frac{(0.1)}{(40)^2} = \frac{1}{8000}$$

Therefore,

$$\Delta f = \left(\frac{1}{8000} \right) f^2 = \left(\frac{1}{8000} \right) (20)^2 = 0.05$$

So, the focal length of the mirror is $(20.00 \pm 0.05) \text{ cm}$

25.(D) We know that

$$Q = mC\Delta T$$

$$\Rightarrow C = \frac{Q}{m\Delta T} \Rightarrow \frac{\Delta C}{C} = \frac{\Delta Q}{Q} + \frac{\Delta m}{m} + \frac{\Delta(\Delta T)}{\Delta T} = 0.05 + 0.01 + 0.02 = 0.08$$

26.(D) We know that

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

If the measured time taken for 20 oscillations is t , then the time period,

$$T = \frac{t}{20} \Rightarrow \Delta T = \frac{\Delta t}{20}$$

Therefore, it is clear that

$$\frac{\Delta T}{T} = \frac{\Delta t}{t}$$

Therefore, $\frac{\Delta g}{g} = \frac{\Delta L}{L} + 2 \left(\frac{\Delta T}{T} \right) = \frac{\Delta L}{L} + 2 \left(\frac{\Delta t}{t} \right) = \frac{0.1}{64} + 2 \left(\frac{0.1}{8} \right) = \frac{17}{640} \approx 2.7\%$

27.(A) Length,

$$L = 8.0 \text{ cm} \quad \text{and} \quad \Delta L = 0.1 \text{ cm}$$

Breadth,

$$B = 6.0 \text{ cm} \quad \text{and} \quad \Delta B = 0.1 \text{ cm}$$

Diagonal,

$$D = \sqrt{L^2 + B^2} = \sqrt{8^2 + 6^2} = 10 \quad \text{and,}$$

$$dD = \frac{2LdL + 2BdB}{2\sqrt{L^2 + B^2}} = \frac{LdL + BdB}{\sqrt{L^2 + B^2}}$$

Therefore, $\Delta D = \frac{L\Delta L + B\Delta B}{\sqrt{L^2 + B^2}} = \frac{(8)(0.1) + (6)(0.1)}{10} = 0.14$

So, the length of a diagonal is $(10 \pm 0.14) \text{ cm}$

28.(B) We are given that

$$\frac{R_1}{R_2} = \frac{25}{100 - 25} = \frac{1}{3} \quad \text{and,}$$

$$\frac{R_1}{\left(\frac{30R_2}{30 + R_2} \right)} = \frac{40}{100 - 40} = \frac{2}{3}$$

Solving, we get

$$R_1 = 10 \Omega \quad \text{and} \quad R_2 = 30 \Omega$$

29.(B) Circumference,

$$C = 2\pi R \Rightarrow \frac{\Delta C}{C} = \frac{\Delta R}{R}$$

Area,

$$A = \pi R^2 \Rightarrow \frac{\Delta A}{A} = 2 \left(\frac{\Delta R}{R} \right)$$

Therefore,

$$\frac{\Delta A}{A} = 2 \left(\frac{\Delta C}{C} \right)$$

30.(C) Surface area of the sphere,

$$A = 4\pi R^2 \quad ; \quad \Rightarrow \quad dA = 8\pi R dR \quad \Rightarrow \quad \Delta A = (8\pi R) \Delta R$$

Level - 2

JEE Advanced Pattern

31.(D) We know that $[Planck's\ constant] = \frac{[Energy]}{[Frequency]}$

$$\Rightarrow [h] = \frac{[ML^2T^{-2}]}{[T^{-1}]} = [ML^2T^{-1}]$$

Also, $[Speed\ of\ light] = [c] = [LT^{-1}]$

Therefore, $[hc] = [ML^2T^{-1}][LT^{-1}] = [ML^3T^{-2}]$

32.(C) We know that in an exponential expression, the exponent must always be dimensionless.

Therefore, the dimensions of B , $[B] = [T^{-1}]$

Also, the exponential itself is also dimensionless. So, the dimensions of A and C must be the same.

So, $[A] = [C] = [Force]$

Therefore, $\left[\frac{A}{B}\right] = \frac{[Force]}{[T^{-1}]} = [Force][Time] = [Impulse] = [Momentum]$

33.(B) We know that the average kinetic energy of a molecule of an ideal at temperature T is $\frac{3}{2}k_B T$

Therefore, the dimensions of $k_B T$ are those of energy

So, $\left[\frac{L}{k_B T}\right] = \frac{[Angular\ Momentum]}{[Energy]} = [Time]$

34.(B) We are given that $U(x) = px - qx^3$

So, $Unit\ of\ p = \frac{Unit\ of\ U}{Unit\ of\ x} = \frac{10^{-6}\ J}{10^{-3}\ m} = 10^{-3}\ N$

And, $Unit\ of\ q = \frac{Unit\ of\ U}{Unit\ of\ x^3} = \frac{10^{-6}\ J}{10^{-9}\ m^3} = 10^3\ Pa$

35.(C) $[Electric\ flux] = [Electric\ field][Area] = \frac{[Force]}{[Charge]}[Area] = \frac{[MLT^{-2}]}{[AT]}[L^2] = [ML^3T^{-3}A^{-1}]$

So, in the new system, the unit of electric flux is:

$$(10^{-3}\ kg)(10^{-3}\ m)^3(10^{-2}\ s)^{-3}(10^{-6}\ A)^{-1} = 1\ Wb$$

36.(C) We know that $[Magnetic\ field] = \frac{[Electric\ field]}{[Velocity]}$

Therefore, $[Magnetic\ flux] = \frac{[Electric\ flux]}{[Velocity]} = \frac{[ML^3T^{-3}A^{-1}]}{[LT^{-1}]} = [ML^2T^{-2}A^{-1}]$

So, in the new system, the unit of magnetic flux is:

$$(10^{-3}\ kg)(10^{-3}\ m)^2(10^{-2}\ s)^{-2}(10^{-6}\ A)^{-1} = 10\ Tm^2$$

$$37.(AC) \frac{\text{Force}}{(\text{Current})(\text{Electric field})} = \frac{(\text{Force})(\text{Time})}{(\text{Charge})(\text{Electric field})} = \text{Time}$$

$$\frac{(\text{Resistivity})(\text{Capacitance})}{(\text{Area})} = (\text{Resistance})(\text{Length})(\text{Capacitance}) = (\text{Length})(\text{Time})$$

We know that $\frac{dQ}{dt} = \frac{KA\Delta\theta}{L} \Rightarrow [KA\Delta\theta] = \frac{\text{Energy}}{(\text{Length})(\text{Time})} = \frac{\text{Force}}{\text{Time}}$

Therefore, $\frac{\text{Force}}{(\text{Thermal conductivity})(\text{Temperature})} = \text{Time}$

We know that $[\Phi_B] = [BA] = \left[\frac{\mu_0 I}{r} (r^2) \right] = [\mu_0 I r]$

And, $[EMF] = \frac{[\Phi_B]}{[\text{Time}]} = \frac{[\mu_0 I r]}{[\text{Time}]}$

But, we also know that $[EMF] = [Current][Resistance]$

So, $\frac{[\mu_0 I r]}{[\text{Time}]} = [IR]$

Therefore, $\frac{(\text{Magnetic permeability})}{(\text{Resistance})(\text{Length})} = \frac{\text{Time}}{\text{Area}}$

$$38.(C) [(\text{Magnetic flux})(\text{Current})] = [BL^2][I] = [BIL][L] = [Force][Length] = [Energy]$$

39.(D) We are given that $r = \frac{x^2}{y} - 2z$

Differentiating, $dr = \frac{2x}{y} dx - \frac{x^2}{y^2} dy - 2dz$

Therefore, $\Delta r = \left(\frac{2x}{y} \right) \Delta x + \left(\frac{x^2}{y^2} \right) \Delta y + 2\Delta z$

40.(B) We are given that $z = ab\sqrt{c}$

Differentiating, $dz = \left(\frac{ab}{2\sqrt{c}} \right) dc + (a\sqrt{c}) db + (b\sqrt{c}) da$

