PHYSICS – CLASS XI

Chapter 1 : Units and Measurement

SOLUTIONS AND MARKING SCHEME (Step-by-Step)

Marks for each step are shown at the right. Alternative correct methods carry full marks.

Quick answer key – Section A

Q	1	2	3	4	5	6	7	8
Ans	(c)	(c)	(b)	(d)	(b)	0.25 rad	[M L² T⁻¹]	(b)

SECTION A

1. **Ans: (c) Plane angle.** **(1)**

The seven SI base quantities are length, mass, time, electric current, thermodynamic temperature, amount of substance and luminous intensity. Plane angle (radian) and solid angle (steradian) are separate, dimensionless quantities and are **not** base quantities.

2. **Ans: (c) 4.** **(1)**

The leading zeros (0.00…) are not significant. The digits 3, 0, 5, 0 remain: the zero between 3 and 5 is significant, and the trailing zero after the decimal point is significant. So there are **4** significant figures (3.050×10^{-3} m).

3. **Ans: (b) Torque and energy.** **(1)**

[Torque] = [r][F] = L · M L T^{-2} = M L^2 T^{-2}; [Energy] = M L^2 T^{-2}. Same.
Other pairs: work M L^2 T^{-2} vs power M L^2 T^{-3}; momentum M L T^{-1} vs force M L T^{-2}; pressure M L^{-1} T^{-2} vs force M L T^{-2}.

4. **Ans: (d) A is false but R is true.** **(1)**

Dimensional consistency is a necessary, not a sufficient, condition. For example, $x = x_0 + v_0 t + at^2$ is dimensionally consistent but physically wrong (the factor ½ is missing). A is false. An equation whose terms have different dimensions must be wrong, so R is true.

5. **Ans: (b) −30.** **(1)**

In scientific notation 9.11×10^{-31}: the number a = 9.11 is greater than 5, so it is rounded up to 10. Then $10 \times 10^{-31} = 10^{-30}$, so the order of magnitude is **−30**.

6. **Ans: 0.25 rad.** **(1)**

$d\theta = ds/r$ = 6.0 cm / 24 cm = **0.25 rad**. (Ratio of two lengths, so it has no dimensions.)

7. **Ans: [M L² T⁻¹].** **(1)**

$h = E/\nu$. [E] = M L^2 T^{-2}, [ν] = T^{-1}. So [h] = M L^2 T^{-2} / T^{-1} = **[M L² T⁻¹]**.

8. **Ans: (b) 4.65 cm.** **(1)**

The least count is 1 mm = 0.1 cm. The digits 4 and 6 are certain and the next digit (5, the estimate between marks) is uncertain, so three significant figures are appropriate. 4.650 cm would claim a precision of 0.001 cm, which the scale does not have; 4.6 cm and 4.7 cm throw away the estimated digit.

SECTION B

9. **(i) Area.** $A = l \times b = 12.52 \times 8.4 = 105.168$ cm². In multiplication the result keeps as many significant figures as the least precise number. 8.4 has 2 significant figures, so A = **1.1×10^2 cm²**. (1) **(1+1)**

(ii) Perimeter. $l + b = 12.52 + 8.4 = 20.92$ cm. In addition the result keeps as many decimal places as the number with the fewest decimal places (8.4 has one), so 20.9 cm. Perimeter = 2×20.9 = **41.8 cm** (the factor 2 is exact). (1)

10. $[k]$ = [Force]/[Length] = M L T^{-2} / L = M T^{-2}. (½) **(2)**

$[m/k]$ = M / (M T^{-2}) = T^2, so $[\sqrt{(m/k)}]$ = T. (½)

The factor 2π is a pure number (no dimensions). So RHS has the dimension T, the same as the LHS $[T]$ = T. (½)

Hence the relation is **dimensionally consistent**. (½)

11. **(a)** 6.0200×10^{-4}: all digits in the base number, including trailing zeros, are significant → **5**. (½) **(2)**

(b) 0.0830: leading zeros not significant, the trailing zero after the decimal point is significant → **3**. (½)

(c) 4500 (no decimal point): trailing zeros are not significant → **2**. (½)

(d) 100.05: zeros between non-zero digits are significant → **5**. (½)

OR

(a) 4.865: the digit to be dropped is 5 and the preceding digit 6 is even, so it is left unchanged → **4.86**. (½)

(b) 4.875: the preceding digit 7 is odd, so it is raised by 1 → **4.88**. (½)

(c) 6.0251: dropped part (51) is more than half a unit → **6.03**. (½)

(d) 0.083949: leading zeros are not significant; the digits are 8, 3, 9 and the next digit 4 is less than 5 → **0.0839**. (½)

12. $d\Omega = dA/r^2 = 0.60$ m² / $(2.0$ m$)^2 = 0.60 / 4.0$ = **0.15 sr**. (1) **(2)**

SI unit: **steradian (sr)**. Since $d\Omega$ is the ratio of an area to an area, it is dimensionless: **[M^0 L^0 T^0]**. (1)

SECTION C

13. **(a) Least count.** 1 main-scale division (MSD) = 1 mm. 10 vernier divisions (VSD) = 9 MSD, so 1 VSD = 0.9 mm. Least count = 1 MSD − 1 VSD = 1 − 0.9 = 0.1 mm = **0.01 cm**. (1) **(3)**

(b) Readings. Fig. (i): the vernier zero lies just beyond the 3.2 cm mark, so main-scale reading = 3.2 cm. The 6th vernier division coincides with a main-scale line, so vernier reading = $6 \times 0.01 = 0.06$ cm. Observed length = 3.2 + 0.06 = **3.26 cm**. (½)

Fig. (ii): the jaws are closed, the vernier zero is to the right of the main zero and the 2nd vernier division coincides, so zero error = $+2 \times 0.01$ = **+0.02 cm**. (½)

