Engineering Mechanics Test 1

Number of Questions: 25 **Time: 60 min.**

Directions for questions 1 to 25: Select the correct alternative from the given choices.

1. The value of coefficient of restitution is one for
(A) perfectly elastic collision
(B) perfectly inelastic collision
(C) neither plastic nor elastic collision
(D) None of these

2. The radius of gyrations for a sphere and cylinder of radius 'R' are respectively.
(A) 0.6324 R and 0.707 R
(B) 0.6234 R and 0.77 R
(C) 0.6432 R and 1.414 R
(D) 0.6324 R and 1.414 R

3. Which of the following relation represents motion under variable acceleration?
(A) $v = a\dfrac{dv}{ds}$ (B) $a = v\dfrac{dv}{ds}$
(C) $v = \dfrac{1}{a}\dfrac{dv}{ds}$ (D) None of these

4. If a projectile motion with usual notations is expressed is
$y = xP - \dfrac{gx^2}{2u^2Q^2}$ (α = Angle of projection), then 'P' and 'Q' are
(A) $\tan\alpha$ and $\cos^2\alpha$
(B) $\tan\alpha$ and $\cos\alpha$
(C) $\tan\alpha$ and $\sec\alpha$
(D) $\tan\alpha$ and $\sec^2\alpha$

5. A mechanism has 5 numbers of joints and 6 members. The number of additional members needed to make it a perfect frame will be
(A) 4 (B) 3
(C) 2 (D) 1

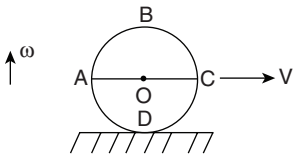
6. The rate of change of velocity and the rate of change of momentum of a moving body respectively are
(A) acceleration and impulse
(B) acceleration and force
(C) displacement and force
(D) force and displacement

7. In the equation of virtual work, which of the following force is neglected?
(A) reaction at any smooth surface with which the body is in contact
(B) reaction of rough surface of a body which rolls on it without shipping
(C) reaction at a point on an axis fixed in space, around which a body is constrained to turn.
(D) All of these

8. Two metallic balls having potential energy in the ratio 3 : 5 are made to slide down a frictionless inclined plane with zero position. What will be the ratio of their kinetic energy when they reach at bottom of inclined plane?
(A) 5 : 3 (B) 3 : 5
(C) 1 : 1 (D) 2 : 3

9. Two forces form a couple only when
(A) magnitude is same have parallel lines of action and same sense
(B) magnitude is different, have parallel lines of action but same sense
(C) magnitude is same have non parallel lines of action but same sense
(D) magnitude is same and have parallel lines of action and opposite sense

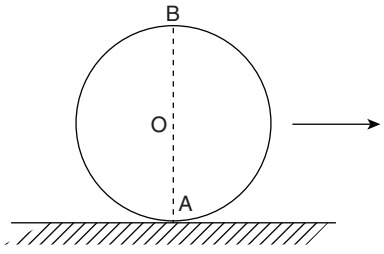
10. A wheel is rolling on a straight road as shown below. For this wheel the acceleration of the center 'O' and its instantaneous center are



(A) $\omega^2 r$ and O (B) $\omega^2 r$ and D
(C) V^2/r and D (D) zero and O

11. A particle moving from rest moves in a straight line. Its acceleration is given by the equation
$a = 10 - 0.006\,S^2$
Velocity of the particle when it has travelled 40 m is
(A) 19.16 m/s (B) 23.32 m/s
(C) 26.84 m/s (D) 30.14 m/s

12.