Therefore, $\Delta z = \left(\frac{ab}{2\sqrt{c}} \right) \Delta c + (a\sqrt{c}) \Delta b + (b\sqrt{c}) \Delta a$

41.(B) If the speed of sound in air is c , the length of the air column is L , the diameter of the tube is d and the frequency of the tuning fork is f_T ,

The first resonance is heard when

$$\frac{c}{4(L + 0.3d)} = f_T$$

And the second resonance is heard when

$$\frac{3c}{4(L + 0.3d)} = f_T$$

So from the given information, we can form the following two equations:

$$\frac{c}{4(22.8 + 0.3(4))(0.01)} = 525 \quad \text{and} \quad \frac{3c}{4(L + 0.3(4))(0.01)} = 1050$$

Solving, we get $L = 34.8 \text{ cm}$

42.(D) We know that $R = \frac{\rho L}{A} = \frac{\rho L^2}{V} \Rightarrow \rho = \frac{RV}{L^2}$

$$\Rightarrow \frac{\Delta \rho}{\rho} = \frac{\Delta R}{R} + \frac{\Delta V}{V} + 2 \left(\frac{\Delta L}{L} \right) \Rightarrow \frac{\Delta \rho}{\rho} = \frac{0.1}{2} + 0.05 + 2 \left(\frac{0.1}{10} \right) = 12\%$$

43.(D) We know that $Young's\ modulus = \frac{Stress}{Strain}$; So, $Y = \frac{\left(\frac{mg}{\left(\frac{\pi d^2}{4} \right)} \right)}{\left(\frac{\Delta l}{L} \right)} = \frac{4mgL}{\pi d^2 (\Delta l)} = \left(\frac{4gL}{\pi d^2} \right) \left(\frac{m}{\Delta l} \right)$

Now, we know that the slope of the straight line graph with m on the X-axis and Δl on the Y-axis must be

$$S = \frac{\Delta l}{m}$$

Therefore, $Y = \frac{4gL}{\pi d^2 S}$ **44.(ABCD)**

45.(C) We are given that $\frac{1}{z} = \frac{1}{x} + \frac{1}{y}$

Differentiating, $-\frac{dz}{z^2} = -\frac{dx}{x^2} - \frac{dy}{y^2}$

Therefore, $\frac{\Delta z}{z^2} = \frac{\Delta x}{x^2} + \frac{\Delta y}{y^2} \Rightarrow \Delta z = \left(\frac{\Delta x}{x^2} + \frac{\Delta y}{y^2} \right) z^2 = \left(\frac{\Delta x}{x^2} + \frac{\Delta y}{y^2} \right) \left(\frac{x^2 y^2}{(x+y)^2} \right) = \frac{y^2 \Delta x + x^2 \Delta y}{(x+y)^2}$

So, $\Delta z = \frac{y^2}{(x+y)^2} \Delta x + \frac{x^2}{(x+y)^2} \Delta y$

46.(B) Let E be the emf of the main battery
 r be the internal resistance of the main battery
 R be the resistance of the potentiometer wire
 L be the total length of the potentiometer wire
 x be the distance of the balancing point from the end A

We are given that

$$E = 60.0\ V \Rightarrow \Delta E = 0.1\ V$$

$$r = 2.0\ \Omega \Rightarrow \Delta r = 0.1\ \Omega$$

$$R = 10.0\ \Omega \Rightarrow \Delta R = 0.1\ \Omega$$

$$L = 100.0\ cm \Rightarrow \Delta L = 0.1\ cm$$

$$x = 40.0\ cm \Rightarrow \Delta x = 0.1\ cm$$

Now, we know that the current in the main branch,

$$I = \frac{E}{R+r} = \frac{60}{10+2} = 5\ A$$

Therefore, $E_2 = I \left(\frac{x}{L} \right) = (5) \left(\frac{40}{100} \right) = 2\ V$; Now, $E_2 = I \left(\frac{x}{L} \right) = \frac{E x}{L(R+r)}$

Therefore, $\frac{\Delta E_2}{E_2} = \frac{\Delta E}{E} + \frac{\Delta x}{x} + \frac{\Delta L}{L} + \frac{\Delta R + \Delta r}{R+r} \Rightarrow \frac{\Delta E_2}{E_2} = \frac{0.1}{60} + \frac{0.1}{40} + \frac{0.1}{100} + \frac{0.1+0.1}{10+2} = \frac{131}{6000}$

So, $\Delta E_2 = \frac{131}{6000} \times E_2 = \frac{131}{3000} \approx 0.044$

Therefore, the emf of the battery is $E_2 = (2.0 \pm 0.044)\ V$

47.(B) We know that $Young's\ modulus = \frac{Stress}{Strain}$

$$Therefore, \quad Y = \frac{\left(\frac{mg}{\left(\frac{\pi d^2}{4} \right)} \right)}{\left(\frac{\Delta L}{L} \right)} = \frac{4mgL}{\pi d^2 (\Delta L)}$$

$$So, \quad Y = \frac{4(4)(10)(0.5)}{\left(\frac{25}{8} \right) (2 \times 10^{-3})^2 (1.6 \times 10^{-4})} = 8 \times 10^{10} \text{ N/m}^2$$

48.(C) We know that $Y = \frac{4mgL}{\pi d^2 (\Delta L)}$

$$So, \quad \frac{\Delta Y}{Y} = \frac{\Delta m}{m} + \frac{\Delta L}{L} + 2 \left(\frac{\Delta d}{d} \right) + \frac{\Delta(\Delta L)}{\Delta L} = \frac{0.01}{4} + \frac{0.1}{50} + 2 \left(\frac{0.02}{2} \right) + \frac{0.01}{0.16} = 8.7\%$$

49.(C) The fractional error in Young's modulus is given by: $\frac{\Delta Y}{Y} = \frac{\Delta m}{m} + \frac{\Delta L}{L} + 2 \left(\frac{\Delta d}{d} \right) + \frac{\Delta(\Delta L)}{\Delta L}$

Now, the absolute errors in the measured quantities (Δm , ΔL , Δd and $\Delta(\Delta L)$) depend on the least counts of the measuring instruments, and are therefore fixed and independent of the length and diameter of the test wire, or the load weight.

So, it is clear that if we increase the values of either of m , L or d , the fractional error in the measurement of Young's modulus will decrease.

And, since this fractional error is $\frac{\Delta Y}{Y}$, and the value of Young's modulus is fixed (a material property), the absolute error ΔY also decreases.

50.(B) Let the unknown resistance be X and the known resistance be Y
Let the balancing length be L (in cm)

$$Then, \quad \frac{X}{Y} = \frac{L}{100 - L} \quad \Rightarrow \quad X = \left(\frac{L}{100 - L} \right) Y$$

$$\Rightarrow \quad \Delta X = \left(\frac{1}{100 - L} + \frac{L}{(100 - L)^2} \right) Y \Delta L = \left(\frac{100}{(100 - L)^2} \right) Y \Delta L \Rightarrow \quad \frac{\Delta X}{X} = \left(\frac{100}{L(100 - L)} \right) \Delta L$$

$$Therefore, \quad \frac{\Delta X}{X} = \left(\frac{100}{(25)(75)} \right) (0.1) = 0.53\%$$

