



Mechanics — JEE (Advanced) Pattern Sample Test

FREE SAMPLE TEST · PHYSICS · PATTERN OF JEE (ADVANCED) PAPER 1

DURATION	MAXIMUM MARKS	QUESTIONS	NAME / ROLL NO.
60 minutes	60	17 (4 + 3 + 6 + 4)	

GENERAL INSTRUCTIONS

1. This question paper has FOUR sections. All questions are compulsory.
2. Read the marking scheme of each section carefully: wrong answers in Sections 1, 2 and 4 carry negative marks.
3. Take $g = 10 \text{ m/s}^2$ unless stated otherwise. Use of a calculator is not allowed.
4. The answer key and worked solutions are at the end of this booklet. Attempt the paper in 60 minutes before you look at them.

SECTION 1 (Q1–4) — +3 / 0 / –1

1. This section contains FOUR (04) questions.
2. Each question has FOUR options. ONLY ONE of these four options is the correct answer.
3. Full Marks: +3 if ONLY the correct option is chosen; Zero Marks: 0 if none of the options is chosen; Negative Marks: –1 in all other cases.

SECTION 2 (Q5–7) — +4 / partial / –2

1. This section contains THREE (03) questions.
2. Each question has FOUR options. ONE OR MORE THAN ONE of these four option(s) is(are) correct answer(s).
3. Full Marks: +4 ONLY if (all) the correct option(s) is(are) chosen; Partial Marks: +3 if all the four options are correct but ONLY three options are chosen; +2 if three or more options are correct but ONLY two options are chosen, both of which are correct; +1 if two or more options are correct but ONLY one option is chosen and it is a correct option; Zero Marks: 0 if unanswered; Negative Marks: –2 in all other cases.

SECTION 3 (Q8–13) — +4 / 0

1. This section contains SIX (06) questions.
2. The answer to each question is a NON-NEGATIVE INTEGER.
3. Full Marks: +4 ONLY if the correct integer is entered; Zero Marks: 0 in all other cases.

SECTION 4 (Q14–17) — +3 / 0 / –1

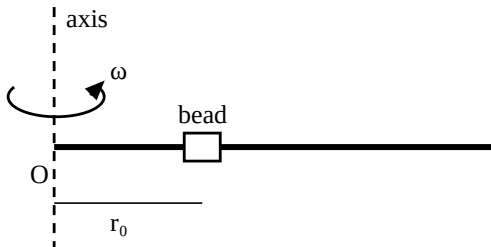
1. This section contains FOUR (04) Matching List Sets.
2. Each set has ONE Multiple Choice Question. Each set has TWO lists: List-I and List-II. List-I has Four entries (P), (Q), (R) and (S) and List-II has Five entries (1), (2), (3), (4) and (5).
3. FOUR options are given in each Multiple Choice Question based on List-I and List-II and ONLY ONE of these four options satisfies the condition asked in the Multiple Choice Question.
4. Full Marks: +3 ONLY if the option corresponding to the correct combination is chosen; Zero Marks: 0 if none of the options is chosen; Negative Marks: –1 in all other cases.

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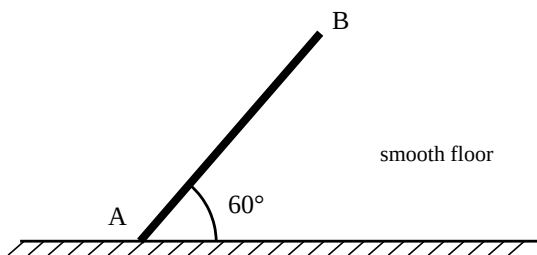
SECTION 1 (Q1–4) · Single correct · +3 / 0 / –1

Each question has FOUR options. ONLY ONE of these four options is the correct answer.

1. A smooth horizontal rod rotates about a fixed vertical axis through its end O with a constant angular speed ω . A small bead threaded on the rod is released from rest relative to the rod at a distance r_0 from O. When the bead is at a distance $2r_0$ from O, its speed relative to the ground is

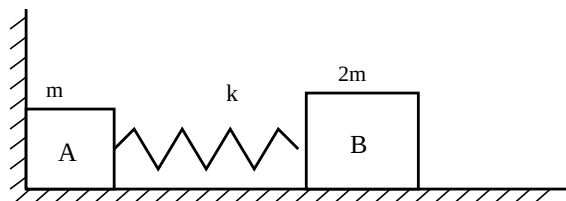


- (A) $2\omega r_0$
(B) $\sqrt{7} \omega r_0$
(C) $\sqrt{3} \omega r_0$
(D) $\sqrt{5} \omega r_0$
2. A uniform rod AB of length L is held with its end A on a smooth horizontal floor, making 60° with the floor, and is released from rest. The speed of the end B just before the rod lies flat on the floor is



