Rajasthan JET Physics Sample Paper-12

Duration: 40 Minutes **Maximum Marks: 160**

Instructions

- This paper contains **40** Multiple Choice Questions (Single Correct).
- Each correct answer carries **+4 marks**.
- Each incorrect answer carries: $-$**1 mark**.
- Use of mobile phones, smartwatches, calculators, or any electronic gadgets is strictly prohibited.

Q1. In the van der Waals equation $\left(P + \frac{a}{V^2}\right)(V - b) = RT$, where P is pressure and V is volume, the dimensional formula of the constant a is:

(A) $[\mathrm{M\,L^{-1}T^{-2}}]$

(B) $[\mathrm{M\,L^{5}T^{-2}}]$

(C) $[\mathrm{M\,L^{2}T^{-2}}]$

(D) $[\mathrm{M^0L^6T^0}]$

Q2. The mass of a cube is measured with a maximum error of 2% and the length of its side with a maximum error of 1%. The maximum percentage error in the calculated density of the cube is:

(A) 3%

(B) 4%

(C) 5%

(D) 7%

Q3. A particle starts from rest and moves with uniform acceleration along a straight line. The distance it covers in the n^{th} second is 2.5 m and in the $(n+2)^{\text{th}}$ second is 3.5 m. The acceleration of the particle is:

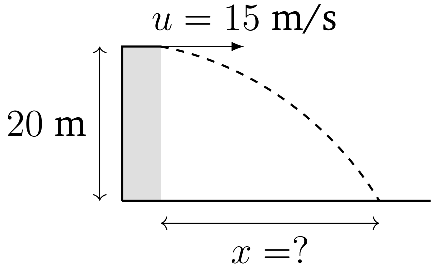
(A) 0.5 m/s^2

(B) 1.0 m/s^2

(C) 0.25 m/s^2

(D) 2.0 m/s^2

Q4. A ball is projected horizontally with a speed of 15 m/s from the top of a cliff of height 20 m, as shown. Taking $g = 10 \text{ m/s}^2$, the horizontal distance from the foot of the cliff at which the ball strikes the ground is:



(A) 15 m

(B) 20 m

(C) 30 m

(D) 45 m

Q5. Two trains of lengths 120 m and 80 m are moving in opposite directions on parallel tracks with speeds 20 m/s and 30 m/s respectively. The time taken by them to completely cross each other is:

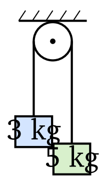
(A) 4 s

(B) 5 s

(C) 8 s

(D) 10 s

Q6. Two blocks of masses 3 kg and 5 kg are connected by a light inextensible string passing over a frictionless, massless pulley, as shown. Taking $g = 10 \text{ m/s}^2$, the acceleration of the system is:



(A) 5.0 m/s^2

(B) 1.25 m/s^2

(C) 3.75 m/s^2

(D) 2.5 m/s^2

Q7. A car moves on a flat (unbanked) circular track of radius 100 m. If the coefficient of static friction between the tyres and the road is 0.4 and $g = 10$ m/s^2, the maximum speed with which the car can take the turn without skidding is:

(A) 10 m/s

(B) 14 m/s

(C) 40 m/s

(D) 20 m/s

Q8. A pump lifts 600 kg of water per minute from a well of depth 20 m and delivers it at the top with negligible speed. Taking $g = 10$ m/s^2, the minimum power of the pump is:

(A) 1 kW

(B) 2 kW

(C) 3 kW

(D) 4 kW

Q9. The potential energy of a particle moving along the x-axis is given by $U(x) = 5x^2 - 4x$ joule, where x is in metre. The force acting on the particle at $x = 2$ m is:

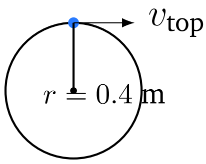
(A) -16 N

(B) $+16$ N

(C) -10 N

(D) $+24$ N

Q10. A small stone tied to a string is whirled in a vertical circle of radius 0.4 m, as shown. Taking $g = 10$ m/s^2, the minimum speed the stone must have at the highest point to just maintain the circular path is:



(A) 4 m/s

(B) 2 m/s

(C) $2\sqrt{5}$ m/s

(D) $\sqrt{5}$ m/s

Q11. A body of mass 2 kg moving with a velocity of 6 m/s makes a head-on elastic collision with a stationary body of mass 4 kg. The velocity of the 2 kg body just after the collision is:

(A) $+2$ m/s

(B) $+4$ m/s

(C) -2 m/s

(D) -4 m/s

Q12. The moment of inertia of a uniform thin rod of mass 3 kg and length 2 m about an axis passing through one end and perpendicular to its length is:

(A) 2 kg m^2

(B) 12 kg m^2

(C) 1 kg m^2

(D) 4 kg m^2

Q13. A uniform solid sphere rolls without slipping on a horizontal surface. The fraction of its total kinetic energy that is associated with rotation about its own axis is:

(A) $\frac{2}{7}$

(B) $\frac{2}{5}$

(C) $\frac{5}{7}$

(D) $\frac{1}{2}$

Q14. A disc of moment of inertia I is rotating freely about its central axis with angular velocity ω. A ring, also of moment of inertia I, is gently placed coaxially on top of the rotating disc. The common angular velocity of the combination is:

(A) ω

(B) $\frac{\omega}{2}$

(C) 2ω

(D) $\frac{\omega}{4}$

Q15. At what depth below the surface of the Earth does the acceleration due to gravity reduce to 60% of its value at the surface? (Take R as the radius of the Earth.)

