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CIVIL ENGINEERING

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UNIT-1  ENGINEERING MECHANICS

SYLLABUS
System of forces, free-body diagrams, equilibrium equations; Internal forces in structures; Friction and its applications; Kinematics of point mass and rigid body; Centre of mass; Euler’s equations of motion; Impulse-momentum; Energy methods; Principles of virtual work.

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1– Mark

1. A simple mass-spring oscillatory system consists of a mass \( m \), suspended from a spring of stiffness \( k \). Considering \( z \) as the displacement of the system at any time \( t \), the equation of motion for the free vibration of the system is \( m \ddot{z} + kz = 0 \). The natural frequency of the system is

(a) \( \sqrt{\frac{k}{m}} \)  
(b) \( \sqrt{\frac{m}{k}} \)  
(c) \( \frac{k}{m} \)  
(d) \( \frac{m}{k} \)

[GA\-TE-2019 SHIFT-I]

2. An assembly made of a rigid arm A-B-C at end A and supported by an elastic rope C-D at end C is shown in the figure. The members may be assumed to be weightless and the lengths of the respective members are as shown in the figure.

Under the action of a concentrated load \( P \) at C as shown, the magnitude of tension developed in the rope is

(a) \( \frac{3P}{\sqrt{2}} \)  
(b) \( \frac{P}{\sqrt{2}} \)  
(c) \( \frac{3P}{8} \)  
(d) \( \sqrt{2P} \)

[GA\-TE-2016 SHIFT-II]

2– Marks

3. A cylinder of radius 250 mm and weight, \( W = 10 \) kN is rolled up an obstacle of height 50 mm by applying a horizontal force \( P \) at its centre as shown in the figure.

All interfaces are assumed frictionless. The minimum value of \( P \) is

(a) 4.5 kN  
(b) 5.0 kN  
(c) 6.0 kN  
(d) 7.5 kN

[GA\-TE-2018 SHIFT-I]

4. Two rigid bodies of mass 5 kg and 4 kg are at rest on a frictionless surface until acted upon by a force of 36 N as shown in the figure. The contact force generated between the two bodies is

(a) 4.0 N  
(b) 7.2 N  
(c) 9.0 N  
(d) 16.0 N

[GA\-TE-2018 SHIFT-II]

5. A particle of mass 2 kg is travelling at a velocity of 1.5 m/s. A force \( f(t) = 3t^2 \) (in N) is applied to it in the direction of motion for a duration of 2 seconds. Where \( t \) denotes time in seconds. The velocity (in m/s up to one decimal place) of the particle immediately after the removal of the force is ______.

[GA\-TE-2017 SHIFT-I]
### EXPLANATIONS

#### 1– Mark

1. (a) For simple harmonic motion

\[ m\ddot{z} + kz = 0 \]
\[ \ddot{z} + \frac{k}{m} z = 0 \]

Standard equation is

\[ \frac{d^2x}{dt^2} + \omega^2 x = 0 \]

\[ \Rightarrow \omega^2 = \frac{k}{m} \]
\[ \Rightarrow \omega = \sqrt{\frac{k}{m}} \]

2. (b) Taking moment about A

\[ PL = \frac{T}{\sqrt{2}} L + \frac{T}{\sqrt{2}} L \Rightarrow \sqrt{2} T = P \]
\[ \Rightarrow T = \frac{P}{\sqrt{2}} \]

#### 2– Marks

3. (d) For rolling, the normal reaction should be zero when the cylinder just starts to roll.

\[ \Sigma M_D = 0 \]

\[ W = 10 \text{ kN} \]

4. (d) Net force = Net mass × acceleration

\[ \Rightarrow 36 = 9 \times a \]
\[ \Rightarrow a = 4 \text{ m/s}^2 \]

Now, considering 5 kg weight only

force on 5 kg = 5 × 4 N = 20 N

\[ 36N - F = 20N \]
\[ \Rightarrow F = 16N \]

5. (5.5 m/s)

\[ f(t) = 3t^2 \]
\[ ma = 3t^2 \]
\[ m \frac{dv}{dt} = 3t^2 \]
\[ 2 \int_{1.5}^{v} dv = \int_{0}^{2} 3t^2 \, dt \]
\[ 2(v - 1.5) = 8 \]
\[ v = 5.5 \text{ m/s} \]
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