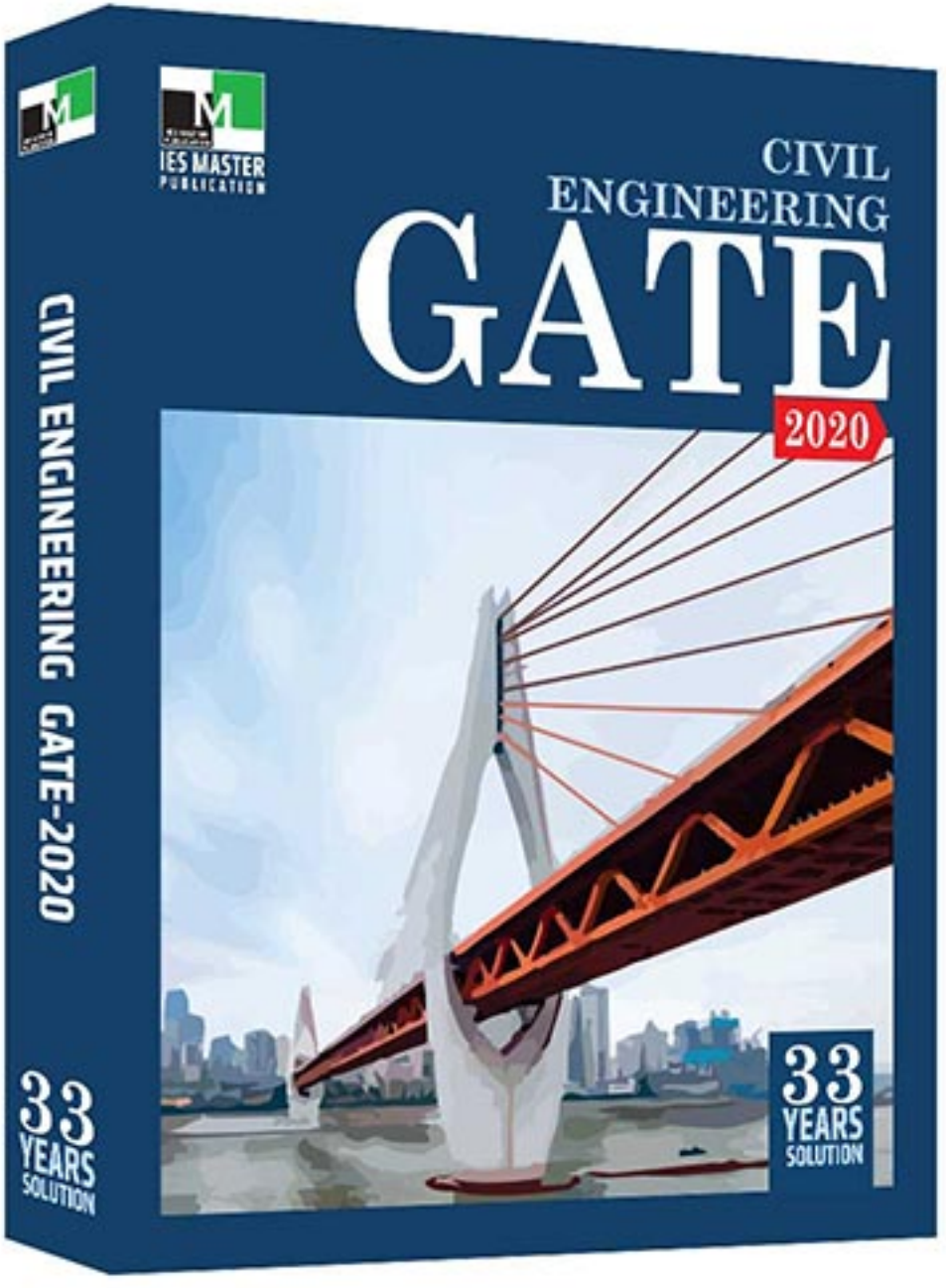
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# PREFACE

The Graduate Aptitude Test in Engineering (GATE) is an All-India examination administered and conducted in eight zones across the country by the GATE Committee comprising of Faculty members from IISc, Bangalore and other seven IITs on behalf of the National Coordinating Board, Department of Education, Ministry of Human Resources Development.

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Every care has been taken to bring an error-free book. However, comments, suggestions, and feedback for improvement in the future editions are most welcome.