(A) $0.25R$

(B) $0.5R$

(C) $0.6R$

(D) $0.4R$

Q16. Two satellites revolve around a planet in circular orbits whose radii are in the ratio $1:4$. According to Kepler's third law, the ratio of their time periods of revolution is:

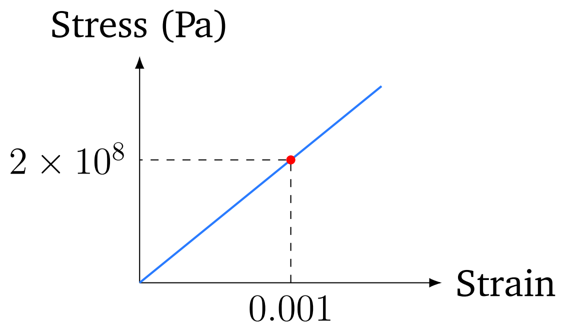
(A) $1:2$

(B) $1:4$

(C) $1:8$

(D) $1 : 16$

Q17. The stress–strain graph for a metal wire (within the elastic limit) is shown below. The Young's modulus of the material of the wire is:



(A) 2×10^8 Pa

(B) 2×10^5 Pa

(C) 2×10^{14} Pa

(D) 2×10^{11} Pa

Q18. Eight identical spherical liquid droplets, each of radius r, coalesce to form a single large drop. The ratio of the total surface energy of the eight small droplets to that of the single large drop is:

(A) $4 : 1$

(B) $2 : 1$

(C) $8 : 1$

(D) $1 : 2$

Q19. Two solid spheres of the same material but radii in the ratio $1 : 2$ fall through the same viscous liquid. The ratio of their terminal velocities is:

(A) $1 : 8$

(B) $1 : 2$

(C) $1 : 16$

(D) $1 : 4$

Q20. A Carnot engine working with a sink at $27°$C has an efficiency of 40%. To raise its efficiency to 50% (keeping the sink temperature unchanged), the temperature of the source must be increased by:

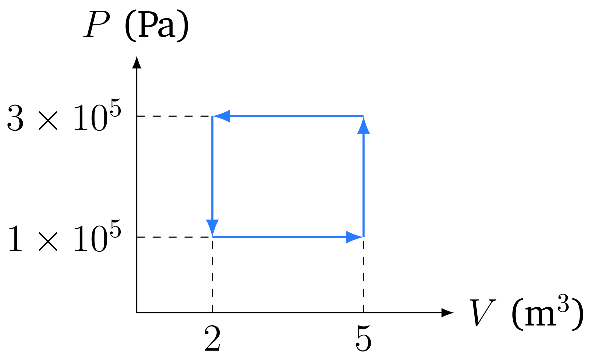
(A) 50 K

(B) 60 K

(C) 100 K

(D) 120 K

Q21. An ideal gas is taken through the cyclic process shown in the P–V diagram. The net work done by the gas in one complete cycle is:



(A) 3×10^5 J

(B) 6×10^5 J

(C) 9×10^5 J

(D) 2×10^5 J

Q22. For the molecules of an ideal gas at a given temperature, the ratio of the root-mean-square speed to the most-probable speed is:

(A) $\sqrt{3} : \sqrt{2}$

(B) $\sqrt{2} : \sqrt{3}$

(C) $3 : 2$

(D) $1 : 1$

Q23. A black body at an absolute temperature 300 K emits radiation whose wavelength of maximum intensity is λ_0. If the temperature of the body is raised to 600 K, the wavelength of maximum intensity becomes:

(A) $\dfrac{\lambda_0}{2}$

(B) $2\lambda_0$

(C) $\dfrac{\lambda_0}{4}$

(D) $4\lambda_0$

Q24. A block of mass 0.5 kg is attached to a spring of force constant 200 N/m and executes simple harmonic motion on a smooth horizontal surface. The time period of oscillation is:

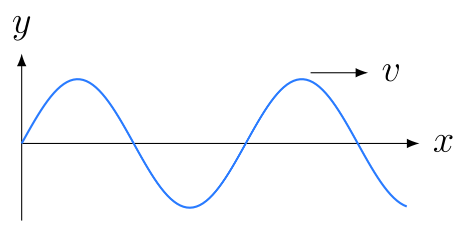
(A) 0.2π s

(B) π s

(C) 0.1π s

(D) 0.05π s

Q25. A transverse progressive wave on a string is described by $y = 0.02\sin(4\pi t - 0.02\pi x)$, where x and y are in metre and t is in second. The speed of the wave is:



(A) 100 m/s

(B) 200 m/s

(C) 400 m/s

(D) 50 m/s

Q26. The fundamental frequency of a closed organ pipe (closed at one end) is 200 Hz. The frequency of its third overtone is:

(A) 600 Hz

(B) 800 Hz

(C) 1000 Hz

(D) 1400 Hz

Q27. An object is placed 20 cm in front of a concave mirror of focal length 15 cm. The magnification produced by the mirror is:

(A) $-\frac{1}{3}$

(B) $+3$

(C) -2

(D) -3

Q28. Light travels from a denser medium of refractive index 1.5 into air. The critical angle for total internal reflection at the interface is approximately:

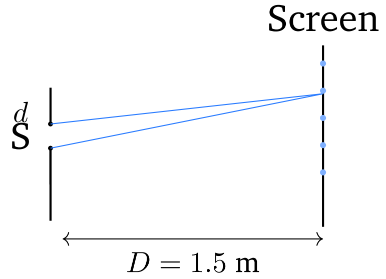
(A) 30°

(B) 60°

(C) 42°

(D) 49°

Q29. In Young's double-slit experiment, light of wavelength 600 nm illuminates two slits separated by 0.3 mm. The fringe pattern is observed on a screen placed 1.5 m away. The fringe width is:



(A) 1.5 mm

(B) 3 mm

(C) 6 mm

(D) 0.3 mm

Q30. A point charge of $2\ \mu$C is placed at the centre of a cube. The electric flux passing through one face of the cube is approximately (take $\varepsilon_0 = 8.85 \times 10^{-12}$ C^{2}N^{-1}m^{-2}):

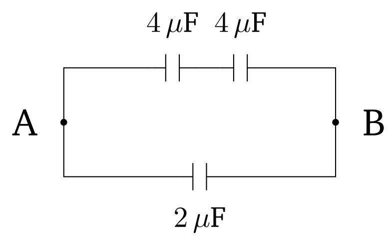
(A) 3.8×10^4 N m^2/C

(B) 2.3×10^5 N m^2/C

(C) 1.1×10^4 N m^2/C

(D) 7.5×10^4 N m^2/C

Q31. In the network shown, two capacitors of $4\ \mu$F each are connected in series, and this combination is connected in parallel with a third capacitor of $2\ \mu$F. The equivalent capacitance between the terminals A and B is:



(A) $2\ \mu$F

(B) $6\ \mu$F

(C) $8\ \mu$F

(D) $4\ \mu$F

Q32. A wire of resistance R is stretched uniformly (keeping its volume constant) until its length becomes three times the original length. The new resistance of the wire is:

(A) $3R$

(B) $6R$

(C) $9R$

(D) $\dfrac{R}{9}$

Q33. In a meter bridge experiment, an unknown resistance X is connected in the left gap and a known resistance of $10\ \Omega$ in the right gap. The balance point is obtained at 40 cm from the left end of the wire. The value of X is:

