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Units and Measurements — JEE (Main) Pattern Topic Test

FREE SAMPLE TEST · PHYSICS · PATTERN OF JEE (MAIN)

DURATION	MAXIMUM MARKS	QUESTIONS	NAME / ROLL NO.
60 minutes	100	25 (20 + 5)	

GENERAL INSTRUCTIONS

1. This question paper has two sections, A and B. All 25 questions are compulsory.
2. Section A has TWENTY (20) multiple-choice questions. Each has FOUR options, (1), (2), (3) and (4), of which ONLY ONE is correct.
3. Section B has FIVE (05) questions whose answer is a numerical value. Enter the value rounded off to the nearest integer.
4. Marking scheme for both sections: +4 for a correct answer, −1 for an incorrect answer, 0 if the question is not attempted.
5. Use of a calculator, log tables or any other aid is not allowed.
6. The answer key and worked solutions are at the end of this booklet. Attempt the paper in 60 minutes before you look at them.

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Topics covered: Units of measurement · SI units · Dimensions of physical quantities · Dimensional analysis and its applications · Significant figures · Errors in measurement · Least count of instruments

SECTION A (Q1–20) · Multiple choice · +4 / 0 / −1

Each question has FOUR options. ONLY ONE of them is correct.

1. The intensity of a wave at distance r from its source and at time t is given by $I = (A/r^2)\, e^{(-Bt)} \sin(Cr - Dt)$, where A, B, C and D are constants. The quantity AC/(BD) has the dimensions of

(1) linear momentum

(2) force

(3) energy

(4) angular momentum

2. If surface tension (S), the speed of sound (v) and frequency (f) are taken as the fundamental quantities, the dimensional formula of Young's modulus is

(1) $[S\ v\ f^{-1}]$

(2) $[S\ v^{-1}\ f]$

(3) $[S\ v^{-1}\ f^{-1}]$

(4) $[S^2\ v^{-1}\ f]$

3. The speed v of short ripples on the surface of a liquid depends only on the wavelength λ, the density ρ of the liquid and its surface tension S. If the wavelength of the ripples is made four times, their speed becomes

(1) four times

(2) twice

(3) one-fourth

(4) half

4. The drag force on a small sphere moving slowly through a fluid depends only on the viscosity η, the radius r and the speed v. On a large sphere moving fast it depends only on the density ρ of the fluid, r and v. Two spheres of the same material fall through the fluid at their terminal speeds, and each sphere's radius is then doubled (ignore buoyancy). The terminal speed becomes, in the slow (viscous) case and in the fast case respectively,

(1) 4 times and √2 times

(2) 2 times and √2 times

(3) 4 times and 2 times

(4) 2 times and unchanged

5. The energy per unit volume u of thermal radiation in a cavity depends only on the temperature T, Planck's constant h, the speed of light c and the Boltzmann constant k. By dimensional analysis, u is proportional to

(1) $k^3T^3/(h^2c^3)$

(2) $k^4T^4/(h^3c^2)$

(3) $k^4T^4/(h^3c^3)$

(4) $k^4T^4/(h^2c^3)$

6. Match List-I with List-II.
List-I: (A) Magnetic flux (B) Permeability of free space μ_0 (C) Self-inductance (D) Permittivity of free space ε_0
List-II: (I) $[M\,L\,T^{-2}\,A^{-2}]$ (II) $[M\,L^2\,T^{-2}\,A^{-2}]$ (III) $[M^{-1}\,L^{-3}\,T^4\,A^2]$ (IV) $[M\,L^2\,T^{-2}\,A^{-1}]$
Choose the correct answer from the options given below:

(1) (A)-(II), (B)-(I), (C)-(IV), (D)-(III)
(2) (A)-(IV), (B)-(III), (C)-(II), (D)-(I)
(3) (A)-(I), (B)-(IV), (C)-(II), (D)-(III)
(4) (A)-(IV), (B)-(I), (C)-(II), (D)-(III)