(c) Corrected length = observed reading − zero error = 3.26 − 0.02 = **3.24 cm**. (1)

14. Let $f = k\, l^a\, F^b\, \mu^c$, where k is a dimensionless constant. $[f] = T^{-1}$, $[l] = L$, $[F] = M\,L\,T^{-2}$, $[\mu] = M\,L^{-1}$. (1) **(3)**

$T^{-1} = L^a\,(M\,L\,T^{-2})^b\,(M\,L^{-1})^c = M^{b+c}\,L^{a+b-c}\,T^{-2b}$. Equating powers: T: $-2b = -1 \rightarrow b = ½$; M: $b + c = 0 \rightarrow c = -½$; L: $a + b - c = 0 \rightarrow a = -1$. (1)

$\boldsymbol{f = (k/l)\,\sqrt{(F/\mu)}}$. The dimensionless constant k **cannot** be found by dimensional analysis (experiment or theory gives $k = ½$ for the fundamental mode). (1)

OR

Let $T = k\,\rho^a\,r^b\,S^c$. $[\rho] = M\,L^{-3}$, $[r] = L$, $[S] = F/L = M\,T^{-2}$. (1)

$T = M^{a+c}\,L^{-3a+b}\,T^{-2c}$. M: $a + c = 0$; L: $-3a + b = 0$; T: $-2c = 1 \rightarrow c = -½$, $a = ½$, $b = 3/2$. (1)

$\boldsymbol{T = k\,\sqrt{(\rho\, r^3 / S)}}$. (1)

15. (i) Volume $V = \pi r^2 h = 3.14 \times (1.25)^2 \times 8.4 = 3.14 \times 1.5625 \times 8.4 \approx 41.2\ cm^3$ (one extra digit kept in the intermediate step). (1) **(3)**

Density $\rho = m/V = 45.36\ g / 41.2\ cm^3 \approx 1.10\ g\ cm^{-3}$. The least precise data is $h = 8.4$ cm (2 significant figures), so the result is $\boldsymbol{\rho = 1.1\ g\ cm^{-3}}$. (1)

(ii) $1\ g\ cm^{-3} = 10^3\ kg\ m^{-3}$, so $\rho = \boldsymbol{1.1 \times 10^3\ kg\ m^{-3}}$. (1)

SECTION D

16. **(a)** The dimensions of every term on the two sides of a physically meaningful equation must be the same (only quantities of the same dimensions can be added, subtracted or equated). (1) **(5)**

(b) Student A: LHS $[R] = L$. RHS $= [u^2][\sin 2\theta]/[g] = L^2\,T^{-2} \cdot 1 / (L\,T^{-2}) = L$ ($\sin 2\theta$ is dimensionless). Dimensions match → **consistent**. (2)

Student B: RHS $= [u]/[g] = L\,T^{-1} / (L\,T^{-2}) = T$, which is not L. Dimensions do not match → **wrong**. (1)

(c) No. Consistency is only a necessary condition. Dimensional analysis cannot detect dimensionless factors; e.g. $R = 2u^2 \sin 2\theta / g$ is also consistent but incorrect (the correct expression is Student A's). (1)

OR

(i) [Energy] $= M\,L^2\,T^{-2}$. One new unit of energy $= (20\ kg)(5\ m)^2(2\ s)^{-2} = 20 \times 25 / 4 =$ **125 J**. (2)

(ii) $625\ J = 625/125 =$ **5** new units of energy. (1)

(iii) [Power] $= M\,L^2\,T^{-3}$. New unit of power $= 20 \times 25 / 2^3 = 500/8 = 62.5\ W$ (= 125 J / 2 s). $125\ W = 125/62.5 =$ **2** new units of power. (2)

17. **(a)** Let $T = k\, l^a\, g^b$. $[T] = \mathrm{T}$, $[l] = \mathrm{L}$, $[g] = \mathrm{L\,T^{-2}}$. $\mathrm{T} = \mathrm{L}^{a+b}\,\mathrm{T}^{-2b}$. (1) **(5)**

T: $-2b = 1 \rightarrow b = -½$; L: $a + b = 0 \rightarrow a = ½$. So $T = k\sqrt{(l/g)}$, i.e. $T^2 = k^2\, l/g \propto l$. (1)

(b) From the graph: A (0.25 m, 1.00 s²) and B (1.25 m, 5.00 s²). (1)

Slope = (5.00 − 1.00) s² / (1.25 − 0.25) m = 4.00 s² m⁻¹. (1)

(c) Slope = $4\pi^2/g$, so $g = 4\pi^2/\text{slope} = 4 \times (3.14)^2 / 4.00 = (3.14)^2 = 9.8596 \approx$ **9.86 m s⁻²** (3 significant figures, as the slope has 3). (1)

OR

(a) Least count = pitch / number of divisions = 0.5 mm / 50 = **0.01 mm**. (1)

(b) Fig. (i): the 46th division is on the reference line, i.e. the zero of the circular scale has not yet reached it; it is 50 − 46 = 4 divisions short. Zero error = **−4 × 0.01 = −0.04 mm**. (1)

(c) Fig. (ii): main-scale reading = 2.5 mm; circular-scale reading = 23 divisions → 23 × 0.01 = 0.23 mm. Observed reading = 2.5 + 0.23 = **2.73 mm**. (1)

(d) Corrected diameter = observed − zero error = 2.73 − (−0.04) = **2.77 mm**. (1)

(e) $A = \pi d^2/4 = 3.14 \times (2.77)^2 / 4 = 3.14 \times 7.6729 / 4 \approx 6.02$ mm². Result keeps 3 significant figures: **6.02 mm²**. (1)

— END OF SOLUTIONS —