A wheel of radius 1 m rolls on a flat horizontal ground without slipping as shown in figure. Resultant velocity at point B is 1 m/s. Angular velocity of the wheel about its centre in rad/s is
(A) $\dfrac{1}{\sqrt{2}}$ (B) $\sqrt{2}$
(C) 1 (D) $\dfrac{1}{2}$

13. Acceleration of a particle is given by
$a = t^3 - 3t^2 + 5$
Where t = time in seconds and a = acceleration in m/s^2. Velocity of particle when $t = 2$ sec is 8 m/s. Velocity of the particle when $t = 4$ sec is
(A) 22 m/s (B) 25 m/s
(C) 28 m/s (D) 32 m/s

Statement for Linked Data Questions 14 and 15:

14. A body of mass 5 kg falls from a height of 50 m and penetrates into the ground by 90 cm. Average resistance to penetration is
(A) 2668 N (B) 2774 N
(C) 2814 N (D) 2892 N

15. Time taken for penetration is
(A) 19.7 s (B) 12.7 s
(C) 17.4 s (D) 15.4 s

16. Angular displacement of a body is given by
$\theta = 6t^2 + 3t + 10$
Where t is in seconds. Angular velocity and angular acceleration of the body when
$t = 10$ seconds are
(A) 123 rad/s, 12 rad /s^2
(B) 135 rad /s, 14 rad /s^2
(C) 142 rad/s, 16 rad/s^2
(D) 153 rad/s, 18 rad/s^2

Statement for Linked Answer Questions 17 and 18:
A ball can be projected with a maximum velocity of 50 m/s. On an inclined plane, the maximum range obtained on projecting the ball is 190 m.

17. Inclination of the plane to the horizontal is
(A) 20° (B) 18°
(C) 16° (D) 14°

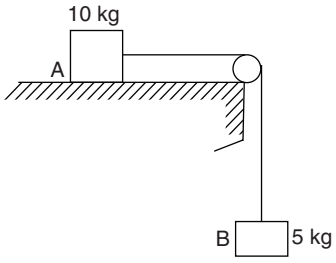
18. The projection angle from horizontal is
(A) 68° (B) 65°
(C) 60° (D) 55°

Statement for Linked Answer Questions 19 and 20:
A projectile is fixed at an angle of 30° in a horizontal level ground with a velocity of 50 m/s.

19. Time taken by the projectile to reach the ground after firing is
(A) 9.8 s (B) 8.6 s
(C) 7.2 s (D) 5.1 s

20. Horizontal range of the projectile is
(A) 220.7 m (B) 208.5 m
(C) 192.6 m (D) 186.1 m

Common Data for Questions 21 to 23:



Block A of mass 10 kg placed on a rough horizontal plane is connected to another block B of mass 5 kg by a string passing over a pulley as shown in figure. Coefficient of friction between block A and horizontal plane is 0.25. If the system is released from rest and block B is falling,

21. Tension on the string is
(A) 28.43 N (B) 33.41 N
(C) 37.62 N (D) 40.88 N

22. Acceleration of block B is
(A) 1.268 m/s^2 (B) 1.635 m/s^2
(C) 1.824 m/s^2 (D) 2.116 m/s^2

23. Velocity acquired by block B when it falls through a vertical distance of 1 m, is
(A) 1.24 m/s (B) 1.56 m/s
(C) 1.81 m/s (D) 2.35 m/s

Common Data for Questions 24 and 25:
Angular displacement of a particle, moving in a circular path of 150 m radius is given by
$\theta = 18t + 3t^2 - 2t^3$

24. Angular acceleration at 2 seconds from start is
(A) 15 rad/s^2 (B) 18 ard/s^2
(C) –15 ard/s^2 (D) –18 rad/s^2

25. Maximum angular velocity is
(A) 16.4 rad/s (B) 19.5 rad/s
(C) 22.3 rad/s (D) 25.4 rad/s

Answer Keys

1. A	**2.** A	**3.** B	**4.** B	**5.** D	**6.** B	**7.** D	**8.** B	**9.** D	**10.** D
11. B	**12.** D	**13.** A	**14.** B	**15.** C	**16.** A	**17.** A	**18.** D	**19.** D	**20.** A
21. D	**22.** B	**23.** C	**24.** D	**25.** B					

Hints and Explanations

2. Radius of gyration = $\sqrt{\frac{I_{min}}{m}}$

I = mass moment of inertia about the central axis
R = radius of sphere or cylinder.

