CBCS SCHEME

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First Semester B.E./B.Tech. Degree Examination, Dec.2025/Jan.2026
Physics for Sustainable Structural Systems

Time: 3 hrs.   Max. Marks: 100

Note: 1. Answer any FIVE full questions, choosing ONE full question from each module.
2. M : Marks , L: Bloom's level , C: Course outcomes.
3. VTU formula handbook is permitted.

		Module – 1	M	L	C
Q.1	a.	Obtain the expression for effective spring constant and Time period for two springs connected in series and parallel.	08	L2	CO1
	b.	Derive an expression for amplitude and phase for a body executing forced oscillations.	08	L2	CO1
	c.	Calculate the maximum amplitude of vibration of a system whose natural frequency is 850 HZ when it oscillates in a resistive medium for which the value of damping/unit mass is 0.008 rad/sec under the action of an external periodic force/unit mass of amplitude 7 N/kg with tunable frequency.	04	L3	CO1
		OR			
Q.2	a.	Define damped oscillation. Explain the various forces acting on the system and write the differential equation of motion. Assuming the solution for displacement, discus the three different cases of damping.	09	L2	CO1
	b.	What are the different types of Spring? Mention its applications.	06	L2	CO1
	c.	A car has a spring system that supports the in-built mass 1000kg.when a person with a weight 980N sits at the center of gravity the spring system sinks by 2.8cm.when the car hits a bump, it starts oscillating vertically. Find the period and frequency of oscillation.	05	L3	CO1
		Module – 2			
Q.3	a.	Define ground motion and list its key parameters? Explain the structural response and soil-structure interaction.	08	L2	CO2
	b.	Enumerate the causes and adverse effects of tsunami waves.	08	L2	CO2
	c.	The intensity of one earthquake is 100 times the intensity of the other. If the magnitude of the first earthquake is 8.9 estimate the magnitude of the other.	04	L3	CO2
		OR			
Q.4	a.	Mention the types of waves. Explain wave propagation in beams, rods, and slabs.	08	L2	CO2
	b.	Discuss the Engineering structures to withstand earthquakes and Tsunami waves.	08	L2	CO2

|					
	c.	The earthquake in city A registered 8.3 on the Richter scale. In the same year, another earthquake was recorded in city B that was four times stronger. What was the magnitude of the earthquake in city B?	04	L3	CO2
		Module – 3			
Q.5	a.	Mention the conditions for good acoustics.	06	L2	CO3
	b.	Define and explain Lambert's cosine law and Inverse Square Law.	09	L2	CO3
	c.	The volume of room is 1500m^3. The wall area of the room is 260m^2, the floor area is 140m^2 and the ceiling area is 140 m^2.The average sound absorption coefficient for wall is 0.03, for the ceiling is 0.8 and for the floor is 0.06, Calculate the average absorption coefficient and the reverberation time.	05	L3	CO3
		OR			
Q.6	a.	Elucidate the impact of noise in multi –storied buildings and explain the noise-control measures.	08	L2	CO3
	b.	Define photometry and explain any three photometric quantities.	08	L2	CO3
	c.	For an empty assembly hall of size 20 X 15 X 10 cubic meter with absorption coefficient 0.106.Calculate reverberation time.	04	L3	CO3
		Module – 4			
Q.7	a.	Describe the principle and process involved in Liquid Penetration Test.	08	L2	CO4
	b.	Discuss the methods of producing ultrasound. Describe the role of probes used in ultrasonics and mention the types of Probes.	08	L2	CO4
	c.	Find the depth of a submarine, if an ultrasonic pulse reflected from the submarine is received 0.33s after sending out the ultrasonic waves. Given the sound velocity in sea water is 1440 m/s.	04	L3	CO4
		OR			
Q.8	a.	Describe the eddy current inspection probes and display methods in eddy current testing.	08	L2	CO4
	b.	Discuss the shadow formation and distortion in radiography.	08	L2	CO4
	c.	Speed of sound in a steel block is 5900 m/s. The observed front-wall echo is at 2μs and back wall echo at 26μs. Find the thickness of the specimen.	04	L3	CO4
		Module – 5			
Q.9	a.	Explain the types of smart materials.	08	L2	CO5
	b.	Deduce the classification of sensors? Explain the working of temperature sensors and mention its applications.	08	L2	CO5