(A) $4\ \Omega$

(B) $6.67\ \Omega$

(C) $15\ \Omega$

(D) $25\ \Omega$

Q34. A long solenoid has 1000 turns per metre and carries a current of 2 A. The magnetic field at the centre, on its axis, is (take $\mu_0 = 4\pi \times 10^{-7}$ T m/A):

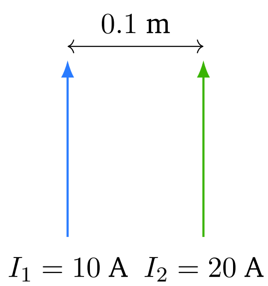
(A) $4\pi \times 10^{-4}$ T

(B) $2\pi \times 10^{-3}$ T

(C) $8\pi \times 10^{-7}$ T

(D) $8\pi \times 10^{-4}$ T

Q35. Two long, straight, parallel wires are separated by 0.1 m and carry currents of 10 A and 20 A in the same direction, as shown. The force per unit length between the wires is (take $\mu_0 = 4\pi \times 10^{-7}$ T m/A):



(A) 4×10^{-4} N/m, attractive

(B) 4×10^{-4} N/m, repulsive

(C) 2×10^{-4} N/m, attractive

(D) 8×10^{-4} N/m, repulsive

Q36. Two coils have a mutual inductance of 0.5 H. If the current in the primary coil changes steadily from 0 to 10 A in 0.1 s, the magnitude of the emf induced in the secondary coil is:

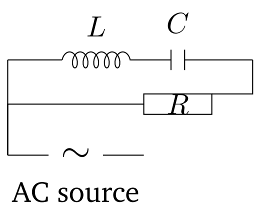
(A) 5 V

(B) 50 V

(C) 100 V

(D) 25 V

Q37. In the series LCR circuit shown, $L = 2$ H and $C = 8$ μF. The angular frequency at which the circuit is in resonance is:



(A) 500 rad/s

(B) 125 rad/s

(C) 250 rad/s

(D) 2500 rad/s

Q38. Light of wavelength 400 nm is incident on a metal surface whose work function is 2.0 eV. Taking $hc = 1240$ eV nm, the maximum kinetic energy of the emitted photoelectrons is:

(A) 5.1 eV

(B) 3.1 eV

(C) 2.0 eV

(D) 1.1 eV

Q39. A radioactive sample has a half-life of 10 days. The fraction of the original active nuclei that remains undecayed after 40 days is:

(A) $\frac{1}{16}$

(B) $\frac{1}{8}$

(C) $\frac{1}{4}$

(D) $\frac{1}{32}$

Q40. A two-input digital logic gate produces the output Y given in the truth table below. The gate is a/an:

A	B	Y
0	0	1
0	1	0
1	0	0
1	1	0

(A) AND gate

(B) NAND gate

(C) NOR gate

(D) XOR gate

Detailed Solutions

Q1.

Solution

In the van der Waals equation the term $\frac{a}{V^2}$ is added to the pressure P, so it must itself have the dimensions of pressure.

$$\left[\frac{a}{V^2}\right] = [P] \quad \Rightarrow \quad [a] = [P]\,[V^2]$$

Dimensions of the two quantities:

- Pressure: $[P] = \frac{\text{Force}}{\text{Area}} = \frac{[\text{M}\,\text{L}\,\text{T}^{-2}]}{[\text{L}^2]} = [\text{M}\,\text{L}^{-1}\text{T}^{-2}]$
- Volume squared: $[V^2] = [\text{L}^3]^2 = [\text{L}^6]$

Therefore:

$$[a] = [\text{M}\,\text{L}^{-1}\text{T}^{-2}] \times [\text{L}^6] = [\text{M}\,\text{L}^5\text{T}^{-2}]$$

Why the other options are wrong: $[\text{M}\,\text{L}^{-1}\text{T}^{-2}]$ is plain pressure (it ignores the V^2 factor); $[\text{M}\,\text{L}^2\text{T}^{-2}]$ is energy; the dimensionless/length-only form ignores the pressure dimensions entirely. Only the constant b has the dimensions of volume $[\text{L}^3]$. **Final Answer:** $[a] = [\text{M}\,\text{L}^5\text{T}^{-2}]$.

Answer: (B) Go Back to Q1

Q2.

Solution

Density is mass divided by volume, and for a cube the volume is the cube of the side length:

$$\rho = \frac{M}{L^3}$$

For a quantity formed by products and powers, the maximum fractional errors add, each multiplied by the magnitude of its power:

$$\frac{\Delta\rho}{\rho} = \frac{\Delta M}{M} + 3\,\frac{\Delta L}{L}$$

Substituting the given percentage errors:

$$\frac{\Delta\rho}{\rho} \times 100 = (2\%) + 3 \times (1\%) = 2\% + 3\% = 5\%$$

Why the other options are wrong: 3% would result from simply adding $2\% + 1\%$

and forgetting that length enters as a cube; 4% uses a power of 2 instead of 3; 7% over-counts the length error. **Final Answer:** The maximum error in density is 5%.

Answer: (C) Go Back to Q2

Q3.

Solution

The distance covered in the n^{th} second of uniformly accelerated motion (starting from rest, $u = 0$) is:

$$s_n = u + \frac{a}{2}(2n-1) = \frac{a}{2}(2n-1)$$

Writing the two given conditions:

$$s_n = \frac{a}{2}(2n-1) = 2.5 \qquad s_{n+2} = \frac{a}{2}\big(2(n+2)-1\big) = 3.5$$

Subtracting the first from the second:

$$s_{n+2} - s_n = \frac{a}{2}\big[(2n+3)-(2n-1)\big] = \frac{a}{2}(4) = 2a$$

$$2a = 3.5 - 2.5 = 1.0 \quad \Rightarrow \quad a = 0.5 \text{ m/s}^2$$

Why the other options are wrong: The remaining values come from mishandling the $(2n-1)$ factor or from dividing the difference by the wrong number of seconds. **Final Answer:** The acceleration is 0.5 m/s^2.

Answer: (A) Go Back to Q3

Q4.