Archive	JEE Main
1.(C) $\frac{1}{\mu_0 \epsilon_0} = C^2 = [L^2 T^{-2}]$ 3.(C) $\eta = \frac{F}{rv} = \frac{MLT^{-2}}{LLT^{-1}} = [ML^{-1}T^{-1}]$ 4.(C) Moment of inertia and moment of a force have different dimensions. 5.(C) $\frac{ML^2}{Q^2}$; In option (C), $H = \frac{BA}{i} = [ML^2 C^{-2}]$ Option (A) : [Weber] = $BA = [MT^{-1}C^{-1}L^2]$ Option (D) $H / m^2 = ML^2 C^{-2} L^{-2} = [MC^{-2}]$	2.(B) [Momentum] = $[MLT^{-1}]$ $[h] = \frac{E}{v} = ML^2 T^{-2} T = [ML^2 T^{-1}]$ 7.(A) 8.(D) $3 + \frac{0.5}{50} \times 35 + 0.03 = 3 + 0.35 + 0.03 = 3.38 \text{ mm}$ 9.(A) $P = mv = 3.513 \times 5.00 = 17.565 \approx 17.6 \text{ kgm/sec.}$ 10.(A) 11.(C) $0.5 \times \frac{1}{30} \times 60 \text{ min} = 1 \text{ minute}$ 12.(A) Reading = $0 \text{ mm} + 52 \times \frac{0.1}{100} = 0.052 \text{ cm}$ 13.(A) $\frac{1}{4\pi\epsilon_0} \frac{q^2}{r^2} = F$, $\epsilon_0 = \frac{[A^2 T^2]}{[MLT^{-2} L^2]} = [M^{-1} L^{-3} A^2 T^4]$ 14.(D) $[L] = mvr = [ML^2 T^{-1}]$, Latent Heat = $\frac{Q}{m} = [L^2 T^{-2}]$, $[C] = \frac{q}{V} = \frac{ATAT}{ML^2 T^{-2}} = [M^{-1} L^{-2} T^4 A^2]$ 15.(D) $\frac{\mu}{\epsilon} = \frac{1}{\epsilon^2 c^2} = \frac{q^2}{\epsilon^2 r^2 q^2 t^{-2}} = \frac{V^2}{i^2} = R^2$ $\left\{ [c] = \frac{[r]}{[t]} \right\}$ 16.(B) Option B is dimension less 17.(D) Least count of vernier caliper is $\frac{1}{10} \text{ mm} = 0.1 \text{ mm} = 0.01 \text{ cm}$ 18.(C) $5 = e^{\frac{1000}{T} - 1} \Rightarrow e^{\frac{1000}{T} - 1} = 6 \dots (1)$ Again, $I = e^{\frac{1000}{T} - 1} \Rightarrow \frac{dI}{dV} = e^{\frac{1000}{T} - 1} \frac{1000}{T}; \quad dI = \frac{1000}{T} e^{\frac{1000}{T} - 1} dV$ Using (1) $\Delta I = \frac{1000}{T} \times 6 \times 0.01 = \frac{60}{T} = \frac{60}{300} = 0.2 \text{ mA}$ 19.(A) $g = \frac{4\pi^2 L}{T^2}$, $\frac{\Delta g}{g} = \frac{\Delta L}{L} + 2 \left(\frac{\Delta T}{T} \right)$, $\frac{\Delta L}{L} = \frac{0.1}{20}$, $\frac{\Delta T}{T} = \frac{0.01}{0.9}$ $100 \left(\frac{\Delta g}{g} \right) = 100 \left(\frac{\Delta L}{L} \right) + 2 \times 100 \times \left(\frac{\Delta T}{T} \right) = 3\%$ 20.(B) $0.58 + 0.03 = 0.61$, $0.54 + 0.03 = 0.57$, $0.56 + 0.03 = 0.59$. Total = 1.77 Average diameter = $\frac{1.77}{3}$ 21.(C) $u = \frac{e}{v} = \frac{e^2}{W} = \frac{e^2 a_0}{hC}$; Here, $W = \frac{hc}{\lambda} = \frac{hc}{a_0} \{ [\lambda] = [a_0] \}$

$$22.(A) \quad LC = \frac{0.5 \text{ mm}}{50} = 0.01 \text{ mm}$$

$$\text{Zero error} = -5(0.01) = 0.05 \text{ mm}, \quad \text{Reading} = 0.5 + 25(0.01) = 0.75 \text{ mm}$$

$$\text{Thickness} = \text{reading} - \text{zero error} = 0.75 - (-0.05) = 0.80 \text{ mm}$$

$$23.(D) \quad t = \frac{t_1 + t_2 + t_3 + t_4}{4} = \frac{90 + 91 + 95 + 92}{4} = 92$$

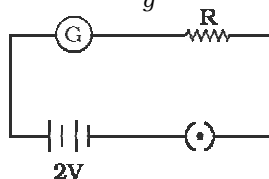
Now mean deviation is equal to $\left(\frac{2+1+3+0}{4} \right) = 1.5$. Since least count of clock is one second, so

$$\Delta t = 2 \text{ sec}$$

24.(A) The circuit given in the question is incorrect. The given figure shows the correct circuit. Let the current which produces full scale deflection in the galvanometer be I_g . Then according to questions.

$$\frac{4}{5} I_g = \frac{V}{G+R} = \frac{2}{G+2400} \quad \dots (i)$$

$$\frac{2}{5} I_g = \frac{2}{G+400} \quad \dots (ii)$$



$$\text{From eqns. (i) and (ii), } \frac{4}{2} = \frac{G+4900}{G+2400} \Rightarrow G = 100 \Omega \quad ; \quad \text{Putting } G \text{ in Eq. (i)}$$

$$\frac{4}{5} I_g = \frac{2}{100 + 2400} \Rightarrow I_g = \frac{2 \times 5}{2500} \Rightarrow 1 \text{ mA} \quad ; \quad \text{For a deflection of 10 divisions}$$

$$\frac{1}{5} I_g = \frac{V}{G+R} \Rightarrow \frac{1}{5} \times 10^{-3} = \frac{2}{100 + R} \Rightarrow R = 9900 \Omega$$

$$\text{Now, current sensitivity} = \frac{I_g}{n} = \frac{1 \text{ mA}}{50 \text{ div}} = 20 \mu\text{A} / \text{division}$$

$$25.(D) \quad \frac{\Delta \rho}{\rho} \times 100 = \frac{\Delta m}{m} \times 100 + \frac{3 \times \Delta a}{a} \times 100 = 4.5\%$$

$$26.(C) \quad t = k \cdot G^x h^y \cdot c^z \quad ; \quad [t] = [k] \left[\frac{Fd^2}{m_1 m_2} \right]^x \left[\frac{E}{v} \right]^y [c]^z$$

$$\left[\frac{MLT^{-2}L^2}{M^2} \right]^x \left[\frac{ML^2T^{-2}}{T^{-1}} \right]^y [LT^{-1}]^z = M^{-x} L^{3x} T^{-2x} M^y L^{2y} T^{-y} L^z T^{-z}$$

$$[t] = M^{y-x} L^{3x+2y+z} T^{-2x-y-z}$$

$$\text{Comparing } y = x, \quad 3x + 2y + z = 0 \quad \Rightarrow \quad z = -5x \text{ and } -3x + 5x = 1$$

$$\Rightarrow \quad x = \frac{1}{2} \quad \Rightarrow \quad y = \frac{1}{2} \quad \Rightarrow \quad z = \frac{-5}{2}$$

$$\text{So } t \propto \sqrt{\frac{Gh}{c^5}}$$

$$27.(A) \quad p = 0.5 \text{ mm}$$

$$N = 100$$

$$\text{Last count } 0.005 \text{ m}$$

This screw gauge has positive zero error

$$R = 5.5 + 48 \times 0.005 - 3 \times 0.005 = 5.725 \text{ mm}$$

$$28.(C) \quad d = 12.6 \pm 0.1 \text{ cm}$$

$$h = 34.2 \pm 0.1 \text{ cm}$$

$$V = \pi \frac{d^2 h}{4} \Rightarrow \frac{\Delta V}{V} = \frac{2\Delta d}{d} + \frac{\Delta h}{h} \quad \Rightarrow \quad \frac{\Delta V}{V} = 2 \times \frac{0.1}{12.6} + \frac{0.1}{34.2} = 80$$

$$V = 4260 \pm 80 \text{ cm}^3$$

$V = 4264.94$ actually but significant digits have to be kept upto 3. So $V = 4260$

29.(B) $\rho = \frac{m}{V}$ $[\rho] = [ML^{-3}]$

$$128(1\text{kg})(1\text{m})^{-3} = x \left(\frac{50}{1000} \text{kg} \right) \left(\frac{25}{100} \text{m} \right)^{-3} \Rightarrow x = 128 \times \frac{1000}{50} \times 4^{-3} = \frac{128 \times 20}{64} = 40$$

30.(A) $\frac{L^2}{\alpha \left(\frac{ML^2T^{-2}}{\theta} \right) \cdot \theta} = 1 \Rightarrow \alpha = \frac{1}{MT^{-2}}$

Also, $MLT^{-2} = \alpha\beta \Rightarrow \beta = M^2LT^{-4}$

31.(C) $\left[\frac{L}{rCV} \right] = \left[\left(\frac{l}{r} \right) \left(\frac{r}{v} \right) \left(\frac{1}{r} \right) \right] = [T] [A^{-1}] \left[\frac{1}{[T]} \right] = [A^{-1}]$

32.(C) Least count of screw gauge

$$= \frac{\text{pitch}}{\text{No. of division on vernier scale}} \Rightarrow 5\mu\text{m} = \frac{1\text{mm}}{N}$$

$$N = 200$$

33.(A) $[y] = [V_x A^y F^z]$

or $[mL^{-1}T^{-2}] = [(LT^{-1})^x (LT^{-2})^y (mLT^{-2})^z]$ or $[mL^{-1}T^{-2}] = [m^z L^{x+y+z} T^{-x-2y-2z}]$

Comparing powers of m , L and T on both sides.

$$z = 1$$

$$x + y + z = -1$$

$$-x - 2y - 2z = -2 \Rightarrow x = -4$$

$$y = 2$$

$$z = 1$$

$\therefore$ Required dimensional formula is $V^{-4}A^2F$.