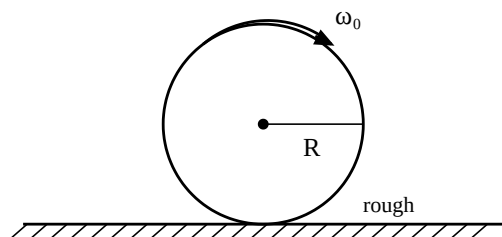
- (A) $\sqrt{3gL}$
(B) $\sqrt{\sqrt{3} gL}$
(C) $\sqrt{3\sqrt{3} gL/8}$
(D) $\sqrt{3\sqrt{3} gL/2}$

3. Blocks A (mass m) and B (mass $2m$) lie on a smooth floor, joined by a light spring of stiffness k . A touches a fixed vertical wall. B is pushed towards the wall, compressing the spring by x_0 , and released. The maximum extension of the spring in the motion that follows is



- (A) $x_0/\sqrt{3}$
- (B) $x_0/\sqrt{2}$
- (C) $x_0/3$
- (D) $x_0\sqrt{2/3}$

4. A uniform disc of radius R , spinning about its own axis with angular speed ω_0 , is gently placed with its axis horizontal and its centre at rest on a rough horizontal floor. When it starts rolling without slipping, the fraction of its initial kinetic energy that remains is

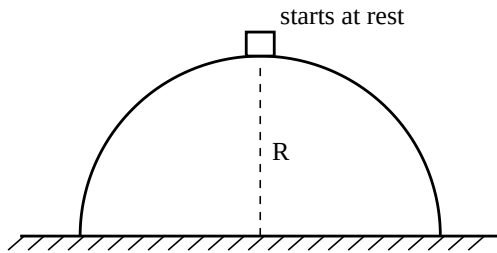


- (A) $1/2$
- (B) $2/3$
- (C) $1/3$
- (D) $1/9$

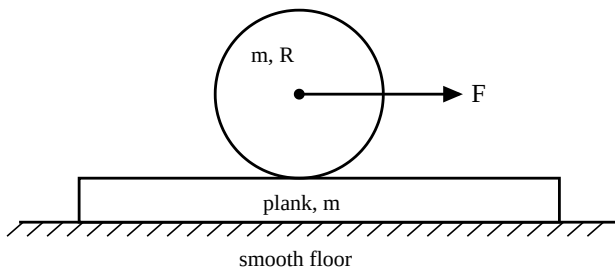
SECTION 2 (Q5–7) · One or more correct · +4 / partial / –2

Each question has FOUR options. ONE OR MORE THAN ONE of these four option(s) is(are) correct answer(s).

5. A small block starts from rest at the top of a smooth fixed hemisphere of radius R and slides down its outer surface. Which of the following is/are correct?

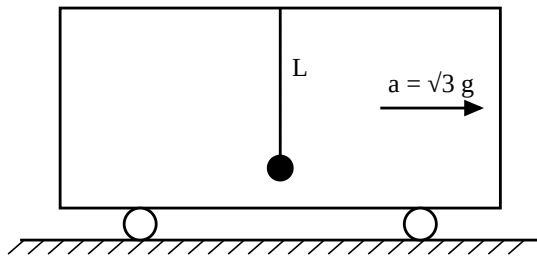


- (A) It leaves the surface at a height $2R/3$ above the centre of the hemisphere.
 - (B) Its speed when it leaves the surface is $\sqrt{(2gR/3)}$.
 - (C) It leaves the surface where the radius to it makes 60° with the vertical.
 - (D) Its tangential acceleration at the moment it leaves the surface is $(\sqrt{5}/3)g$.
6. A solid cylinder of mass m and radius R rests on a plank of mass m , which lies on a smooth horizontal floor. A horizontal force F is applied at the axis of the cylinder, and the cylinder rolls on the plank without slipping. Which of the following is/are correct?



- (A) The acceleration of the plank is $F/(4m)$.
- (B) The friction force on the cylinder has magnitude $F/4$ and acts opposite to F .
- (C) The angular acceleration of the cylinder is $F/(2mR)$.
- (D) The acceleration of the axis of the cylinder is $2F/(3m)$.