7. The SI unit of the ratio h/e, where h is Planck's constant and e the elementary charge, is the same as that of

(1) magnetic field (tesla)
(2) magnetic flux (weber)
(3) inductance (henry)
(4) potential difference (volt)

8. Consider the following statements about the International System of Units (SI).
(A) The candela is an SI base unit.
(B) The radian and the steradian are SI base units.
(C) The mole is the SI base unit of amount of substance.
(D) The SI unit of luminous intensity is the lumen.
(E) The kelvin is the SI base unit of thermodynamic temperature.
Choose the correct answer from the options given below:

(1) (A), (B) and (C) only
(2) (B), (D) and (E) only
(3) (A), (C) and (E) only
(4) (A), (C), (D) and (E) only

9. In a new system of units, the unit of force is 10 N, the unit of length is 5 m and the unit of time is 2 s. In this system, the numerical values of an energy of 100 J and of a power of 300 W are, respectively,

(1) 2 and 12
(2) 2 and 3
(3) 8 and 12
(4) 0.5 and 48

10. Consider the following statements.
(A) 0.0030 has two significant figures.
(B) 4.700×10^3 has four significant figures.
(C) 6400, written as 6.40×10^3, has three significant figures.
(D) 2.745 rounded off to three significant figures is 2.75.
(E) 0.050×10^{-2} has three significant figures.
Choose the correct answer from the options given below:

(1) (A), (B), (C) and (D) only
(2) (A), (B) and (C) only
(3) (B), (C) and (E) only
(4) (A) and (D) only

11. The edge of a solid cube is measured as 2.50 cm and its mass as 47.3 g. Its density, written with the correct number of significant figures, is

(1) 3.0272×10^{3} kg m^{-3}

(2) 3.0×10^{3} kg m^{-3}

(3) 3.027×10^{3} kg m^{-3}

(4) 3.03×10^{3} kg m^{-3}

12. A cyclist covers three stretches measured as 12.4 m, 0.182 m and 3.25 m, taking 4.0 s in all. The total distance and the average speed, each written with the correct number of significant figures, are

(1) 15.832 m and 3.958 m s^{-1}

(2) 15.8 m and 4.0 m s^{-1}

(3) 15.83 m and 3.96 m s^{-1}

(4) 15.8 m and 4 m s^{-1}

13. Two resistors of resistances $R_1 = (60 \pm 1.2)\ \Omega$ and $R_2 = (30 \pm 0.9)\ \Omega$ are connected in parallel. The equivalent resistance, with its maximum error, is

(1) $(20 \pm 2.1)\ \Omega$

(2) $(20 \pm 0.7)\ \Omega$

(3) $(20 \pm 0.53)\ \Omega$

(4) $(20 \pm 0.27)\ \Omega$

14. The time period of a pendulum is measured six times as 1.96 s, 2.04 s, 2.01 s, 1.99 s, 2.05 s and 1.95 s. The result, written as the mean value with the mean absolute error, is

(1) (2.00 ± 0.03) s

(2) (2.00 ± 0.05) s

(3) (2.00 ± 0.20) s

(4) (2.0 ± 0.1) s

15. In a simple pendulum experiment, the effective length is measured as 100.0 cm with a metre scale of least count 1 mm, and the time for 40 oscillations as 80.0 s with a stopwatch of resolution 0.2 s. The maximum percentage error in the value of g found from $g = 4\pi^2 L/T^2$ is

(1) 0.35%

(2) 0.45%

(3) 0.7%

(4) 0.6%

16. The main scale of a vernier callipers is graduated in 0.5 mm, and 25 divisions of its vernier scale coincide with 24 divisions of the main scale. With the jaws closed, the zero of the vernier scale lies to the right of the zero of the main scale and its 7th division coincides with a main scale division. When a rod is held between the jaws, the main scale reading just before the vernier zero is 35.5 mm and the 12th vernier division coincides. The corrected length of the rod is

(1) 35.88 mm

(2) 35.74 mm

(3) 35.60 mm

(4) 35.46 mm

17. Which one of the following relations is dimensionally INCORRECT? (S is surface tension, ρ density, η viscosity, p pressure difference, G the gravitational constant, M a mass and the other symbols have their usual meanings.)