34.(C) $F = Mg$

$$\rightarrow \text{stress } \sigma = \frac{F}{A} = \frac{Mg}{A}$$

Since $\frac{\sigma}{\epsilon} = \gamma \rightarrow \epsilon = \frac{\sigma}{\gamma}$

In first case, $\epsilon = \frac{\Delta l}{l} = \frac{4 \times 10^{-3}}{2} = 2 \times 10^{-3}$

$$\rightarrow \gamma = \frac{Mg/A}{(2 \times 10^{-3})}$$

After dipping in liquid,

Consider equilibrium of block of mass M .

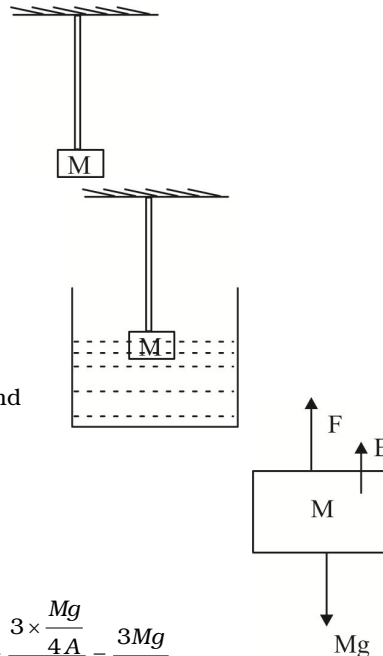
Where F is the force applied by steel wire and

B = Buoyant force $= \rho_l Vg$

Since $M = \rho V$ and $\frac{\rho_l}{\rho} = \frac{2}{8} = 0.25$ (given)

$$B = \frac{Mg}{4}$$

$$F = Mg - \frac{Mg}{4} = \frac{3Mg}{4} ; \quad \epsilon = \frac{F/A}{Y} = \frac{3 \times \frac{Mg}{4A}}{Y} = \frac{3Mg}{4AY}$$



$$\epsilon = \frac{3Mg}{4A} \times \frac{2 \times 10^{-3}}{Mg/A} = 1.5 \times 10^{-3} \quad ; \quad \frac{\Delta l}{l} = 1.5 \times 10^{-3}$$

$$\Delta l = 2 \times 1.5 \times 10^{-3} m ; \quad \Delta l = 3 mm$$

35.(C) $f = \frac{V}{4L + 4e}$

$$512 = \frac{V}{4 \times \frac{11}{100} + 4e} \quad \dots (i)$$

$$256 = \frac{V}{4 \times \frac{27}{100} + 4e} \quad \dots (ii)$$

From equation (i) and (ii)

$$2 = \frac{4 \times \frac{27}{100} + 4e}{4 \times \frac{11}{100} + 4e} \quad ; \quad 2(0.11 + e) = 0.27 + e ; \quad 0.11 \times 2 + 2e = 0.27 + e ;$$

$$2e - e = 0.27 - 0.22$$

$$e = 0.05$$

Put in equation (i) $512 = \frac{V}{4 \times 0.11 + 4 \times 0.05}$

$$V = 0.64 \times 512 ; \quad V = 327.68 \text{ m / s}$$

36.(C) $[S] = [MT^{-2}] \quad ; \quad [I] = [ML^2] \quad ; \quad [h] = [ML^2T^{-1}]$

Linear momentum, $[P] = [MLT^{-1}]$

$$[P] = [S]^a [I]^b [h]^c \quad ; \quad = [M^{a+b+c} L^{2b+2c} T^{-2a-c}]$$

Comparing we get

$$a + b + c = 1, \quad 2b + 2c = 1, \quad -2a - c = -1$$

Solving we get

$$a = \frac{1}{2}, b = \frac{1}{2}, c = 0$$

37.(B) $T = 2\pi \sqrt{\frac{l}{g}} \Rightarrow g = \frac{4\pi^2 l}{T^2}$

$$\frac{\Delta g}{g} \times 100 = \frac{\Delta l}{l} \times 100 + 2 \frac{\Delta T}{T} \times 100 = \frac{1}{550} \times 100 + 2 \times \frac{1}{30} \times 100 \approx 6.8\%$$

38.(none) $\rho = \frac{10}{(0.1)^3} = 10^4 \text{ kg/m}^3$

$$\text{Also } \rho = \frac{M}{l^3} \therefore \frac{\Delta \rho}{\rho} = \frac{\Delta M}{M} + \frac{3\Delta l}{l} = \frac{0.1}{10} + \frac{0.01}{0.1} \times 3 = \frac{1}{100} + \frac{3}{10} = \frac{31}{100} = 0.31$$

$$\Delta \rho = 0.31 \times 10^4 \text{ kg / m}^3$$

39.(3) We have confidence only till two places of decimal in actual measurement so the final answer accurate to the just 2 decimal place.

Note : It is actual measurement taken using some device with least count.

40.(C) $X = 5YZ^2$

$$Y = \frac{X}{5Z^2} \Rightarrow [Y] = \frac{[X]}{[Z^2]} = \frac{M^{-1}L^{-2}T^4A^2}{M^2T^{-4}A^{-2}} = M^{-3}L^{-2}T^8A^4$$

41.(D) We know $c = \frac{1}{\sqrt{\mu_0 \epsilon_0}} \Rightarrow c \epsilon_0 = \sqrt{\frac{\epsilon_0}{\mu_0}}$

$$F = \frac{1}{4\pi \epsilon_0} \frac{q_1 q_2}{r^2} \quad [\epsilon_0] = \frac{[q_1 q_2]}{[F][r^2]} = \frac{[A^2 T^2]}{[MLT^{-2}][L^2]} = [M^{-1} L^{-3} T^4 A^2]$$

$$\therefore [c \epsilon_0] = [LT^{-1}][M^{-1} L^{-3} T^4 A^2] = [M^{-1} L^{-2} T^3 A^2]$$

42.(B) $V = IR$

$$R = \frac{V}{I}$$

$$R = \frac{W/q}{I}$$

$$[R] = \left[\frac{ML^2 T^{-2}}{I^2 T} \right]$$

$$[R] = [ML^2 T^{-3} A^{-2}]$$

$$F = \frac{1}{4\pi \epsilon_0} \frac{q_1 q_2}{r^2}$$

$$\epsilon_0 = \frac{q_1 q_2}{F_1 r^2}$$

$$[\epsilon_0] = \left[\frac{A^2 T^2}{MLT^{-2} L^2} \right]$$

$$[\epsilon_0] = \left[\frac{A^2 T^2}{ML^3 T^{-2}} \right]$$

$$[\epsilon_0] = [M^{-1} L^{-3} T^4 A^2]$$

$$C^2 = \frac{1}{\mu_0 \epsilon_0}$$

$$\mu_0 = \frac{1}{C^2 \epsilon_0}$$

$$[\mu_0] = \left[\frac{1}{L^2 T^{-2} M^{-1} L^{-3} T^4 A^2} \right]$$

$$[\mu_0] = [M^1 A^{-2} L T^{-2}]$$

$$\left[\frac{\epsilon_0}{\mu_0} \right] = \left[\frac{M^{-1} L^{-3} T^4 A^2}{M^1 A^{-2} L T^{-2}} \right] ; \quad \left[\frac{\epsilon_0}{\mu_0} \right] = [M^{-2} L^{-4} T^6 A^4]$$

$$\left[\frac{\mu_0}{\epsilon_0} \right] = [M^2 L^4 T^{-6} A^{-4}] ; \quad \left[\sqrt{\frac{\mu_0}{\epsilon_0}} \right] = [ML^2 T^{-3} A^{-2}]$$