Solution

For a horizontal projectile the vertical and horizontal motions are independent. Vertically the ball starts with zero vertical velocity and falls a height H:

$$H = \frac{1}{2}gt^2$$

$$20 = \frac{1}{2}(10)t^2 \quad \Rightarrow \quad t^2 = 4 \quad \Rightarrow \quad t = 2 \text{ s}$$

Horizontally the speed is constant at $u = 15$ m/s, so the horizontal distance (range) is:

$$x = u\,t = 15 \times 2 = 30 \text{ m}$$

Why the other options are wrong: 15 m uses $t = 1$ s; 45 m uses $t = 3$ s; 20 m simply copies the height. The correct time of flight is fixed only by H and g. **Final**

Answer: The ball lands 30 m from the foot of the cliff.

Answer: (C) Go Back to Q4

Q5.

Solution

When two bodies move in opposite directions, their relative speed is the sum of their individual speeds:

$$v_{\text{rel}} = 20 + 30 = 50 \text{ m/s}$$

To completely cross each other, the trains together must cover a distance equal to the sum of their lengths:

$$L = 120 + 80 = 200 \text{ m}$$

Therefore the time taken is:

$$t = \frac{L}{v_{\text{rel}}} = \frac{200}{50} = 4 \text{ s}$$

Why the other options are wrong: Using the difference of speeds (10 m/s) gives the (incorrect) same-direction answer of 20 s; the other values arise from using only one train's length. **Final Answer:** The trains cross each other in 4 s.

Answer: (A) Go Back to Q5

Q6.

Solution

For an Atwood machine the heavier mass accelerates downward and the lighter mass upward with a common magnitude of acceleration. Applying Newton's second law to the system:

$$a = \frac{(m_2 - m_1)\, g}{m_1 + m_2}$$

Substituting $m_1 = 3$ kg, $m_2 = 5$ kg, $g = 10$ m/s^2:

$$a = \frac{(5-3)\times 10}{3+5} = \frac{2\times 10}{8} = \frac{20}{8} = 2.5 \text{ m/s}^2$$

Why the other options are wrong: 5.0 m/s^2 forgets to divide by the total mass; 1.25 m/s^2 uses twice the total mass; 3.75 m/s^2 uses the wrong mass difference. **Final Answer:** The acceleration of the system is 2.5 m/s^2.

Answer: (D) Go Back to Q6

Q7.

Solution

On a flat circular track the centripetal force needed for the turn is supplied entirely by static friction. At the maximum speed friction is at its limiting value:

$$\frac{mv_{\max}^2}{r} = \mu mg$$

The mass cancels, giving:

$$v_{\max} = \sqrt{\mu g r}$$

Substituting $\mu = 0.4$, $g = 10$ m/s^2, $r = 100$ m:

$$v_{\max} = \sqrt{0.4 \times 10 \times 100} = \sqrt{400} = 20 \text{ m/s}$$

Why the other options are wrong: They come from forgetting the square root or from misplacing the factor of r. Note the result is independent of the car's mass. **Final Answer:** The maximum safe speed is 20 m/s.

Answer: (D) Go Back to Q7

Q8.

Solution

Power is the rate of doing work. The pump must raise the gravitational potential energy of the water lifted each second:

$$P = \frac{mgh}{t}$$

First convert the rate: 600 kg per minute means $t = 60$ s for $m = 600$ kg. Substituting with $h = 20$ m, $g = 10$ m/s^2:

$$P = \frac{600 \times 10 \times 20}{60} = \frac{120000}{60} = 2000 \text{ W} = 2 \text{ kW}$$

Why the other options are wrong: They result from forgetting to divide by 60 s, or from using the wrong depth. Since the water is delivered with negligible speed, no extra kinetic-energy term is needed. **Final Answer:** The minimum power of the pump is 2 kW.

Answer: (B) Go Back to Q8

Q9.

Solution

For a conservative force in one dimension the force is the negative gradient of the potential energy:

$$F = -\frac{dU}{dx}$$

Differentiating $U(x) = 5x^2 - 4x$:

$$\frac{dU}{dx} = 10x - 4$$

$$F = -(10x - 4) = 4 - 10x$$

At $x = 2$ m:

$$F = 4 - 10(2) = 4 - 20 = -16 \text{ N}$$

The negative sign means the force points in the $-x$ direction. **Why the other options are wrong:** $+16$ N drops the negative sign of the gradient; -10 N ignores the constant term; $+24$ N uses the wrong sign throughout. **Final Answer:** The force on the particle is -16 N.

Answer: (A) Go Back to Q9

Q10.

Solution

At the highest point of a vertical circle, gravity acts downward toward the centre. The minimum (critical) speed is the one for which the string tension just becomes zero and gravity alone provides the centripetal force:

$$mg = \frac{mv_{\text{top}}^2}{r}$$

The mass cancels:

$$v_{\text{top}} = \sqrt{gr}$$

Substituting $g = 10$ m/s^2 and $r = 0.4$ m:

$$v_{\text{top}} = \sqrt{10 \times 0.4} = \sqrt{4} = 2 \text{ m/s}$$

Why the other options are wrong: $2\sqrt{5}$ m/s is the minimum speed at the *lowest* point ($\sqrt{5gr}$), not the top; $\sqrt{5}$ m/s and 4 m/s do not satisfy the critical condition $v^2 = gr$. **Final Answer:** The minimum speed at the top is 2 m/s.

Answer: (B) Go Back to Q10

Q11.

Solution

For a one-dimensional elastic collision in which the target (m_2) is initially at rest, the velocity of the incoming body (m_1) afterwards is:

$$v_1' = \left(\frac{m_1 - m_2}{m_1 + m_2}\right) u$$

Substituting $m_1 = 2$ kg, $m_2 = 4$ kg, $u = 6$ m/s:

$$v_1' = \left(\frac{2-4}{2+4}\right)(6) = \left(\frac{-2}{6}\right)(6) = -2 \text{ m/s}$$

The negative sign shows that the lighter body rebounds (reverses direction), which is expected when it strikes a heavier target. **Why the other options are wrong:** $+2$ m/s and $+4$ m/s ignore the rebound; -4 m/s uses the wrong mass ratio. (For completeness, the 4 kg body moves off at $v_2' = \frac{2m_1}{m_1+m_2}u = +4$ m/s.) **Final Answer:** The 2 kg body moves at -2 m/s after the collision.

Answer: (C) Go Back to Q11

Q12.