(1) Speed of ripples, $v = \sqrt{(g\lambda/2\pi + 2\pi S/(\rho\lambda))}$

(2) Rate of flow of a liquid through a tube, $Q = \pi pr^4/(8\eta\ell)$

(3) Speed of a satellite in a circular orbit, $v = \sqrt{(GM/r^2)}$

(4) Rise of a liquid in a capillary tube, $h = 2S\cos\theta/(\rho gr)$

18. Statement I: If $a = (10.2 \pm 0.1)$ cm and $b = (9.8 \pm 0.1)$ cm, the maximum percentage error in $a - b$ is 50%.
Statement II: The maximum absolute error in the difference of two quantities is the difference of their absolute errors.
In the light of the above statements, choose the correct answer from the options given below:

(1) Both Statement I and Statement II are true

(2) Both Statement I and Statement II are false

(3) Statement I is true but Statement II is false

(4) Statement I is false but Statement II is true

19. The quantity $\sqrt{(\mu_0/\varepsilon_0)}$, where μ_0 and ε_0 are the permeability and permittivity of free space, has the same dimensions as

(1) capacitance

(2) inductance

(3) electrical conductance

(4) electrical resistance

20. The frequency of vibration of a stretched string depends only on its tension, its length and its mass per unit length. If the tension is increased by 44% and the length by 20%, keeping the mass per unit length the same, the frequency

(1) increases by 20%

(2) decreases by 20%

(3) remains unchanged

(4) increases by 44%

SECTION B (Q21–25) · Numerical value · +4 / 0 / −1

The answer to each question is a NUMERICAL VALUE. Enter it rounded off to the nearest integer.

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21. How many of the following quantities have the dimensions of time? (L is inductance, R resistance, C capacitance, Φ magnetic flux, V potential difference, h Planck's constant, E energy (in h/E) and electric field (in B/E), B magnetic field, ℓ a length, g the acceleration due to gravity, S surface tension, η viscosity, μ_0 and ε_0 the permeability and permittivity of free space.)
L/R, CR, $\sqrt{(LC)}$, $\ell\sqrt{(\mu_0\varepsilon_0)}$, Φ/V, h/E, B/E, $\sqrt{(\ell/g)}$, S/η

Answer: _____

22. In Searle's experiment, Young's modulus is found from $Y = 4MgL/(\pi d^2\ell)$. The load is $M = (4.00 \pm 0.02)$ kg, the length of the wire $L = (2.000 \pm 0.002)$ m, its diameter $d = (0.400 \pm 0.004)$ mm and the extension $\ell = (0.500 \pm 0.002)$ mm. Treating g as exact, the maximum percentage error in Y is _____.

Answer: _____

23. In a system of units in which the unit of mass is 1 tonne (1000 kg), the unit of length is 1 km and the unit of time is 1 minute, the numerical value of an energy of 1 kWh is _____ (to the nearest integer).

Answer: _____

24. The power P radiated by a point charge q moving with acceleration a depends only on q, a, the speed of light c and the permittivity of free space ε_0, as P ∝ q^x a^y c^z ε_0^w. The value of x + y − z − w is _____.

Answer: _____

25. A screw gauge has a pitch of 1 mm and 100 divisions on its circular scale. With the studs in contact, the zero of the circular scale is 4 divisions above the reference line. When a wire is placed between the studs, the main scale reading is 2 mm and the 63rd circular scale division is on the reference line. The diameter of the wire, in units of 0.01 mm, is _____.