43.(C) $T = MB$

$$C\phi = NIAB$$

$$B = \frac{10^{-6} \times \pi}{175 \times 10^{-4} \times 10^{-3} \times 180} \approx 10^{-3} T$$

$$44.(B) \quad \frac{B^2}{2\mu_0} \text{ Energy density} = \frac{\text{Energy}}{\text{volume}} = \frac{[ML^2T^{-2}]}{[L^3]} = [ML^{-1}T^{-2}]$$

45.(Bonus)

$$V_0 = kh^x c^y G^z A^t$$

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

$$t = -1 \quad \dots (1)$$

$$x - 2 = 1 \quad \dots (2)$$

$$2x + y + 3z = 2 \quad \dots (3)$$

$$-x - y - 2z = -3 \quad \dots (4)$$

$$(3) + (4) : x + 2 = -1 \quad \dots (5)$$

$$(2) + (5) : 2x = 0 \Rightarrow x = 0$$

$$\therefore 2 = -1, y = 5 \therefore \text{No option is correct}$$

$$46.(D) \quad [c] = [LT^{-1}] \quad ; \quad [h] = [ML^2T^{-1}]$$

$$[G] = [M^{-1}L^3T^{-2}]$$

$$[f] = [h]^{1/2} [c]^{5/2} [G]^{-1/2}$$

$$= [M^{1/2}L^1T^{-1/2}] [L^{5/2}T^{-5/2}] [M^{1/2}L^{-3/2}T^1]$$

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

$$47.(D) \quad T = 2\pi\sqrt{\frac{\ell}{g}} \Rightarrow g = \frac{4\pi^2\ell}{T^2} \quad ; \quad \frac{\Delta g}{g} = \frac{\Delta \ell}{\ell} + 2\frac{\Delta T}{T} = \frac{0.1}{25} + 2\left(\frac{1}{50}\right)$$

$$\frac{\Delta g}{g} \times 100 = 0.4 + 4 = 4.4\%$$

$$48.(C) \quad \text{Pitch of the screw gauge} = \frac{3}{6} \text{ mm} = 0.5 \text{ mm}$$

$$\text{Least count} = \frac{\text{Pitch}}{(\text{No. of divisions on circular scale})} = \frac{0.5}{50} \text{ mm} = 0.01 \text{ mm} = 0.001 \text{ cm}$$

49.(Bonus)

$$A_1 + B_1 + C_1 = 280.6324 = 280.6 \text{ (Rounded off to 1 decimal)}$$

$$A_2 + B_2 + C_2 = 280.722 = 280.7 \text{ (Rounded off to 1 decimal)}$$

$$A_3 + B_3 + C_3 = 280.6642 = 280.7 \text{ (Rounded off to 1 decimal)}$$

$$A_4 + B_4 + C_4 = 280.691 = 281 \text{ (Rounded off to 0 decimal)}$$

(In addition or subtraction, the final result should retain as many decimal places as are there in the number with least decimal places.) No option gives correct relation

$$50.(B) \quad Y = C \cdot F^x A^y V^z$$

$$[ML^{-1}T^{-2}] = [(MLT^{-2})^x L^{2y} (LT^{-1})^z] = M^x L^{x+2y+z} T^{-2x-z}$$

Comparing

$$x = 1$$

$$-2x - z = -2$$

$$z = 0 \text{ and } y = -1$$

So, $Y = C \cdot F A^{-1} V^\circ$

51.(A) Vernier constant = $0.1 \text{ mm} = 0.01 \text{ cm}$

Reading = $3.1 + 4C - (+7C) = 3.1 - 3C = 3.1 - 0.03 = 3.07 \text{ cm}$

52.(A) Energy = $\frac{P^2}{2m}$

$$E \propto P^a$$

$$E \propto A^b$$

$$E \propto T^c$$

$$E = P^a A^b T^c$$

Putting dimensions

$$[ML^2T^{-2}] = [MLT^{-1}]^a [L^2]^b [T]^c$$

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

Comparing coefficient

$$a = 1$$

$$a + 2b = 2$$

$$b = \frac{1}{2}$$

$$-a + c = -2$$

$$c = -1$$

On putting values $E = [P^1 A^{1/2} T^{-1}]$

53.(A) $\therefore N = N_0 e^{-\lambda t}$

$$\frac{N}{N_0} = e^{-\lambda t} = \left(\frac{9}{16}\right)$$

At $t = \frac{t}{2}$

$$\frac{N'}{N_0} = e^{-\lambda t/2} = \left(e^{-\lambda t}\right)^{1/2} \Rightarrow \frac{N'}{N_0} = \left(\frac{9}{16}\right)^{1/2} = \frac{3}{4}$$

54.(D) Pitch, $p = 0.1 \text{ cm}$, $N = 50$

$$\therefore L.C = \frac{p}{N} = \frac{0.1}{50} = 0.002 \text{ cm}$$

Reading of screw gauge is $x = x_0 + n \times (L.C.)$

If n is an integer, then last digit of $n \times (L.C.)$ should be an even number

So, 2.124 cm can be the correct measurement

55.(D) [Solar constant] = $\left[\frac{\text{Energy}}{\text{Area time}} \right] = \frac{ML^2T^{-2}}{L^2T} = ML^0T^{-3}$

56.(A) $H = CA \frac{T_H - T_L}{L}$; $C = \frac{HL}{A(T_H - T_L)}$

$$[C] = \frac{ML^2T^{-3}}{L.K} = MLT^{-3}K^{-1}$$

57.(D) $x = \frac{IFv^2}{WL^4}$

$$= \left(\frac{I}{L^2} \right) \times \left(\frac{F}{W} \right) \left(\frac{v^2}{L^2} \right)$$

$$= [M] \left[\frac{1}{L} \right] \left[\frac{1}{T^2} \right]$$

$$x = [ML^{-1}T^{-2}]$$

$$\frac{U}{V} = \left[\frac{ML^2T^2}{L^3} \right] = [ML^{-1}T^{-2}] \quad (\text{Energy density})$$

58.(B) % error in $z = 2 \times \% \text{ error in } a$

$$+ \frac{2}{3} \% \text{ error in } b.$$

$$+ \frac{1}{2} \times \% \text{ error in } c$$

$$+ 3 \times \% \text{ error in } d$$

$$= 2 \times 2 + \frac{2}{3} \times 1.5 + \frac{1}{2} \times 4 + 3 \times 2.5$$

$$= 4 + 1 + 2 + 7.5$$

$$= 14.5\%$$

59.(A) Here, x , y and z

Dimension as of velocity

60.(C) Least count = $\frac{\text{pitch}}{\text{no. of division}} = \frac{0.5\text{mm}}{50} = 0.01\text{mm} = 10\mu\text{m}$

and zero of circular scale is ahead of pitch scale $\Rightarrow$ positive zero error