Solution

The moment of inertia of a uniform thin rod about an axis through one end, perpendicular to its length, is:

$$I = \frac{ML^2}{3}$$

Substituting $M = 3$ kg and $L = 2$ m:

$$I = \frac{3 \times (2)^2}{3} = \frac{3 \times 4}{3} = 4 \text{ kg m}^2$$

Why the other options are wrong: 1 kg m^2 corresponds to the axis through the *centre* ($ML^2/12 = 1$); 2 kg m^2 and 12 kg m^2 come from using the wrong denominator. The end axis is farther from the mass distribution, so the rod's I about the end is four times its I about the centre, consistent with the parallel-axis theorem. **Final Answer:** The moment of inertia about the end is 4 kg m^2.

Answer: (D) Go Back to Q12

Q13.

Solution

For a body rolling without slipping, the total kinetic energy is the sum of translational and rotational parts:

$$KE_{\text{total}} = \frac{1}{2}mv^2 + \frac{1}{2}I\omega^2$$

For a solid sphere $I = \frac{2}{5}mR^2$ and the rolling condition gives $v = \omega R$, so:

$$KE_{\text{rot}} = \frac{1}{2}\left(\frac{2}{5}mR^2\right)\left(\frac{v}{R}\right)^2 = \frac{1}{5}mv^2$$

The total kinetic energy is:

$$KE_{\text{total}} = \frac{1}{2}mv^2 + \frac{1}{5}mv^2 = \frac{7}{10}mv^2$$

Therefore the fraction that is rotational is:

$$\frac{KE_{\text{rot}}}{KE_{\text{total}}} = \frac{\frac{1}{5}mv^2}{\frac{7}{10}mv^2} = \frac{2}{7}$$

Why the other options are wrong: $\frac{2}{5}$ is the moment-of-inertia coefficient, not the energy fraction; $\frac{5}{7}$ is the *translational* fraction; $\frac{1}{2}$ would hold only if $I = mR^2$ (a ring). **Final Answer:** The rotational fraction of the kinetic energy is $\frac{2}{7}$.

Answer: (A) Go Back to Q13

Q14.

Solution

No external torque acts about the common axis while the ring is dropped on, so angular momentum is conserved:

$$L_{\text{initial}} = L_{\text{final}}$$

$$I\,\omega = (I + I)\,\omega'$$

The total moment of inertia doubles because the ring adds an equal I:

$$\omega' = \frac{I\,\omega}{2I} = \frac{\omega}{2}$$

Why the other options are wrong: ω would require no change in I; 2ω violates conservation (it would *increase* angular momentum); $\frac{\omega}{4}$ assumes I becomes four times larger. Note kinetic energy is not conserved here (the "collision" is rotationally inelastic). **Final Answer:** The common angular velocity is $\frac{\omega}{2}$.

Answer: (B) Go Back to Q14

Q15.

Solution

The acceleration due to gravity at a depth d below the Earth's surface is:

$$g_d = g\left(1 - \frac{d}{R}\right)$$

We need $g_d = 60\%$ of g, i.e. $g_d = 0.6\,g$:

$$0.6\,g = g\left(1 - \frac{d}{R}\right)$$

$$0.6 = 1 - \frac{d}{R} \quad \Rightarrow \quad \frac{d}{R} = 1 - 0.6 = 0.4$$

$$d = 0.4\,R$$

Why the other options are wrong: $0.6R$ confuses the remaining fraction with the depth; $0.5R$ and $0.25R$ do not satisfy the linear depth relation. (Note that the variation with depth is linear, unlike the inverse-square variation with height.) **Final Answer:** The required depth is $0.4R$.

Answer: (D) Go Back to Q15

Q16.

Solution

Kepler's third law states that the square of the orbital period is proportional to the cube of the orbital radius:

$$T^2 \propto r^3 \quad \Rightarrow \quad \frac{T_1}{T_2} = \left(\frac{r_1}{r_2}\right)^{3/2}$$

Substituting $r_1 : r_2 = 1 : 4$:

$$\frac{T_1}{T_2} = \left(\frac{1}{4}\right)^{3/2} = \frac{1}{4^{3/2}} = \frac{1}{8}$$

Why the other options are wrong: $1 : 4$ uses the radius ratio directly (power 1); $1 : 2$ uses power $\frac{1}{2}$; $1 : 16$ uses power 2. The correct exponent is $\frac{3}{2}$. **Final Answer:** The ratio of periods is $1 : 8$.

Answer: (C) Go Back to Q16

Q17.

Solution

Within the elastic limit, stress is proportional to strain, and Young's modulus is the constant of proportionality, i.e. the slope of the stress–strain graph:

$$Y = \frac{\text{Stress}}{\text{Strain}}$$

From the marked point on the graph, the stress is 2×10^8 Pa when the strain is 0.001:

$$Y = \frac{2 \times 10^8}{0.001} = \frac{2 \times 10^8}{1 \times 10^{-3}} = 2 \times 10^{11}\ \text{Pa}$$

Why the other options are wrong: 2×10^8 Pa is just the stress value (forgetting to divide by strain); 2×10^5 Pa multiplies instead of divides; 2×10^{14} Pa mishandles the powers of ten. The value 2×10^{11} Pa is typical of a metal such as steel. **Final Answer:** Young's modulus is 2×10^{11} Pa.

Answer: (D) Go Back to Q17

Q18.

Solution

When n small droplets of radius r merge into one big drop, the volume is conserved:

$$n \cdot \frac{4}{3}\pi r^3 = \frac{4}{3}\pi R^3 \quad \Rightarrow \quad R = n^{1/3} r$$

For $n = 8$: $R = 8^{1/3} r = 2r$. Surface energy equals surface tension times surface area, so the ratio of total surface energies (before : after) is the ratio of total surface areas:

$$\frac{E_{\text{small}}}{E_{\text{big}}} = \frac{n\,(4\pi r^2)}{4\pi R^2} = \frac{8r^2}{(2r)^2} = \frac{8r^2}{4r^2} = \frac{2}{1}$$

Why the other options are wrong: $8 : 1$ ignores the growth of the big drop's radius; $4 : 1$ and $1 : 2$ invert or mis-square the radius. Because the surface area shrinks, energy is released on coalescence. **Final Answer:** The ratio of surface energies is $2 : 1$.

Answer: (B) Go Back to Q18

Q19.