Answer: _____

END OF THE QUESTION PAPER

ANSWER KEY

Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10
(1)	(2)	(4)	(1)	(3)	(4)	(2)	(3)	(1)	(2)

Q11	Q12	Q13	Q14	Q15	Q16	Q17	Q18	Q19	Q20
(4)	(2)	(3)	(1)	(4)	(3)	(3)	(3)	(4)	(3)

Q21	Q22	Q23	Q24	Q25
7	3	13	8	267

WORKED SOLUTIONS

Q1. Answer (1). Intensity is power per unit area, $[M\,T^{-3}]$, and the arguments of e and sin must be dimensionless. So $[A] = [I\,r^2] = [M\,L^2\,T^{-3}]$, $[B] = [D] = [T^{-1}]$ and $[C] = [L^{-1}]$. $AC/(BD) = [M\,L^2\,T^{-3}][L^{-1}]/[T^{-2}] = [M\,L\,T^{-1}]$, the dimensions of linear momentum.

Q2. Answer (2). $[S] = [M\,T^{-2}]$, $[v] = [L\,T^{-1}]$, $[f] = [T^{-1}]$ and Young's modulus has $[M\,L^{-1}\,T^{-2}]$. Write Y = S^a v^b f^c: M gives a = 1; L gives b = −1; T gives −2a − b − c = −2, so −2 + 1 − c = −2 and c = 1. Hence $[Y] = [S\,v^{-1}\,f]$.

Q3. Answer (4). Let v ∝ S^a ρ^b λ^c: $[L\,T^{-1}] = [M\,T^{-2}]^a\,[M\,L^{-3}]^b\,[L]^c$. M: a + b = 0; T: −2a = −1, so a = ½ and b = −½; L: −3b + c = 1, so c = −½. So $v \propto \sqrt{(S/(\rho\lambda))}$, and making λ four times halves the speed.

Q4. Answer (1). Slow case: F ∝ η^a r^b v^c with $[M\,L\,T^{-2}]$ gives a = b = c = 1, F ∝ ηrv. Fast case: F ∝ ρ^a r^b v^c gives a = 1, b = 2, c = 2, $F \propto \rho r^2 v^2$. At terminal speed the drag equals the weight, which is $\propto r^3$. Slow: $\eta r v \propto r^3$, so $v \propto r^2$ and doubling r makes v four times. Fast: $\rho r^2 v^2 \propto r^3$, so $v \propto \sqrt{r}$ and v becomes √2 times.

Q5. Answer (3). The kelvin appears only in k $[M\,L^2\,T^{-2}\,K^{-1}]$ and T [K], so they enter as the energy kT. Let u ∝ (kT)^a h^b c^d: $[M\,L^{-1}\,T^{-2}] = [M\,L^2\,T^{-2}]^a\,[M\,L^2\,T^{-1}]^b\,[L\,T^{-1}]^d$. M: a + b = 1; L: 2a + 2b + d = −1, so d = −3; T: −2a − b − d = −2, so 2a + b = 5, a = 4, b = −3. So $u \propto k^4T^4/(h^3c^3)$, the T^4 law of black-body radiation.

Q6. Answer (4). From F = qvB, $[B] = [M\,T^{-2}\,A^{-1}]$; flux Φ = BA has $[M\,L^2\,T^{-2}\,A^{-1}]$ (IV). From $B = \mu_0 I/2\pi r$, $[\mu_0] = [B\,L\,A^{-1}] = [M\,L\,T^{-2}\,A^{-2}]$ (I). From Φ = LI, $[L] = [M\,L^2\,T^{-2}\,A^{-2}]$ (II). From $F = q^2/(4\pi\varepsilon_0 r^2)$, $[\varepsilon_0] = [A^2\,T^2]/[M\,L^3\,T^{-2}] = [M^{-1}\,L^{-3}\,T^4\,A^2]$ (III).

Q7. Answer (2). h/e has the unit $J\,s\,C^{-1} = (J\,C^{-1})\,s = V\,s$. By Faraday's law (emf = −dΦ/dt) a weber is a volt second, so h/e is measured in webers. Its dimensions $[M\,L^2\,T^{-1}]/[A\,T] = [M\,L^2\,T^{-2}\,A^{-1}]$ are those of magnetic flux.