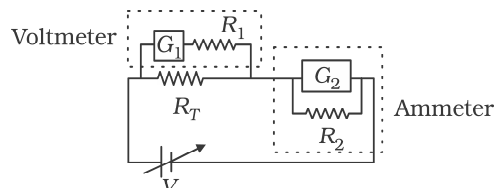
61.(1050) $\rho = \frac{M}{\frac{4\pi}{3}r^3} = \frac{6M}{\pi r^3}$

$$\frac{\Delta\rho}{\rho} = \frac{\Delta M}{M} + \frac{3\Delta d}{d} = 6 + (1.5)3 = 10.5$$

$$\frac{x}{100} = 10.5 \Rightarrow x = 1050$$

62.(B) Basic of significant figures

- 1.(C)** The correct dimensional formula for $(1/2)\epsilon_0 E^2$ which is simply energy density (i.e. energy per unit volume) is $ML^{-1}T^{-2}$.
- 2.(D)** $[\epsilon_0 L] = [\text{capacitance}] = [Q] / [\Delta V]$ Therefore $[\epsilon_0 L(\Delta V / \Delta t)] = [Q / \Delta t]$
- 3.(A)** Rounding off to two significant figures.
- 4.(A)** $\rho = \frac{m}{\ell \pi r^2} \Rightarrow \frac{\Delta \rho}{\rho} = \frac{\Delta m}{m} + \frac{2\Delta r}{r} + \frac{\Delta \ell}{\ell} = \frac{0.003}{0.3} + \frac{2 \times 0.005}{0.5} + \frac{0.06}{6} = \frac{4}{100} = 4\%$
- 5.(C)** $\frac{\alpha z}{k\theta}$ should be dimensionless, hence $\alpha = MLT^{-2}$; $\alpha / \beta = ML^{-1}T^{-2} = P$, hence $\beta = M^0 L^2 T^0$
- 6.(C)** $\ell_1 + e = \frac{v}{4f}$; $\ell_2 + e = \frac{3v}{4f}$; $\ell_2 - \ell_1 = \frac{2v}{4f} \Rightarrow \frac{\Delta(\ell_2 - \ell_1)}{(\ell_2 - \ell_1)} = \frac{\Delta v}{v}$
 $\Delta v = 2f\Delta(\ell_2 - \ell_1) = 2f(\Delta \ell_1 + \Delta \ell_2)$ (For maximum error) ; $\Delta v = 2 \times 512 \times 0.2 = 204.8 \text{ cm/s}$ **7.(B)**
- 8.(B)** Zero error $= 5 \times \frac{0.5}{50} = 0.05 \text{ mm}$
 Actual measurement $= 2 \times 0.5 \text{ mm} + 25 \times \frac{0.5}{50} - 0.05 \text{ mm} = 1 \text{ mm} + 0.25 \text{ mm} - 0.05 \text{ mm} = 1.20 \text{ mm}$
- 9.(B)** $\frac{1}{f} = \frac{1}{v} - \frac{1}{u} \Rightarrow f = 5 \text{ cm}$; $f = \frac{uv}{u+v} \Rightarrow \frac{\Delta f}{f} = \left| \frac{\Delta u}{u} \right| + \left| \frac{\Delta v}{v} \right| + \left| \frac{\Delta u}{u} \right| + \left| \frac{\Delta v}{v} \right|$
 $\Rightarrow \Delta f = 0.15$ (for $f = 5 \text{ cm}$) ; The most appropriate answer is $5.00 \pm 0.10 \text{ cm}$
- 10.(B)** $Y = \frac{4Fl}{\pi d^2 \Delta l} \Rightarrow \frac{\Delta Y}{Y} = \frac{2\Delta D}{D} + \frac{\Delta(L)}{\Delta L} = 0.1125$; $\Delta Y = 2 \times 10^{11} \times 0.1125$
- 11.(B)** By concept of parallax
- 12.(B)** $g = 4\pi^2 \left(\frac{l}{T^2} \right) \Rightarrow \frac{\Delta g}{g} = \frac{\Delta l}{l} + 2 \frac{\Delta T}{T} \Rightarrow E = \frac{\Delta l}{l} + 2 \frac{\Delta t}{t}$, greater the value of t , lesser the error.
 Hence, fractional error in the 1st observation is minimum.
- 13.(D)** L.C. = 1 M.S.D - 1 V.S.D $= \left(1 - \frac{16}{20} \right) \text{ M.S.D} = \left(1 - \frac{4}{5} \right) (1 \text{ mm}) = 0.2 \text{ mm}$
- 14.(C)** G_1 is used as a voltmeter by connecting it in series with high resistance R_1 and connected it across R_T in parallel and G_2 is used as an ammeter by connecting it in parallel with small resistance R_2 (called shunt) and connecting in series with R_T as shown in the figure.



Hence, above circuit is used to verify Ohm's law.

- 15.(B)** Applying the condition of balanced Wheatstone bridge, we get

$$\frac{X}{10\Omega} = \frac{(52+1) \text{ cm}}{(48+2) \text{ cm}} = \frac{53}{50} \Rightarrow X = 10\Omega \times \frac{53}{50} = 10.6\Omega$$

16.(C) Diameter = $2.5 + \frac{0.5}{50} \times 20 = 2.70 \text{ mm}$; % error = $\left(\frac{dm}{m} + 3 \frac{dr}{r} \right) \times 100 = 2 + 3 \times \frac{0.01}{2.70} \times 100 = 3.1\%$

17.(A) L.C. = $\frac{0.5}{100} = 0.005 \text{ mm}$; $\frac{\Delta Y}{Y} = \frac{\Delta l}{l} + \frac{2\Delta(d)}{d} \Rightarrow \frac{\Delta l}{l} = \frac{0.005 \times 10^{-3}}{0.25 \times 10^{-3}} = \frac{1}{50}$

$2 \frac{\Delta(d)}{d} = \frac{2 \times 0.005 \times 10^{-3}}{0.5 \times 10^{-3}} = \frac{1}{50}$

18.(B) $512 = \frac{336}{4(\ell + 0.3 \times 0.04)} \Rightarrow \ell = 0.152 \text{ m} = 15.2 \text{ cm}$

19.(B) Main scale division (s) = 0.05 cm, Vernier scale division (v) = $\frac{49}{100} = 0.049$

Least count = $0.05 - 0.049 = 0.001 \text{ cm}$, Diameter : $5.10 + 24 \times 0.001 = 5.124 \text{ cm}$

20.(D) $d = \frac{\lambda}{2 \sin \theta} \Rightarrow \ln d = \ln \left(\frac{\lambda}{2} \right) - \ln \sin \theta \Rightarrow \frac{\Delta d}{d} = 0 - \frac{\cos \theta \Delta \theta}{\sin \theta}$

$\left(\frac{\Delta d}{d} \right)_{\max} = \pm \cot \theta \Delta \theta$ Also $(\Delta d)_{\max} = d \cot \theta \Delta \theta$

$\frac{\lambda}{2 \sin \theta} \cot \theta \Delta \theta = \frac{\lambda \cos \theta}{2 \sin^2 \theta} \Delta \theta$; as θ increases, $\cot \theta$ decreases and $\frac{\cos \theta}{\sin^2 \theta}$ also decreases.

21.(C) $R = \frac{x}{100-x} 90$ $\therefore R = 60 \Omega$

$\frac{dR}{R} = \frac{100}{(x)(100-x)} dx$ $\therefore dR = \frac{100}{(40)(60)} 0.1 \times 60 = 0.25 \Omega$

22.(D) In first; main scale reading = 2.8 cm. Vernier scale reading = $7 \times \frac{1}{10} = 0.07 \text{ cm}$

So reading = 2.87 cm, In second; main scale reading = 2.8 cm

Vernier scale reading = $7 \times \frac{-0.1}{10} = \frac{-0.7}{10} = -0.07 \text{ cm}$. So reading = $(2.80 + 0.10 - 0.07) \text{ cm} = 2.83 \text{ cm}$

23.(B) $m = \rho \frac{4}{3} \pi R^3$

$0 = \rho \cdot 4\pi R^2 \frac{dR}{dt} + \frac{4}{3} \pi R^3 \frac{d\rho}{dt} \Rightarrow -\frac{1}{\rho} \frac{d\rho}{dt} = \frac{3}{R} \frac{dR}{dt} \Rightarrow -\frac{R}{3\rho} \frac{d\rho}{dt} = \frac{dR}{dt} \Rightarrow \frac{dR}{dt} \propto R \quad v \propto R$

24.(C) $t = \sqrt{\frac{2L}{g}} + \frac{1}{LC}$; $\frac{dt}{dL} = \sqrt{\frac{L}{g}} \times \frac{1}{2\sqrt{L}} + \frac{1}{C}$

$dL = \frac{dt}{\frac{1}{\sqrt{2gL}} + \frac{1}{C}} \Rightarrow \frac{dL}{L} \times 100 = \left(\frac{dt}{\frac{1}{\sqrt{2gL}} + \frac{1}{C}} \right) \frac{1}{L} \times 100 = \frac{15}{16} \% \approx 1\%$