	c.	A tensile specimen test uses a strain gauge with a gauge factor of 2.0 and an initial resistance of 120Ω. The measured strain is $3000\mu\varepsilon$. Calculate the change in resistance of the strain gauge.	04	L3	CO5
OR					
Q.10	a.	Explain shape memory alloys. Describe their phase transformation behavior and list their applications.	08	L2	CO5
	b.	Describe the concept of structural health monitoring.	08	L2	CO5
	c.	A piezoelectric disk has a charge coefficient $d = 200 \times 10^{-12} CN^{-1}$ under an applied compressive force $F = 50.0N$. If the disk is connected to an input stage with an effective capacitance $C = 50.0$ pF, compute the open-circuit voltage V.	04	L3	CO5

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Physics for Sustainable Structural Systems 1BPHYC102,

Q1(a) Obtain the expression for effective spring constant & Time period for two springs connected in series & parallel — (8M).

Soln: Springs in series
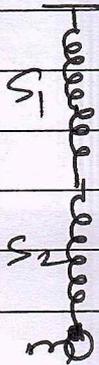
In a series connection, two springs with spring constants k_1 & k_2 are connected in series (end-to-end), when a force F is applied to a mass 'm' attached to the system

① The force acting on both springs is the same. (F)

② The total displacement (x) is the sum of the individual displacements of each spring (x_1 & x_2).

Total displacement $x = x_1 + x_2$

From Hooke's law, $(F = -kx)$

we know $x = \dfrac{F}{k}$

substituting for each component

$$\frac{F}{k_s} = \frac{F}{k_1} + \frac{F}{k_2}$$

Dividing by F

$$\frac{1}{k_s} = \frac{1}{k_1} + \frac{1}{k_2}$$

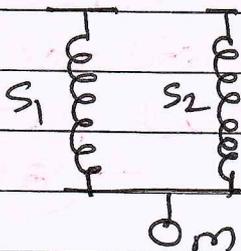$$k_s = \frac{k_1 k_2}{k_1 + k_2}$$

Time period: $T = 2\pi \sqrt{\dfrac{m}{k_s}}$

Substituting for k_s

$$T = 2\pi \sqrt{\frac{m(k_1 + k_2)}{k_1 k_2}}$$

Springs in Parallel

In parallel connection, the springs are attached side by side to the same mass, when the mass 'm' is displaced

① the displacement (x) is the same for both springs

② The total restoring force (F) is the sum of the forces exerted by each spring (F_1 & F_2).

Total force
$$F = F_1 + F_2$$

From Hooke's law
$$F = kx$$
$$k_p x = k_1 x + k_2 x$$
$$k_p = k_1 + k_2$$

Time period
$$T = 2\pi\sqrt{\frac{m}{(k_1 + k_2)}}$$

Q.1 (b) Derive an expression for amplitude & phase for a body executing forced oscillation. — (8M)

Soln: Consider a body of mass m subjected to a restoring force, a damping force & an external periodic force. The forces acting on the body are

① Restoring force $F_r = -kx$

② Damping force $F_d = -b\dfrac{dx}{dt}$

③ Driving force $F_{ext} = F_0 \sin \omega t$

Here $k \to$ spring const. $b \to$ damping coefficient $F_0 \to$ peak force & ω is driving frequency

$$m \frac{d^2x}{dt^2} = -kx - b\frac{dx}{dt} + f_0 \sin \omega t$$

Rearranging the terms

$$\frac{d^2x}{dt^2} + \frac{b}{m}\frac{dx}{dt} + \frac{k}{m}x = \frac{f_0}{m}\sin \omega t$$

Let $\frac{b}{m} = 2\gamma$ & $\frac{k}{m} = \omega_0^2$ & $f_0 = \frac{f_0}{m}$

$$\frac{d^2x}{dt^2} + 2\gamma \frac{dx}{dt} + \omega_0^2 x = f_0 \sin \omega t$$

we assume steady-state solution
$$x(t) = A \sin(\omega t - \phi)$$
where $A \to$ amplitude & $\phi \to$ phase lag.