Q8. Answer (3). The seven SI base units are the metre, kilogram, second, ampere, kelvin, mole and candela. So (A), (C) and (E) are correct. The radian and the steradian are dimensionless derived units (once called supplementary units), not base units, so (B) is wrong. Luminous intensity is measured in candela; the lumen is the unit of luminous flux, so (D) is wrong.

Q9. Answer (1). With force, length and time as the base quantities, energy = force × length, so the new unit of energy is 10 × 5 = 50 J and 100 J = 2 units (the unit of time does not enter). Power = force × length/time, so the new unit of power is 10 × 5/2 = 25 W and 300 W = 12 units.

Q10. Answer (2). (A) The zeros before the 3 only locate the decimal point; the trailing zero after the decimal point counts: 2. Correct. (B) Trailing zeros after a decimal point count: 4. Correct. (C) The power of ten does not count, so 6.40×10^3 has 3. Correct. (D) By the rounding rule for a dropped 5, the preceding digit is left unchanged if it is even: 2.745 becomes 2.74, so (D) is wrong. (E) 0.050×10^{-2} has 2 significant figures (5 and the trailing 0), so (E) is wrong.

Q11. Answer (4). Volume $= (2.50)^3 = 15.625\ cm^3$, so density $= 47.3/15.625 = 3.0272\ g\,cm^{-3}$. Both data have three significant figures, so the result keeps three: $3.03\ g\,cm^{-3} = 3.03 \times 10^3\ kg\,m^{-3}$.

Q12. Answer (2). In a sum, the result keeps as many decimal places as the least precise term (12.4 m, one decimal place): 15.832 → 15.8 m. In a quotient, it keeps as many significant figures as the least precise factor (4.0 s, two): 15.8/4.0 = 3.95 → 4.0 m s^{-1}. Writing '4 m s^{-1}' drops a significant figure.

Q13. Answer (3). $R = R_1R_2/(R_1 + R_2) = 1800/90 = 20\ \Omega$. From $1/R = 1/R_1 + 1/R_2$, $\Delta R/R^2 = \Delta R_1/R_1^2 + \Delta R_2/R_2^2 = 1.2/3600 + 0.9/900 = 1/750$, so $\Delta R = 400/750 \approx 0.53\ \Omega$. Adding the absolute errors (2.1 Ω) treats the combination like a sum, which it is not.

Q14. Answer (1). Mean = 12.00/6 = 2.00 s. Absolute errors: 0.04, 0.04, 0.01, 0.01, 0.05, 0.05 s, which add to 0.20 s; the mean absolute error is 0.20/6 = 0.033 s ≈ 0.03 s. So T = (2.00 ± 0.03) s, an error of 1.5%. 0.05 s is the largest single error, not the mean.

Q15. Answer (4). $\Delta L/L = 0.1/100.0 = 0.1\%$. The period comes from the time for 40 oscillations, so $\Delta T/T = 0.2/80.0 = 0.25\%$. $\Delta g/g = \Delta L/L + 2\Delta T/T = 0.1\% + 0.5\% = 0.6\%$. 0.35% forgets the factor 2 on the period.

Q16. Answer (3). Least count = 1 MSD − 1 VSD = 0.5 mm × (1 − 24/25) = 0.02 mm. The vernier zero is to the right of the main scale zero, so the zero error is positive: +7 × 0.02 = +0.14 mm. Observed reading = 35.5 + 12 × 0.02 = 35.74 mm. Corrected length = 35.74 − 0.14 = 35.60 mm. Adding the zero error instead gives 35.88 mm.

Q17. Answer (3). (1) $g\lambda$ and $S/(\rho\lambda)$ both have $[L^2\ T^{-2}]$, so v has $[L\ T^{-1}]$. (2) $pr^4/(\eta\ell) = [M\ L^{-1}\ T^{-2}][L^4]/([M\ L^{-1}\ T^{-1}][L]) = [L^3\ T^{-1}]$, a volume per second. (4) $S/(\rho gr) = [M\ T^{-2}]/([M\ L^{-3}][L\ T^{-2}][L]) = [L]$. (3) GM/r^2 has $[L\ T^{-2}]$, an acceleration, so its square root is not a speed: the correct relation is $v = \sqrt{(GM/r)}$.