7. A simple pendulum (bob of mass m , string of length L) hangs from the roof of a car moving on a level road with a constant acceleration $\sqrt{3}g$. The bob is held at rest, relative to the car, vertically below the point of suspension and then released. Which of the following is/are correct?

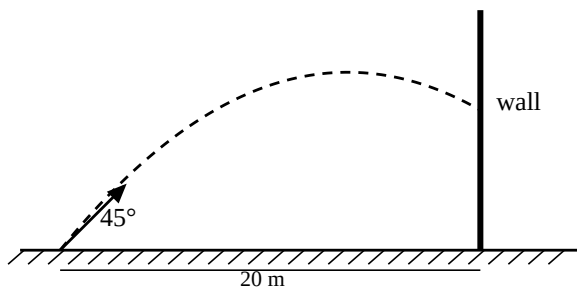


- (A) The equilibrium position of the bob, relative to the car, makes 60° with the vertical.
- (B) The tension in the string as the bob passes the equilibrium position is $2mg$.
- (C) The period of small oscillations about the equilibrium position is $2\pi\sqrt{L/2g}$.
- (D) The string swings up to an angle of 120° with the vertical.

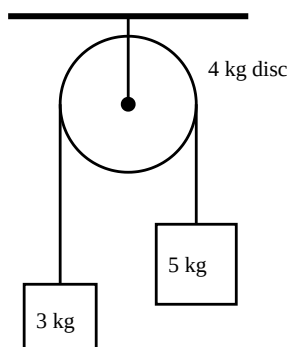
SECTION 3 (Q8–13) · Non-negative integer · +4 / 0

The answer to each question is a NON-NEGATIVE INTEGER.

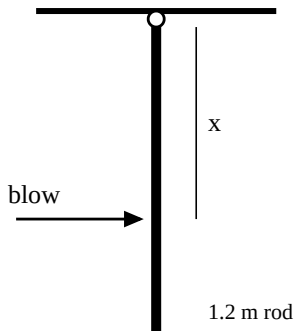
8. A ball is thrown from the ground with a speed of 20 m/s at 45° above the horizontal towards a smooth vertical wall 20 m away. The coefficient of restitution between the ball and the wall is 0.5 . Find the distance, in metres, from the wall of the point where the ball first lands on the ground. (Take $g = 10 \text{ m/s}^2$.)



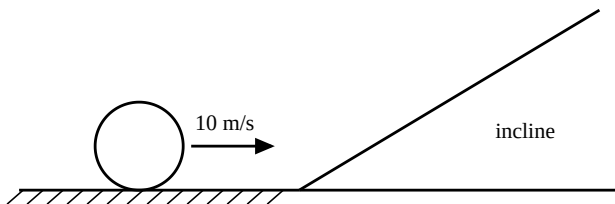
9. Blocks of 3 kg and 5 kg hang from the two ends of a light string that passes over a pulley in the form of a uniform disc of mass 4 kg , mounted on a fixed frictionless horizontal axle. The string does not slip on the pulley. Find the magnitude, in newtons, of the force exerted by the axle on the pulley. (Take $g = 10 \text{ m/s}^2$.)



10. A uniform rod of length 1.2 m hangs vertically from a frictionless hinge at its upper end. It is given a horizontal blow at a distance x below the hinge, and the hinge exerts no horizontal impulse on the rod. Find x in centimetres.



11. A solid sphere rolls without slipping on a horizontal floor at 10 m/s and then moves up a long incline. Let h_1 be the greatest height it reaches if the incline is rough enough for it to keep rolling without slipping, and h_2 the greatest height if the incline is perfectly smooth. Find $h_1 - h_2$ in metres. (Take $g = 10 \text{ m/s}^2$.)



12. A satellite is launched horizontally (tangent to the surface) from the surface of the Earth with speed v_0 , and moves in an elliptical orbit whose farthest point is at a distance $2R$ from the centre of the Earth (R is the radius of the Earth). If $v_0 = \sqrt{(NgR/3)}$, find N . (Ignore air resistance and the rotation of the Earth.)

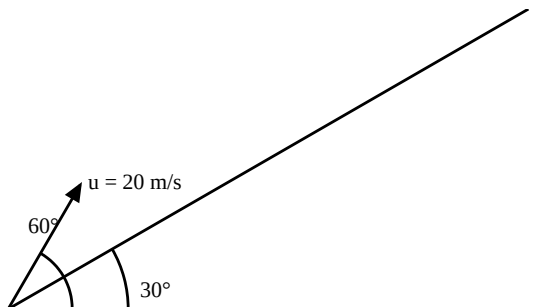
13. A block of mass 1 kg fixed to a spring of stiffness 100 N/m oscillates on a smooth horizontal floor with an amplitude of 10 cm. As it passes through the equilibrium position, a block of mass 3 kg is placed gently on it and the two move together from then on. Find the new amplitude in centimetres.