Solution

The terminal velocity of a sphere falling through a viscous liquid is given by Stokes' law:

$$v_t = \frac{2}{9}\frac{r^2(\rho - \sigma)g}{\eta}$$

Since both spheres are of the same material (same ρ) and fall in the same liquid (same σ and η), the terminal velocity depends only on r^2:

$$v_t \propto r^2$$

For radii in the ratio $1 : 2$:

$$\frac{v_{t1}}{v_{t2}} = \left(\frac{1}{2}\right)^2 = \frac{1}{4}$$

Why the other options are wrong: $1 : 2$ uses a linear dependence; $1 : 8$ uses a cube; $1 : 16$ uses a fourth power. Terminal velocity scales as the square of the radius. **Final Answer:** The ratio of terminal velocities is $1 : 4$.

Answer: (D) **Go Back to Q19**

Q20.

Solution

The efficiency of a Carnot engine in terms of the source (T_H) and sink (T_C) absolute temperatures is:

$$\eta = 1 - \frac{T_C}{T_H}$$

The sink is at $27°\text{C} = 300$ K. For the initial efficiency of 40%:

$$0.40 = 1 - \frac{300}{T_H} \quad \Rightarrow \quad \frac{300}{T_H} = 0.60 \quad \Rightarrow \quad T_H = \frac{300}{0.60} = 500 \text{ K}$$

For the new efficiency of 50%:

$$0.50 = 1 - \frac{300}{T'_H} \quad \Rightarrow \quad \frac{300}{T'_H} = 0.50 \quad \Rightarrow \quad T'_H = \frac{300}{0.50} = 600 \text{ K}$$

The required increase in source temperature is:

$$\Delta T = T'_H - T_H = 600 - 500 = 100 \text{ K}$$

Why the other options are wrong: They follow from forgetting to convert $27°$C to kelvin, or from computing only one of the two source temperatures. **Final Answer:** The source temperature must be increased by 100 K.

Answer: (C) Go Back to Q20

Q21.

Solution

The net work done by a gas in a cyclic process equals the area enclosed by the loop in the P–V diagram. The loop here is a rectangle.

$$\text{Width} = \Delta V = (5 - 2) = 3\ \text{m}^3$$

$$\text{Height} = \Delta P = (3 \times 10^5 - 1 \times 10^5) = 2 \times 10^5\ \text{Pa}$$

$$W_{\text{net}} = \Delta P \times \Delta V = (2 \times 10^5) \times 3 = 6 \times 10^5\ \text{J}$$

Because the cycle is traced clockwise, the work done by the gas is positive. **Why the other options are wrong:** 3×10^5 J and 2×10^5 J use only one side of the rectangle; 9×10^5 J uses an incorrect span. Only the fully enclosed area gives the net work. **Final Answer:** The net work done in one cycle is 6×10^5 J.

Answer: (B) Go Back to Q21

Q22.

Solution

The characteristic molecular speeds of an ideal gas are:

$$v_{\text{rms}} = \sqrt{\frac{3RT}{M}}, \qquad v_{\text{mp}} = \sqrt{\frac{2RT}{M}}$$

Taking their ratio, the common factor $\sqrt{RT/M}$ cancels:

$$\frac{v_{\text{rms}}}{v_{\text{mp}}} = \frac{\sqrt{3RT/M}}{\sqrt{2RT/M}} = \sqrt{\frac{3}{2}} = \frac{\sqrt{3}}{\sqrt{2}}$$

Why the other options are wrong: $\sqrt{2} : \sqrt{3}$ is the reciprocal; $3 : 2$ forgets the square roots; $1 : 1$ would require the two speeds to be equal, which they are not (the rms speed is always the largest of the three characteristic speeds). **Final Answer:** $v_{\text{rms}} : v_{\text{mp}} = \sqrt{3} : \sqrt{2}$.

Answer: (A) Go Back to Q22

Q23.

Solution

Wien's displacement law states that the wavelength of maximum emission is inversely proportional to the absolute temperature:

$$\lambda_{\max} \propto \frac{1}{T} \quad \Rightarrow \quad \lambda_{\max} T = \text{constant}$$

Writing the law for the two states:

$$\lambda_0 \cdot 300 = \lambda'_{\max} \cdot 600$$

$$\lambda'_{\max} = \lambda_0 \times \frac{300}{600} = \frac{\lambda_0}{2}$$

Why the other options are wrong: $2\lambda_0$ and $4\lambda_0$ assume the wavelength increases with temperature (it decreases); $\frac{\lambda_0}{4}$ would require the temperature to quadruple. As the body gets hotter its peak shifts to shorter wavelengths. **Final Answer:** The new peak wavelength is $\dfrac{\lambda_0}{2}$.

Answer: (A) Go Back to Q23

Q24.

Solution

The time period of a mass–spring oscillator is:

$$T = 2\pi\sqrt{\frac{m}{k}}$$

Substituting $m = 0.5$ kg and $k = 200$ N/m:

$$\frac{m}{k} = \frac{0.5}{200} = 0.0025 \text{ s}^2$$

$$\sqrt{\frac{m}{k}} = \sqrt{0.0025} = 0.05 \text{ s}$$

$$T = 2\pi(0.05) = 0.1\pi \text{ s} \approx 0.314 \text{ s}$$

Why the other options are wrong: 0.2π s drops the square root of m/k; 0.05π s omits the factor of 2; π s uses incorrect values. **Final Answer:** The time period is 0.1π s (≈ 0.314 s).

Answer: (C) Go Back to Q24

Q25.

Solution

Comparing $y = 0.02\sin(4\pi t - 0.02\pi x)$ with the standard travelling wave $y = A\sin(\omega t - kx)$:

$$\omega = 4\pi \text{ rad/s}, \qquad k = 0.02\pi \text{ rad/m}$$

The wave speed is the ratio of angular frequency to wave number:

$$v = \frac{\omega}{k} = \frac{4\pi}{0.02\pi} = \frac{4}{0.02} = 200 \text{ m/s}$$

Why the other options are wrong: They come from misreading ω or k, or from inverting the ratio. The π factors cancel cleanly. **Final Answer:** The wave speed is 200 m/s.

Answer: (B) Go Back to Q25

Q26.

Solution

A pipe closed at one end supports only odd harmonics of its fundamental frequency f_1:

$$f = f_1,\ 3f_1,\ 5f_1,\ 7f_1,\ \ldots$$

The overtones are the resonances above the fundamental, so:

- 1st overtone $= 3f_1$
- 2nd overtone $= 5f_1$
- 3rd overtone $= 7f_1$

With $f_1 = 200$ Hz:

$$f_{\text{3rd overtone}} = 7 \times 200 = 1400 \text{ Hz}$$

Why the other options are wrong: 600 Hz is the 1st overtone ($3f_1$); 1000 Hz is the 2nd overtone ($5f_1$); 800 Hz ($4f_1$) is an even harmonic, which a closed pipe cannot produce. **Final Answer:** The third overtone has a frequency of 1400 Hz.