**IES Master Publication**
**New Delhi**

# CONTENT

# 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.

## CONTENTS

# 1 ENGINEERING MECHANICS

## 1– Mark

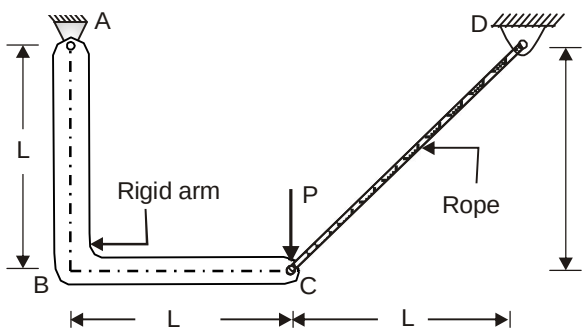
**1.** A simple mass-spring oscillatory system consists of a mass *m*, suspended from a spring of stiffness *k*. Considering *z* as the displacement of the system at any time *t*, the equation of motion for the free vibration of the system is $m\ddot{z} + kz = 0$. The natural frequency of the system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

(a) $\sqrt{\frac{k}{m}}$ (b) $\sqrt{\frac{m}{k}}$

(c) $\frac{k}{m}$ (d) $\frac{m}{k}$

***[GATE-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

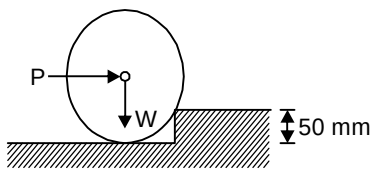
(a) $\frac{3P}{\sqrt{2}}$ (b) $\frac{P}{\sqrt{2}}$

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

***[GATE-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.



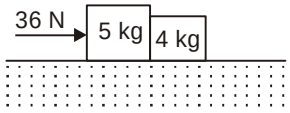

All interfaces are assumed frictionless. The minimum value of P is

(a) 4.5 kN (b) 5.0 kN

(c) 6.0 kN (d) 7.5 kN

***[GATE–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

***[GATE–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 _____.

***[GATE-2017 SHIFT-I]***

## ANSWER KEY

| 1 Mark : – | –: 2 Marks : – | |
|---|---|---|
| **1.** (a) | **3.** (d) | **5.** (5.5 m/s) |
| **2.** (b) | **4.** (d) | |

## EXPLANATIONS

### 1– Mark

**1.** (a) For simple harmonic motion

$$m\ddot{z} + kz = 0$$

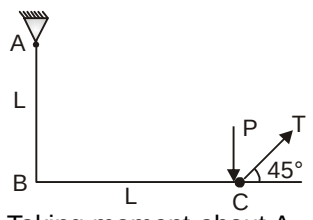
$$\ddot{z} + \frac{k}{m}z = 0$$

Standard equation is $\frac{d^2x}{dt^2} + w^2x = 0$

$$\Rightarrow \quad w^2 = \frac{k}{m}$$

$$\Rightarrow \quad w = \sqrt{\frac{k}{m}}$$

**2.** (b) $\frac{P}{\sqrt{2}}$



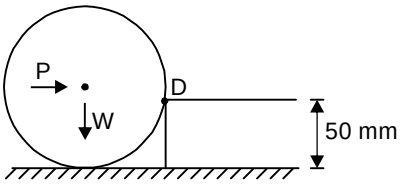

Taking moment about A

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

$$\Rightarrow \quad \boxed{T = \frac{P}{\sqrt{2}}}$$

### 2– Marks

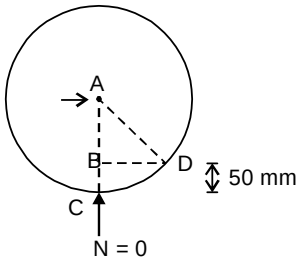
**3.** (d)




W = 10 kN

$$\Sigma M_D = 0$$

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



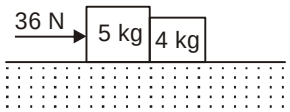

$$BD = \sqrt{AD^2 - AB^2} = \sqrt{(250)^2 - (200)^2}$$

$$= BD = 150 \text{ mm}$$

$$P \times 200 - W \times 150 = 0$$

$$P = \frac{10 \times 150}{200} = 7.5 \text{ kN}$$

**4.** (d)



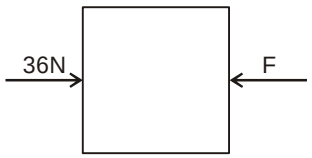

Net force = Net mass × acceleration

$\Rightarrow$ 36 = 9 × a

$\Rightarrow$ a = 4 $ms^{-2}$

Now, considering 5 kg weight only

force on 5 kg = 5 × 4 N = 20 N




$\Rightarrow$ 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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