SECTION 4 (Q14–17) · Matching lists · +3 / 0 / –1

Each set has ONE Multiple Choice Question. Each set has TWO lists: List-I and List-II. List-I has Four entries (P), (Q), (R) and (S) and List-II has Five entries (1), (2), (3), (4) and (5).

14. A particle is projected with speed 20 m/s at 60° above the horizontal from the foot of a fixed incline of angle 30° , in the vertical plane containing the line of greatest slope, and lands on the incline. (Take $g = 10 \text{ m/s}^2$.)

Match each quantity in List-I with its value in List-II.



List-I	List-II
(P) Time of flight	(1) $20/\sqrt{3} \text{ m/s}$
(Q) Range along the incline	(2) $80/3 \text{ m}$
(R) Greatest distance from the incline	(3) $4/\sqrt{3} \text{ s}$
(S) Speed on landing	(4) $40/3 \text{ m}$
	(5) $10/\sqrt{3} \text{ m}$

(A) $P \rightarrow 3, Q \rightarrow 4, R \rightarrow 5, S \rightarrow 1$

(B) $P \rightarrow 1, Q \rightarrow 2, R \rightarrow 5, S \rightarrow 3$

(C) $P \rightarrow 3, Q \rightarrow 2, R \rightarrow 5, S \rightarrow 1$

(D) $P \rightarrow 3, Q \rightarrow 2, R \rightarrow 1, S \rightarrow 5$

15. Four bodies roll without slipping down a rough incline of angle 30° , each starting from rest. (Take $g = 10 \text{ m/s}^2$.) Match each body in List-I with the acceleration of its centre, in m/s^2 , in List-II.

List-I	List-II
(P) Thin ring	(1) 3
(Q) Uniform disc	(2) $25/7$
(R) Solid sphere	(3) 2.5
(S) Thin hollow sphere	(4) 5
	(5) $10/3$

(A) $P \rightarrow 3, Q \rightarrow 5, R \rightarrow 2, S \rightarrow 1$

(B) $P \rightarrow 3, Q \rightarrow 2, R \rightarrow 5, S \rightarrow 1$

(C) $P \rightarrow 4, Q \rightarrow 5, R \rightarrow 2, S \rightarrow 1$

(D) $P \rightarrow 3, Q \rightarrow 5, R \rightarrow 1, S \rightarrow 2$

16. A satellite in a circular orbit around the Earth is moved to another circular orbit of four times the radius. Match each quantity in List-I with the factor by which it changes, in List-II.

List-I	List-II
(P) Orbital speed	(1) 2
(Q) Period of revolution	(2) $1/4$
(R) Kinetic energy	(3) 8
(S) Angular momentum about the Earth's centre	(4) $1/2$
	(5) $1/8$

- (A) $P \rightarrow 4, Q \rightarrow 5, R \rightarrow 2, S \rightarrow 1$
 (B) $P \rightarrow 2, Q \rightarrow 3, R \rightarrow 4, S \rightarrow 1$
 (C) $P \rightarrow 4, Q \rightarrow 3, R \rightarrow 1, S \rightarrow 2$
 (D) $P \rightarrow 4, Q \rightarrow 3, R \rightarrow 2, S \rightarrow 1$

17. A ball A of mass m moving at 6 m/s collides head-on with a ball B of mass $2m$ at rest. Match each quantity in List-I with its value in List-II.

List-I	List-II
(P) Speed of B after the collision, if it is elastic	(1) 4 m/s
(Q) Speed of B after the collision, if the coefficient of restitution is $1/2$	(2) $1/2$
(R) Speed of A after the collision, if it is elastic	(3) 3 m/s
(S) Fraction of the kinetic energy lost, if the coefficient of restitution is $1/2$	(4) 2 m/s
	(5) 1 m/s

- (A) $P \rightarrow 1, Q \rightarrow 3, R \rightarrow 5, S \rightarrow 2$
 (B) $P \rightarrow 1, Q \rightarrow 3, R \rightarrow 4, S \rightarrow 2$
 (C) $P \rightarrow 3, Q \rightarrow 1, R \rightarrow 4, S \rightarrow 2$
 (D) $P \rightarrow 1, Q \rightarrow 4, R \rightarrow 3, S \rightarrow 2$