Answer: (D) Go Back to Q26

Q27.

Solution

Using the mirror formula with the sign convention (distances measured from the pole, real objects/foci negative for a concave mirror): $f = -15$ cm, $u = -20$ cm.

$$\frac{1}{v} + \frac{1}{u} = \frac{1}{f}$$

$$\frac{1}{v} = \frac{1}{f} - \frac{1}{u} = \frac{1}{-15} - \frac{1}{-20} = -\frac{1}{15} + \frac{1}{20}$$

$$\frac{1}{v} = \frac{-4+3}{60} = -\frac{1}{60} \quad \Rightarrow \quad v = -60 \text{ cm}$$

The magnification is:

$$m = -\frac{v}{u} = -\frac{(-60)}{(-20)} = -3$$

The image is real, inverted and magnified three times. **Why the other options are wrong:** $+3$ drops the inversion (negative) sign; $-\frac{1}{3}$ inverts the ratio; -2 uses an incorrect image distance. **Final Answer:** The magnification is -3.

Answer: (D) Go Back to Q27

Q28.

Solution

At the critical angle, light travelling from the denser medium grazes along the interface (angle of refraction $= 90°$). Snell's law gives:

$$\sin\theta_c = \frac{1}{n}$$

Substituting $n = 1.5$:

$$\sin\theta_c = \frac{1}{1.5} = 0.667$$

$$\theta_c = \sin^{-1}(0.667) \approx 41.8° \approx 42°$$

Why the other options are wrong: $49°$ corresponds to $n \approx 1.33$ (water); $30°$ would need $n = 2$; $60°$ gives $\sin\theta_c = 0.866$, i.e. $n \approx 1.15$. For total internal reflection the angle of incidence must exceed this critical value. **Final Answer:** The critical angle is approximately $42°$.

Answer: (C) Go Back to Q28

Q29.

Solution

The fringe width in Young's double-slit experiment is:

$$\beta = \frac{\lambda D}{d}$$

Convert the data to SI units: $\lambda = 600 \text{ nm} = 600 \times 10^{-9}$ m, $d = 0.3 \text{ mm} = 0.3 \times 10^{-3}$ m, $D = 1.5$ m.

$$\beta = \frac{(600 \times 10^{-9})(1.5)}{0.3 \times 10^{-3}}$$

$$\beta = \frac{9.0 \times 10^{-7}}{3.0 \times 10^{-4}} = 3.0 \times 10^{-3} \text{ m} = 3 \text{ mm}$$

Why the other options are wrong: 1.5 mm and 6 mm come from doubling or halving D or d incorrectly; 0.3 mm forgets to convert units. The fringe width is directly proportional to λ and D and inversely proportional to d. **Final Answer:** The fringe width is 3 mm.

Answer: (B) Go Back to Q29

Q30.

Solution

By Gauss's law the total electric flux through any closed surface enclosing a charge q is:

$$\phi_{\text{total}} = \frac{q}{\varepsilon_0}$$

Substituting $q = 2 \times 10^{-6}$ C:

$$\phi_{\text{total}} = \frac{2 \times 10^{-6}}{8.85 \times 10^{-12}} \approx 2.26 \times 10^{5} \text{ N m}^2/\text{C}$$

By symmetry, a charge at the centre of a cube sends equal flux through each of its 6 faces:

$$\phi_{\text{face}} = \frac{\phi_{\text{total}}}{6} = \frac{2.26 \times 10^{5}}{6} \approx 3.8 \times 10^{4} \text{ N m}^2/\text{C}$$

Why the other options are wrong: 2.3×10^5 is the *total* flux (not divided by 6); the other values use the wrong number of faces. The symmetry argument (centre of cube) is essential. **Final Answer:** The flux through one face is about 3.8×10^4 N m^2/C.

Answer: (A) Go Back to Q30

Q31.

Solution

First combine the two $4\ \mu$F capacitors in series:

$$\frac{1}{C_s} = \frac{1}{4} + \frac{1}{4} = \frac{2}{4} = \frac{1}{2} \quad \Rightarrow \quad C_s = 2\ \mu\text{F}$$

This series combination is in parallel with the $2\ \mu$F capacitor, so the capacitances add:

$$C_{\text{eq}} = C_s + 2 = 2 + 2 = 4\ \mu\text{F}$$

Why the other options are wrong: $2\ \mu$F gives only the series part; $8\ \mu$F adds all three as if in parallel; $6\ \mu$F mixes the rules. Capacitances add in parallel and combine reciprocally in series. **Final Answer:** The equivalent capacitance is $4\ \mu$F.

Answer: (D) Go Back to Q31

Q32.

Solution

When a wire is stretched at constant volume, its resistance changes with the square of the length. Starting from $R = \rho\frac{L}{A}$ and using $A = \frac{\text{Volume}}{L}$:

$$R = \rho\frac{L}{A} = \rho\frac{L^2}{\text{Volume}} \quad \Rightarrow \quad R \propto L^2$$

If the length becomes 3 times ($L' = 3L$):

$$\frac{R'}{R} = \left(\frac{L'}{L}\right)^2 = (3)^2 = 9 \quad \Rightarrow \quad R' = 9R$$

Why the other options are wrong: $3R$ ignores the simultaneous thinning of the wire; $R/9$ inverts the relation; $6R$ uses a wrong factor. Both the length increase and the cross-section decrease push the resistance up, giving the L^2 dependence. **Final Answer:** The new resistance is $9R$.

Answer: (C) Go Back to Q32

Q33.

Solution

In a balanced meter bridge, the ratio of the gap resistances equals the ratio of the two segments of the bridge wire:

$$\frac{X}{R} = \frac{l}{100 - l}$$

Here $R = 10\ \Omega$ (right gap) and the balance length from the left is $l = 40$ cm:

$$X = R \cdot \frac{l}{100 - l} = 10 \times \frac{40}{100 - 40} = 10 \times \frac{40}{60}$$

$$X = 10 \times \frac{2}{3} = \frac{20}{3} \approx 6.67\ \Omega$$

Why the other options are wrong: $15\ \Omega$ inverts the length ratio ($\frac{60}{40}$); $4\ \Omega$ uses $\frac{40}{100}$; $25\ \Omega$ is unrelated to the balance condition. **Final Answer:** The unknown resistance is about $6.67\ \Omega$.