Q18. Answer (3). Statement I: a − b = 0.4 cm and the maximum error is 0.1 + 0.1 = 0.2 cm, i.e. 0.2/0.4 = 50%. True. (Subtracting nearly equal quantities magnifies the relative error.) Statement II: the absolute errors add in a difference as well as in a sum (here 0.2 cm, not 0), so it is false.

Q19. Answer (4). $[\mu_0] = [M\ L\ T^{-2}\ A^{-2}]$ and $[\varepsilon_0] = [M^{-1}\ L^{-3}\ T^4\ A^2]$, so $\mu_0/\varepsilon_0 = [M^2\ L^4\ T^{-6}\ A^{-4}]$ and $\sqrt{(\mu_0/\varepsilon_0)} = [M\ L^2\ T^{-3}\ A^{-2}] = [V/A]$, the dimensions of resistance. (Its value, about 377 Ω, is the impedance of free space.)

Q20. Answer (3). Let $f \propto F\text{^}a\ \ell\text{^}b\ \mu\text{^}c$: $[T^{-1}] = [M\ L\ T^{-2}]\text{^}a\ [L]\text{^}b\ [M\ L^{-1}]\text{^}c$. M: a + c = 0; T: −2a = −1, so a = ½, c = −½; L: a + b − c = 0, so b = −1. So $f \propto \sqrt{(F/\mu)}/\ell$, and the new frequency is √1.44/1.2 = 1.2/1.2 = 1 times the old: unchanged.

Q21. Answer 7. L/R, CR and √(LC) are the time constants of LR, CR and LC circuits: time. $\sqrt{(\mu_0\varepsilon_0)} = 1/c$, so $\ell\sqrt{(\mu_0\varepsilon_0)} = \ell/c$: time. Φ/V: a weber is a volt second: time. h/E: (J s)/J: time. $\sqrt{(\ell/g)}$: time. B/E = 1/(speed) (E = vB), so not time. $S/\eta = [M\ T^{-2}]/[M\ L^{-1}\ T^{-1}] = [L\ T^{-1}]$, a speed. So 7 of the 9.

Q22. Answer 3. $\Delta Y/Y = \Delta M/M + \Delta L/L + 2\Delta d/d + \Delta\ell/\ell = 0.02/4.00 + 0.002/2.000 + 2 \times 0.004/0.400 + 0.002/0.500 = 0.5\% + 0.1\% + 2\% + 0.4\% = 3\%$.

Q23. Answer 13. The new unit of energy is $(1000\ kg)(1000\ m)^2/(60\ s)^2 = 10^9/3600\ J \approx 2.78 \times 10^5\ J$. 1 kWh = 1000 W × 3600 s = 3.6×10^6 J = $3.6 \times 10^6 \times 3600/10^9 = 12.96$ new units, i.e. 13 to the nearest integer.

Q24. Answer 8. $[q] = [A\ T]$, $[a] = [L\ T^{-2}]$, $[c] = [L\ T^{-1}]$, $[\varepsilon_0] = [M^{-1}\ L^{-3}\ T^4\ A^2]$, $[P] = [M\ L^2\ T^{-3}]$. M: −w = 1, w = −1. A: x + 2w = 0, x = 2. L: y + z − 3w = 2, so y + z = −1. T: x − 2y − z + 4w = −3, so 2y + z = 1. Hence y = 2, z = −3 ($P \propto q^2a^2/(\varepsilon_0c^3)$, Larmor's formula). x + y − z − w = 2 + 2 + 3 + 1 = 8.

Q25. Answer 267. Least count = 1 mm/100 = 0.01 mm. When the zero of the circular scale is above the reference line the zero error is negative: −4 × 0.01 = −0.04 mm. Observed reading = 2 + 63 × 0.01 = 2.63 mm. Corrected diameter = 2.63 − (−0.04) = 2.67 mm = 267 × 0.01 mm.

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