For sphere: $I = \frac{2}{5} mR^2$ or $mK^2 = \frac{2}{5} mR^2$

k = radius of gyration

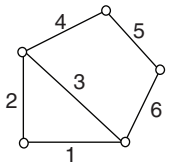
$\therefore \quad k = \sqrt{\frac{2}{5}} R = 0.6324R$

For cylinder:

$I = \frac{mR^2}{2}$ or $mk^2 = \frac{mR^2}{2}$

$\therefore \quad k = R = 0.707R.$ Choice (A)

5. Kutzbach equation
$F = 3(\ell - 1) - 2j - h$
F = degree of freedom
ℓ = number of links or member
J = number of lower pair
H = number of higher pair
When 5 joints and 6 members are there



$\ell = 6$
$J = 7$
$\therefore \quad F = 1$(kinematic chain)
For perfect frame, $F = 0$
$\therefore$ When 5 joints and 7 members then
$\ell = 7$
$J = 9$
$\therefore \quad F = 0$ (perfect frame)
Number of additional member = 1. Choice (D)

8. Since plane is frictionless, so KE at ground will be equal to $P.E$ at top.

$m_1 gh = \frac{1}{2} m_1 v_1^2$ and $m_2 gh = \frac{1}{2} m_2 v_2^2$

$\frac{KE_1}{KE_2} = \frac{m_1 gh}{m_2 gh} = \frac{PE_1}{PE_2} = \frac{3}{5}$ Choice (B)

11. $a = \frac{dv}{dt} = \frac{dv}{dS} \cdot \frac{dS}{dt} = v \cdot \frac{dv}{dS}$

$\therefore \quad v \frac{dv}{dS} = 10 - 0.006S^2$

$vdv = (10 - 0.006S^2)\, dS$

Integrating,

$\frac{v^2}{2} = 10S - \frac{0.006S^3}{3} + C$

When $S = 0$, $v = 0$
$\therefore \quad C = 0$
$\therefore \quad \frac{v^2}{2} = 10S \;\; 0.002S^3$

When $S = 40$ m

$\frac{v^2}{2} = 10 \times 40 - 0.002 \times (40)^3$

$v = 23.32$ m/s. Choice (B)

12. Resultant velocity at B
$R = 2\, v = 2\, \omega\, r$
$\therefore \quad 1 = 2\, \omega \times 1$
$\omega = \frac{1}{2}$ radian. Choice (D)

13. $a = \frac{dv}{dt} = t^3 - 3t^2 + 5$

$dv = (t^3 - 3t^2 + 5)\, dt$
Integrating,
$v = \int (t^3 - 3t^2 + 5)\, dt$

$= \frac{t^4}{4} - t^3 + 5t + C$

when $t = 2$, $v = 8$

$\therefore \quad 8 = \frac{2^4}{4} - 2^3 + 5 \times 2 + C$, $C = 2$

$\therefore \quad v = \frac{t^4}{4} - t^3 + 5t + 2$

When $t = 4$

$v = \frac{4^4}{4} - 4^3 + 5 \times 4 + 2 = 22$ m/s. Choice (A)

14. $m = 5$ kg, h = 50 m
$x = 90$ cm $= 0.9$ m
$v_1 = \sqrt{2gh} = 4.43 \sqrt{h} = 4.43 \sqrt{50} = 31.32$ m/s
$v_2 = 0$
Let R be the average resistance of penetration

$\frac{1}{2} m(v_2^2 - v_1^2) = (mg - R)\, x$

$\frac{1}{2} \times 5(0 - 31.32^2) = (5 \times 9.81 - R)\, 0.9 - 2724.84$

$= 49.05 - R$

$R = 2773.89$ N. Choice (B)