25.(AD)

26.(BC)

27.(CD)

28.(AD)

29.(AC) $T = \frac{40s}{20} = 2s$

Further, $t = nT = 20T$ or $\Delta t = 20\Delta T$ $\therefore \frac{\Delta t}{t} = \frac{\Delta T}{T}$ or $\Delta T = \frac{T}{t} \Delta t = \left(\frac{2}{40} \right) (1) = 0.05s$

Further, $T = 2\pi \sqrt{\frac{l}{g}}$ or $T \propto g^{-1/2}$ $\therefore \frac{\Delta T}{T} \times 100 = -\frac{1}{2} \times \frac{\Delta g}{g} \times 100$

Percentage error in determination of g is $\frac{\Delta g}{g} \times 100 = -200 \times \frac{\Delta T}{T} = -\frac{200 \times 0.05}{2} = -5\%$

$$\begin{aligned} 30.(AC) \quad B\ell c = VI &\Rightarrow \mu_0 I^2 c = VI \Rightarrow \mu_0 I c = V \\ &\Rightarrow \mu_0^2 I^2 c^2 = V^2 \Rightarrow \mu_0 I^2 = \epsilon_0 V^2 \Rightarrow \epsilon_0 c V = I \end{aligned}$$

31.(BC) For vernier callipers,

$$1 \text{ main scale division} = \frac{1}{8} \text{ cm}, 1 \text{ vernier scale division} = \frac{1}{10} \text{ cm}, \text{ So least count} = \frac{1}{40} \text{ cm}$$

For screw gauge, pitch (p) = 2 main scale division, So least count = $\frac{p}{100}$. So option (B) & (C) are correct.

$$32.(ACD) \quad h \equiv [ML^2T^{-1}], c \equiv [LT^{-1}], G \equiv [M^{-1}L^3T^{-2}] \Rightarrow M \propto \sqrt{\frac{hc}{G}}, L \propto \sqrt{\frac{hG}{c^3}}$$

33.(BD) $k_B T \approx FL, \epsilon \approx \frac{Q^2}{FL^2}$ and $n \approx L^{-3}$; where F is force, Q is charge and L is length. So (B) and (D) are correct

34.(ABD) Error in T

$$T_{\text{mean}} = \frac{0.52 + 0.56 + 0.57 + 0.54 + 0.59}{5} = 0.556 \text{ s} \approx 0.56 \text{ s}$$

$$\Delta T_{\text{mean}} = 0.02 \quad \therefore \quad \text{Error in T is given by } \frac{0.02}{0.56} \times 100 = 3.57\% ; \text{ Error in } r = \frac{1}{10} \times 100 = 10\%$$

$$\text{Error in } g \quad \therefore \quad T = 2\pi \sqrt{\frac{7(R-r)}{5g}} \Rightarrow T^2 = 4\pi^2 \frac{7}{5} \left(\frac{R-r}{g} \right) \Rightarrow g = \frac{28\pi^2}{5} \left(\frac{R-r}{T^2} \right)$$

$$\frac{\Delta g}{g} = \left(\frac{\Delta R + \Delta r}{R-r} \right) + 2 \frac{\Delta T}{T} = \frac{2}{50} + 2 \times 0.0357 \quad \therefore \quad \frac{\Delta g}{g} \times 100 \approx 11\%$$

35.(ACD) $L = mVR$

As L and m are dimension less and $[R] = L \quad \therefore \quad [V] = L^{-1}$

Kinetic energy, $K = \frac{1}{2}mv^2 \Rightarrow [K] = L^{-2} \quad \therefore \quad \text{(C) is correct}$

Dimension of work is also L^{-2}

$$[F]L = L^{-2} \Rightarrow [F] = L^{-3}$$

Power, $P = FV \Rightarrow [P] = [F][v] = L^{-3}L^{-1} = L^{-4} \quad \therefore \quad \text{(B) is wrong}$

Linear momentum $p = mv$

$$[p] = [m][v] = L^{-1} \quad \therefore \quad \text{(D) is correct} \quad \quad \quad \mathbf{36.(C)} \quad \quad \quad \mathbf{37.(B)} \quad \omega = 2\pi C / \lambda$$

$$38.(B) \quad r + \Delta r = \frac{1 - (a + \Delta a)}{1 + (a + \Delta a)}$$

$$\Delta r = \frac{1 - (a + \Delta a)}{1 + (a + \Delta a)} - \frac{1 - a}{1 + a} = \frac{[1 - (a + \Delta a)][1 + a] - [1 + (a + \Delta a)][1 - a]}{(1 + a + \Delta a)(1 + a)} \Rightarrow |\Delta r| = \left| \frac{-2\Delta a}{(1 + a)^2} \right|$$

$$\text{Alternate : } \Delta r = \frac{1 - a}{1 + a} \left[\frac{\Delta a}{1 - a} + \frac{\Delta a}{1 + a} \right] \quad \Delta r = \frac{2\Delta a}{(1 + a)^2}$$

$$39.(C) \quad N_d = N_0(1 - e^{-\lambda t}) \Rightarrow 1000 = 3000(1 - e^{-\lambda t}) \Rightarrow e^{-\lambda t} = \frac{2}{3}$$

$$\Delta N_d = N_0 e^{-\lambda t} \Delta \lambda \Rightarrow 40 = 3000 \times \frac{2}{3} \times \Delta \lambda \quad \Delta \lambda = 0.02$$

Alternate :

$$N = N_0 e^{-\lambda t} \Rightarrow N + \Delta N = N_0 e^{-(\lambda + \Delta \lambda)t}$$

$$\Delta N = N_0[e^{-(\lambda+\Delta\lambda)t} - e^{-\lambda t}] \Rightarrow \Delta N = N_0[e^{-\lambda t}e^{-\Delta\lambda t} - e^{-\lambda t}]$$

$$\Delta N = N_0e^{-\lambda t}[e^{-\Delta\lambda t} - 1] \Rightarrow \Delta N \approx N[\Delta\lambda t] \quad \Delta\lambda = 0.02$$

40.(C) $E = \frac{F}{q}$; $F = qvB$, $E = BV$; $[E] = [B][L][T]^{-1}$ **41.(D)** $\epsilon_0 \mu_0 = \frac{1}{C^2}$; $\mu_0 = [\epsilon_0]^{-1}[L]^{-2}[T]^2$

42. **A-Q; B-P; C-S; D-U; E-R; F-T**

43. **A-Q, R; B-P, T; C-S**

Deduction: $t = \frac{L}{R}$ $\therefore L = tR = \text{ohm-sec}$

$$U = \frac{q^2}{2C} \quad \therefore C = \frac{q^2}{U} = \text{coulomb}^2/\text{joule}$$

$$q = CV \quad \therefore C = \frac{q}{V} = \text{coulomb-volt}^{-1}$$

$$L = \frac{\epsilon}{di/dt} \quad \therefore L = \frac{\text{volt-second}}{\text{ampere}}$$

$$F = BIl \quad \therefore B = \frac{F}{Il} = \frac{\text{newton}}{\text{ampere-metre}}$$

44. **A-P, Q; B-R, S; C-R, S; D-R, S**

45.(C) $P \rightarrow (4)$; $Q \rightarrow (2)$; $R \rightarrow (1)$; $S \rightarrow (3)$

P. $KE = \frac{3}{2}K'T \Rightarrow [ML^2T^2] = K'[K] \Rightarrow K' = [ML^2T^{-2}K^{-1}]$

Q. $F = 6\pi\eta rv \Rightarrow [MLT^{-2}] = \eta[L][LT^{-1}] \Rightarrow \eta = [ML^{-1}T^{-1}]$

R. $E = hf \Rightarrow [ML^2T^{-2}] = \frac{h}{[T]} \Rightarrow h = [ML^2T^{-1}]$

S. $\frac{dQ}{dt} = \frac{K'A(\Delta T)}{\Delta x} \Rightarrow \frac{[ML^2T^{-2}]}{[T]} = \frac{k[L^2][K']}{[L]}$
 $K' = [MLT^{-3}K^{-1}]$

46. **(a = -5 / 6, b = 1 / 2, c = 1 / 3)**

Given : $T \propto P^a d^b E^c$ or $[T] = [P]^a [d]^b [E]^c$ or $[M^0 L^0 T^1] = [ML^{-1}T^{-2}]^a [ML^{-3}]^b [ML^2T^{-2}]^c$

$$\therefore \begin{aligned} a + b + c &= 0 & \dots(i), & -a - 3b + 2c = 0 & \dots(ii) \\ -2a - 2c &= 1 & \dots(iii) \end{aligned}$$

On solving, we get $a = -5/6$, $b = 1/2$, $c = 1/3$.