Answer: (B) Go Back to Q33

Q34.

Solution

The magnetic field on the axis, deep inside a long solenoid, is:

$$B = \mu_0 n I$$

where n is the number of turns per metre. Substituting $n = 1000\ \text{m}^{-1}$, $I = 2$ A, $\mu_0 = 4\pi \times 10^{-7}$ T m/A:

$$B = (4\pi \times 10^{-7})(1000)(2)$$

$$B = 4\pi \times 10^{-7} \times 2000 = 8\pi \times 10^{-4}\ \text{T} \approx 2.5 \times 10^{-3}\ \text{T}$$

Why the other options are wrong: $4\pi \times 10^{-4}$ T forgets the current of 2 A; $8\pi \times 10^{-7}$ T forgets the factor of 1000 turns/m; $2\pi \times 10^{-3}$ T mishandles the constants. The field inside a long solenoid is uniform and independent of its radius. **Final Answer:** The axial field is $8\pi \times 10^{-4}$ T.

Answer: (D) Go Back to Q34

Q35.

Solution

The force per unit length between two long parallel wires carrying currents I_1 and I_2 separated by distance d is:

$$\frac{F}{L} = \frac{\mu_0 I_1 I_2}{2\pi d}$$

Substituting $I_1 = 10$ A, $I_2 = 20$ A, $d = 0.1$ m, $\mu_0 = 4\pi \times 10^{-7}$:

$$\frac{F}{L} = \frac{(4\pi \times 10^{-7})(10)(20)}{2\pi(0.1)}$$

$$\frac{F}{L} = \frac{4\pi \times 10^{-7} \times 200}{0.2\pi} = \frac{8\pi \times 10^{-5}}{0.2\pi} = 4 \times 10^{-4} \text{ N/m}$$

Currents in the *same* direction attract each other. **Why the other options are wrong:** The same magnitude with "repulsive" is wrong because parallel currents attract; the other magnitudes mishandle the factor $2\pi d$. **Final Answer:** The force per unit length is 4×10^{-4} N/m, attractive.

Answer: (A) Go Back to Q35

Q36.

Solution

The emf induced in the secondary coil due to a changing primary current is governed by the mutual inductance:

$$\varepsilon = M\frac{dI}{dt}$$

The rate of change of current is:

$$\frac{dI}{dt} = \frac{10 - 0}{0.1} = 100 \text{ A/s}$$

Substituting $M = 0.5$ H:

$$\varepsilon = 0.5 \times 100 = 50 \text{ V}$$

Why the other options are wrong: 5 V forgets to divide by the 0.1 s interval; 100 V drops the factor M; 25 V halves the result incorrectly. **Final Answer:** The induced emf in the secondary is 50 V.

Answer: (B) Go Back to Q36

Q37.

Solution

A series LCR circuit is in resonance when the inductive and capacitive reactances are equal, which occurs at the angular frequency:

$$\omega_0 = \frac{1}{\sqrt{LC}}$$

Substituting $L = 2$ H and $C = 8 \times 10^{-6}$ F:

$$LC = 2 \times 8 \times 10^{-6} = 16 \times 10^{-6}$$

$$\sqrt{LC} = \sqrt{16 \times 10^{-6}} = 4 \times 10^{-3} \text{ s}$$

$$\omega_0 = \frac{1}{4 \times 10^{-3}} = 250 \text{ rad/s}$$

Why the other options are wrong: 500 rad/s and 125 rad/s come from mistaking the square root; 2500 rad/s mishandles the powers of ten. At resonance the impedance is minimum and equals R. **Final Answer:** The resonant angular frequency is 250 rad/s.

Answer: (C) Go Back to Q37

Q38.

Solution

By Einstein's photoelectric equation, the maximum kinetic energy of the ejected electrons is the photon energy minus the work function:

$$KE_{\text{max}} = E_{\text{photon}} - \phi$$

The photon energy for $\lambda = 400$ nm, using $hc = 1240$ eV nm:

$$E_{\text{photon}} = \frac{hc}{\lambda} = \frac{1240}{400} = 3.1 \text{ eV}$$

Subtracting the work function $\phi = 2.0$ eV:

$$KE_{\text{max}} = 3.1 - 2.0 = 1.1 \text{ eV}$$

Why the other options are wrong: 3.1 eV is the photon energy alone; 2.0 eV is the work function; 5.1 eV adds instead of subtracting. Only the excess of photon energy over the work function appears as kinetic energy. **Final Answer:** The maximum kinetic energy is 1.1 eV.

Answer: (D) Go Back to Q38

Q39.

Solution

The number of half-lives elapsed is:

$$n = \frac{\text{total time}}{\text{half-life}} = \frac{40}{10} = 4$$

After n half-lives the surviving fraction of nuclei is:

$$\frac{N}{N_0} = \left(\frac{1}{2}\right)^n = \left(\frac{1}{2}\right)^4 = \frac{1}{16}$$

Why the other options are wrong: $\frac{1}{8}$ corresponds to 3 half-lives; $\frac{1}{4}$ to 2; $\frac{1}{32}$ to 5. The number of half-lives in 40 days is exactly 4. **Final Answer:** The fraction remaining is $\dfrac{1}{16}$.

Answer: (A) Go Back to Q39

Q40.

Solution

Read the truth table carefully: the output Y is 1 only when *both* inputs are 0, and 0 for every other input combination.

- This is exactly the behaviour of the OR gate followed by inversion, i.e. $Y = \overline{A + B}$
- A gate whose output is the complement of OR is a **NOR gate**

Checking against the others:

- AND gives $Y = 1$ only when both inputs are 1 – opposite of this table
- NAND gives $Y = 0$ only when both inputs are 1 – does not match
- XOR gives $Y = 1$ when the inputs differ – does not match

Final Answer: The gate is a NOR gate ($Y = \overline{A + B}$).

Answer: (C) Go Back to Q40

Answer Key

Q	Ans	Q	Ans	Q	Ans	Q	Ans	Q	Ans
1	B	2	C	3	A	4	C	5	A
6	D	7	D	8	B	9	A	10	B
11	C	12	D	13	A	14	B	15	D
16	C	17	D	18	B	19	D	20	C
21	B	22	A	23	A	24	C	25	B
26	D	27	D	28	C	29	B	30	A
31	D	32	C	33	B	34	D	35	A
36	B	37	C	38	D	39	A	40	C