15. Applying impulse momentum equation,
$F \times t = m(v_2 - v_1)$
$F = mg - R = 49.05 - 2773.89 = -2724.84$ N

$\therefore \quad -2724.84 \times t = 5(0 - 31.32)$

$t = 17.4$ sec. Choice (C)

16. $\theta = 6t^2 + 3t + 10$

Angular velocity

$$\omega = \frac{d\theta}{dt} = 12t + 3$$

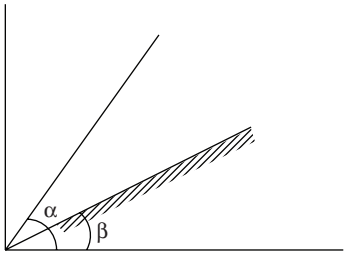
when $t = 10$

$\omega = 12 \times 10 + 3 = 123$ rad/s

Angular acceleration

$$\alpha = \frac{d\omega}{dt} = 12 \text{ rad/s}^2.$$ Choice (A)

17.



$$R_{max} = \frac{u^2}{g(1+\sin\beta)}$$

$$190 = \frac{50^2}{9.81(1+\sin\beta)}$$

$\sin\beta = 0.3413$

$\beta = 19.95°$ or $20°$. Choice (A)

18. $\beta = 19.95° = 0.3482$ radian

$$\frac{1}{2}\left(\frac{\pi}{2} - \beta\right) = \alpha - \beta$$

$$\frac{1}{2}\left(\frac{\pi}{2} - 0.3482\right) = \alpha - 0.3482$$

$\alpha = 0.9595$ radian $= 54.98$ or $55°$. Choice (D)

19. Time taken is given by

$$t = \frac{2u\sin\alpha}{g} = \frac{2 \times 50 \times \sin 30}{9.81}$$

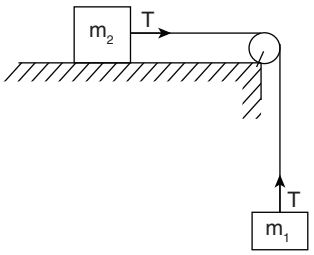
$= 5.097$ sec or 5.1 sec . Choice (D)

20. Horizontal range

= Horizontal velocity × time of flight = ($u \cos\alpha$) × t

$= 50 \cos 30 \times 5.097 = 220.7$ m. Choice (A)

21. Let mass of block B be m_1 and block A be m_2



$m_1 g - T = m_1 a$

$T - \mu m_2 g = m_2 a$

$$\therefore \quad a = g\frac{(m_1 - \mu m_2)}{(m_1 + m_2)}$$

$$T = \frac{m_1 m_2 g(1+\mu)}{m_1 + m_2}$$

$$T = \frac{5 \times 10 \times 9.81(1+0.25)}{5+10} = 40.88 \text{ N.}$$ Choice (D)

22. $$a = \frac{g(m_1 - \mu m_2)}{m_1 + m_2}$$

$$a = \frac{9.81(5 - 0.25 \times 10)}{5+10} = 1.635 \text{ m/s}^2.$$ Choice (B)

23. $v^2 = u^2 + 2as = 0 + 2 \times 1.635 \times 1$

$v = 1.81$ m/s. Choice (C)

24. $\theta = 18t + 3t^2 - 2t^3$

Angular velocity

$$\omega = \frac{d\theta}{dt} = 18 + 6t - 6t^2$$

Angular acceleration

$$\alpha = \frac{d\omega}{dt} = \frac{d^2\theta}{dt^2} = 6 - 12t$$

When $t = 2$

$\alpha = 6 - 12 \times 2 = -18$ rad/s^2. Choice (D)

25. Angular velocity is maximum when

$$\frac{d\omega}{dt} = 0$$

i.e., $6 - 12t = 0$ or $t = 0.5$ sec

Maximum angular velocity

$= 18 + 6 \times 0.5 - 6 \times (0.5)^2 = 19.5$ rad/s. Choice (B)