47.(2.66) Least count = $\frac{1}{10} = 0.1 \text{ mm}$

Side = $10 + 1 \times 0.1$

Density = $\frac{2.736}{(1.01)^2} = 2.66 \text{ g/cm}^3$

48.(3) $d \propto \rho^x S^y F^z$

$$\Rightarrow [L] = [ML^{-3}]^x [MT^{-3}]^y [T^{-1}]^z \Rightarrow x + y = 0, -3x = 1, -3y - z = 0$$

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

$$49.(4) \quad y = \frac{wl}{Ax} \quad (x = \text{elongation}) \quad x = 45 \times L.C. - 20 \times L.C. = 25 \times L.C. = 25 \times 1 \times 10^{-5} m$$

$$\left| \frac{\Delta y}{y} \right| = \left| \frac{\Delta x}{x} \right| \Rightarrow \left| \frac{\Delta y}{y} \right| \times 100 = \left| \frac{\Delta x}{x} \right| \times 100 = \frac{1 \times 10^{-5}}{25 \times 10^{-5}} \times 100 = 4\%$$

$$x = x_2 - x_1$$

$$50.(4) \quad E = A^2 e^{-\alpha t} \quad \ln E = 2 \ln A - \alpha t \quad \therefore \quad \frac{\Delta E}{E} \times 100 = 2 \frac{\Delta A}{A} 100 - \alpha \Delta t \times 100 \quad \dots (i)$$

$$\text{For time : } \frac{\Delta t}{t} \times 100 = 1.5$$

$$\text{At } t = 5s, \Delta t = \frac{1.5 \times 5}{100} = \frac{7.5}{100} \quad \text{Using Equation (i) \% error in } E = 2 \times (1.25) + \alpha \times \frac{7.5}{100} \times 100 = 2.5 + 1.5 = 4$$

$$51.(3) \quad \Delta \ell = \frac{F \ell}{AY} = \frac{4 F \ell}{\pi d^2 Y} = \frac{4 \times 12 \times 1}{\pi \times 25 \times 10^{-8} \times 2 \times 10^{11}} = 0.3 \text{ mm}$$

$$10 \text{ VSD} = 9 \text{ MSD}; 1 \text{ VSD} = \frac{9}{10} \text{ MSD} \quad \therefore \quad \text{Least count, L.C.} = 1 \text{ MSD} - 1 \text{ VSD} ; = \left(1 - \frac{9}{10} \right) \text{ MSD}$$

$$= \frac{1}{10} \text{ MSD} = 0.1 \text{ mm.} \quad \therefore \quad 3^{\text{rd}} \text{ vernier scale division coincides with a main scale division.}$$

$$52.(1.38) \text{ L.C. of scale of optical bench} = \frac{1 \text{ cm}}{4} = 0.25 \text{ cm}$$

$$u = -(x_2 - x_1) \Rightarrow \Delta u = \Delta x_1 + \Delta x_2 = 0.5 \text{ cm}$$

$$\Rightarrow \Delta v = 0.5 \text{ cm}$$

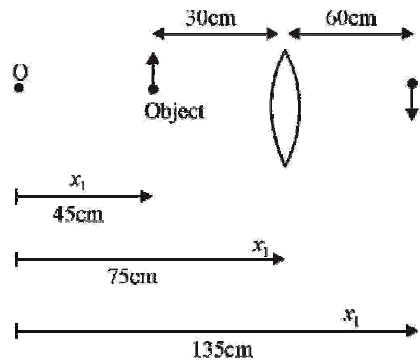
$$\Rightarrow f = \frac{uv}{u-v} = \frac{-30 \times 60}{-30-60} = \frac{-1800}{-90} = 20 \text{ cm}$$

$$\frac{1}{f} = \frac{1}{v} - \frac{1}{u} \quad (\text{lens equation})$$

$$\frac{-df}{f^2} = \frac{-dv}{v^2} + \frac{du}{u^2}$$

$$\Rightarrow \frac{\Delta f}{f^2} = \frac{\Delta v}{v^2} + \frac{\Delta u}{u^2} \Rightarrow \frac{\Delta f}{f} \times 100 = 100 f \left[\frac{\Delta v}{v^2} + \frac{\Delta u}{u^2} \right]$$

$$= 100 \times 20 \left[\frac{0.5}{60 \times 60} + \frac{0.5}{30 \times 30} \right] = 100 \times 20 \times 0.5 \left[\frac{1+4}{3600} \right] = \frac{2000 \times 0.5 \times 5}{3600} = 1.38$$



$$53. \quad (i) \quad N/m^2 \quad (ii) \quad \text{Weber/m}^2 \quad (iii) \quad \text{Diopetre}$$

$$54. \quad (i) \quad ML^2T^{-1}Q^{-1} \quad (ii) \quad ML^{-1}T^{-2}$$

$$55. \quad (ML^2T^{-1}) \quad 56. \quad (M^{-3}L^{-2}T^4Q^4)$$

$$57. \quad (ML^5T^{-2}) \quad ; \quad [P] = \frac{[a]}{[v^2]} \Rightarrow ML^{-1}T^{-2} = \frac{[a]}{L^6} \Rightarrow [a] = ML^5T^{-2}$$

$$58.(AB) \quad L = x^\alpha$$

$$LT^{-1} = x^\beta$$

$$LT^{-2} = x^p$$

$$MLT^{-1} = x^q$$

$$MLT^{-2} = x^r$$

$$(A) \quad L \times LT^{-2} = x^\alpha x^p$$

$$L^2 T^{-2} = x^{\alpha+p}$$

$$(x^\beta)^2 = x^{\alpha+p} \Rightarrow \alpha + p = 2\beta$$

$$(B) \quad \frac{LT^{-2} \times MLT^{-1}}{MLT^{-2}} = x^{p+q-r}$$

$$x^\beta = x^{p+q-r} \Rightarrow p + q - r = \beta$$

$$(C) \quad \frac{LT^{-2} \times MLT^{-2}}{MLT^{-1}} = x^{p+r-q}$$

$$LT^{-3} = x^{p+r-q}$$

$$(D) \quad LT^{-2} \times MLT^{-1} \times MLT^{-2} = x^{p+q+r}$$

$$M^2 L^3 T^{-5} = x^{p+q+r}$$

$$59.(1.3) \quad U = \frac{1}{2} CV^2$$

$$\frac{\Delta U}{U} = \frac{\Delta C}{C} + \frac{2\Delta V}{V}$$

$$\frac{1}{C} = \frac{1}{C_1} + \frac{1}{C_2}$$

$$\frac{1}{C} = \frac{1}{2000} + \frac{1}{3000} \Rightarrow C = 1200 \mu F$$

$$\frac{\Delta C}{C^2} = \frac{\Delta C_1}{C_1^2} + \frac{\Delta C_2}{C_2^2}$$

$$\frac{\Delta C}{C^2} = \left[\frac{10}{(2000)^2} + \frac{15}{(3000)^2} \right] 1200 = \left(\frac{10}{4} \times 10^{-6} + \frac{5}{3} \times 10^{-6} \right) 1200$$

$$= \frac{50}{12} \times 10^{-6} \times 1200 = 5 \times 10^{-3}$$

$$\frac{\Delta V}{V} = \frac{0.02}{5.00} = 4 \times 10^{-3}$$

$$\frac{\Delta U}{U} = 5 \times 10^{-3} + 2(4 \times 10^{-3}) = 13 \times 10^{-3}$$

$$\text{Percentage error} = \frac{\Delta U}{U} \times 100 = 1.3$$