ANSWER KEY

Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9
B	D	A	C	A, B, D	A, B, C	A, C, D	10	116

Q10	Q11	Q12	Q13	Q14	Q15	Q16	Q17
80	2	4	5	C	A	D	B

WORKED SOLUTIONS

Q1. Answer B. Along the rod (rotating frame) the bead feels only the centrifugal force: $\ddot{r} = \omega^2 r$, so $\dot{r}^2 = \omega^2(r^2 - r_0^2)$ and $\dot{r} = \sqrt{3} \omega r_0$ at $r = 2r_0$. The rod also carries it sideways at $\omega r = 2\omega r_0$. Speed = $\sqrt{(3 + 4)} \omega r_0 = \sqrt{7} \omega r_0$.

Q2. Answer D. No horizontal force acts, so the centre of mass C falls vertically: $y = (L/2) \sin \theta$. Just before the rod is flat ($\theta = 0$), $v_C = (L/2)\omega$, and A, which moves along the floor, is momentarily at rest, so $v_B = L\omega$. Energy: $mg(L/2) \sin 60^\circ = \frac{1}{2}m(L\omega/2)^2 + \frac{1}{2}(mL^2/12)\omega^2 = mL^2\omega^2/6$, so $\omega^2 = 3\sqrt{3} g/(2L)$ and $v_B = \sqrt{(3\sqrt{3} gL/2)}$.

Q3. Answer A. A stays at the wall until the spring regains its natural length; then B has $v_0 = x_0\sqrt{(k/2m)}$ and A leaves the wall. After that, momentum is conserved: $v_{cm} = 2v_0/3$. The energy available for stretching is the kinetic energy relative to the centre of mass, $\frac{1}{2}\mu v_0^2$ with $\mu = 2m/3$: $\frac{1}{2}kx^2 = \frac{1}{2}(2m/3)(kx_0^2/2m)$, so $x = x_0/\sqrt{3}$.

Q4. Answer C. Angular momentum about the contact point is conserved (friction acts there): $\frac{1}{2}mR^2\omega_0 = mvR + \frac{1}{2}mR^2(v/R)$, so $v = \omega_0 R/3$. Initial KE = $\frac{1}{4}mR^2\omega_0^2$; final KE = $\frac{1}{2}mv^2(1 + \frac{1}{2}) = (3/4)m(\omega_0 R/3)^2 = mR^2\omega_0^2/12$. Fraction = $1/3$.

Q5. Answer A, B, D. At angle θ from the vertical: $v^2 = 2gR(1 - \cos \theta)$ and $N = mg \cos \theta - mv^2/R$. $N = 0$ gives $\cos \theta = 2/3$, i.e. a height $2R/3$ above the centre (A true, C false since $\cos 60^\circ = 1/2$). Then $v^2 = 2gR/3$ (B true), and the tangential acceleration is $g \sin \theta = g\sqrt{(1 - 4/9)} = (\sqrt{5}/3)g$ (D true).

Q6. Answer A, B, C. Let friction f on the cylinder act opposite to F . Cylinder: $F - f = ma_1$ and $fR = (\frac{1}{2}mR^2)\alpha$. Plank: $f = ma_2$. No slipping: $a_1 - \alpha R = a_2$. Then $\alpha = 2a_2/R$, $a_1 = 3a_2$, $F = 4ma_2$: $a_2 = F/4m$ (A), $f = F/4$ opposite to F (B), $\alpha = F/(2mR)$ (C), $a_1 = 3F/4m$, not $2F/3m$ (D false).

Q7. Answer A, C, D. In the car frame the effective gravity is $g_{\text{eff}} = \sqrt{(g^2 + 3g^2)} = 2g$, tilted at $\tan^{-1}\sqrt{3} = 60^\circ$ to the vertical (A). At equilibrium $v^2 = 2g_{\text{eff}} L(1 - \cos 60^\circ) = 2gL$, so tension = $m \cdot g_{\text{eff}} + mv^2/L = 4mg$, not $2mg$ (B false). Small oscillations: $T = 2\pi\sqrt{(L/g_{\text{eff}})} = 2\pi\sqrt{(L/2g)}$ (C). Released 60° from equilibrium, the bob swings 60° beyond it, to 120° from the vertical (D).

Q8. Answer 10. Time of flight $2u \sin 45^\circ/g = 2\sqrt{2} s$; horizontal speed $10\sqrt{2} \text{ m/s}$. It reaches the wall after $20/(10\sqrt{2}) = \sqrt{2} s$ (at a height of 10 m), so $\sqrt{2} s$ of flight remain. The wall reverses and halves the horizontal speed to $5\sqrt{2} \text{ m/s}$; the vertical motion is unchanged. Distance from the wall = $5\sqrt{2} \times \sqrt{2} = 10 \text{ m}$.

Q9. Answer 116. $a = (5 - 3)g/(5 + 3 + \frac{1}{2} \cdot 4) = 2 \text{ m/s}^2$. Tensions: $T_1 = 3(10 + 2) = 36 \text{ N}$ and $T_2 = 5(10 - 2) = 40 \text{ N}$. The pulley is in equilibrium as a whole: axle force = $T_1 + T_2 + Mg = 36 + 40 + 40 = 116 \text{ N}$.

Q10. Answer 80. With no impulse from the hinge: $J = m v_{cm} = m \omega L/2$, and about the hinge $Jx = (mL^2/3) \omega$. Dividing: $x = (L^2/3)/(L/2) = 2L/3 = 0.8 \text{ m} = 80 \text{ cm}$.

Q11. Answer 2. Rough incline: all the kinetic energy, $\frac{1}{2}mv^2(1 + 2/5) = 0.7mv^2$, becomes potential energy: $h_1 = 0.7v^2/g = 7 \text{ m}$. Smooth incline: friction is absent, so the spin is unchanged and only $\frac{1}{2}mv^2$ is converted: $h_2 = v^2/2g = 5 \text{ m}$. $h_1 - h_2 = 2 \text{ m}$.

Q12. Answer 4. Angular momentum: $v_0 R = v \cdot 2R$, so $v = v_0/2$ at the far point. Energy, with $GM = gR^2$: $\frac{1}{2}v_0^2 - gR = \frac{1}{2}(v_0/2)^2 - gR/2$, so $(3/8)v_0^2 = gR/2$ and $v_0^2 = 4gR/3$. $N = 4$.

Q13. Answer 5. Momentum is conserved: $v' = v/4$. The angular frequency falls from $\sqrt{(k/1)}$ to $\sqrt{(k/4)}$, i.e. to half. New amplitude = $v'/\omega' = (v/4)/(\omega/2) = A/2 = 5 \text{ cm}$.

Q14. Answer C. Along and across the incline: $u_{\parallel} = 20 \cos 30^\circ = 10\sqrt{3}$, $u_{\perp} = 20 \sin 30^\circ = 10$, $g_{\parallel} = 5$, $g_{\perp} = 5\sqrt{3}$. Time = $2u_{\perp}/g_{\perp} = 4/\sqrt{3}$ s (P → 3). Range = $u_{\parallel}T - \frac{1}{2}g_{\parallel}T^2 = 40 - 40/3 = 80/3$ m (Q → 2). Greatest distance = $u_{\perp}^2/2g_{\perp} = 10/\sqrt{3}$ m (R → 5). On landing, $v_x = 10$ and $v_y = 10\sqrt{3} - 40/\sqrt{3} = -10/\sqrt{3}$, so speed = $\sqrt{(100 + 100/3)} = 20/\sqrt{3}$ m/s (S → 1).

Q15. Answer A. $a = g \sin \theta / (1 + k^2/r^2)$ with $g \sin \theta = 5$ m/s². Ring: $k^2/r^2 = 1$, so 2.5 (P → 3). Disc: $\frac{1}{2}$, so $10/3$ (Q → 5). Solid sphere: $2/5$, so $25/7$ (R → 2). Hollow sphere: $2/3$, so 3 (S → 1).

Q16. Answer D. $v = \sqrt{GM/r}$: $\times 1/2$ (P → 4). $T \propto r^{3/2}$: $\times 8$ (Q → 3). $KE \propto v^2$: $\times 1/4$ (R → 2). $L = mvr$: $\times (1/2)(4) = 2$ (S → 1).

Q17. Answer B. $v_B = m_1 u(1 + e)/(m_1 + m_2) = 2(1 + e)$: 4 m/s if elastic (P → 1), 3 m/s if $e = 1/2$ (Q → 3). $v_A = (m_1 - e m_2)u/(m_1 + m_2) = 2(1 - 2e) = -2$ m/s if elastic: speed 2 m/s, rebounding (R → 4). Fraction lost = $(1 - e^2) m_2/(m_1 + m_2) = (3/4)(2/3) = 1/2$ (S → 2).

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