$$\frac{dx}{dt} = A\omega \cos(\omega t - \phi)$$

$$\frac{d^2x}{dt^2} = -A\omega^2 \sin(\omega t - \phi)$$

Substituting the above into the differential Eqs.

$$-A\omega^2 \sin(\omega t - \phi) + 2\gamma A\omega \cos(\omega t - \phi) + \omega_0^2 A \sin(\omega t - \phi)$$
$$= f_0 \sin(\omega t)$$

Using the identity
$$\sin(\omega t) = \sin[(\omega t - \phi) + \phi]$$
$$= \sin(\omega t - \phi)\cos\phi + \cos(\omega t - \phi)\sin\phi$$

$$A(\omega_0^2 - \omega^2)\sin(\omega t - \phi) + 2\gamma A\omega \cos(\omega t - \phi) =$$
$$f_0 \cos \phi \sin(\omega t - \phi) + f_0 \sin\phi \cos(\omega t - \phi)$$

By comparing the coefficients of $\sin(\omega t - \phi)$ & $\cos(\omega t - \phi)$ on both sides

$$A(\omega_0^2 - \omega^2) = f_0 \cos\phi \quad - \text{①}$$
$$2\gamma A\omega = f_0 \sin\phi \quad - \text{②}$$

Divide Eqs ② by ①.

$$\tan\phi = \frac{2\gamma\omega}{\omega_0^2 - \omega^2}$$

$$\phi = \tan^{-1}\left(\frac{2\gamma\omega}{\omega_0^2 - \omega^2}\right) \quad \text{//}$$

Expression for amplitude

$$[A(\omega_0^2 - \omega^2)]^2 + (2\gamma A\omega)^2 = (f_0 \cos\phi)^2 + (f_0 \sin\phi)^2$$

$$A^2 = \frac{f_0^2}{(\omega_0^2 - \omega^2)^2 + 4\gamma^2\omega^2}$$

$$A = \frac{f_0/m}{\sqrt{(\omega_0^2 - \omega^2)^2 + 4\gamma^2\omega^2}}$$

Q.1(C) Calculate the maximum amplitude of vibration of a system whose natural frequency is 850 Hz when it oscillates in a resistive medium for which the value of damping/unit mass is 0.008 rad/s under the action of an external periodic force/unit mass of amplitude 7 N/kg with tunable frequency — (4M)

Soln:-
Natural freq $(f_0) = 850$ Hz

Natural angular freq. $(\omega_0) = 2\pi f_0$

$\omega_0 = 2 \times \pi \times 850$

$= 1700\pi$ rad/s

Damping/unit mass $(2\gamma \text{ or } b/m) = 0.008$ rad/s

$\therefore \gamma = \frac{0.008}{2} = 0.004$ rad/s

External periodic force $(f_0 \text{ of } f_0/m) = 7$ N/kg

$$A_{max} = \frac{f_0}{2\gamma\omega_0} - \frac{f_0}{2\gamma\omega_0}$$

$\omega_0 = 2 \times \pi \times 850 = 5340.71$ rad

$$A_{max} = \frac{7}{0.008 \times 5340.71}$$

$$A_{max} = 0.1638 \text{ m}$$

Q 2 (a) Define damped oscillation. Explain the various forces acting on the system & write the differential equation of motion. Assuming the solution for displacement, discuss the three different cases of damping — (09) marks

Soln: Damped oscillations are the oscillations of a body whose amplitude decreases gradually with time due to the presence of resistive forces, eventually leading to the body coming to rest. In this process, the mechanical energy of the system is dissipated as heat.

Two main forces act on damped harmonic oscillator

① Restoring force $(f_r) = -kx$.

② Damping force $(f_d) = -b\dfrac{dx}{dt}$

Differential Equation of motion:

$$m\frac{d^2x}{dt^2} = -kx - b\frac{dx}{dt}$$

$$\frac{d^2x}{dt^2} + \frac{b}{m}\frac{dx}{dt} + \frac{k}{m}x = 0$$

$$\frac{d^2x}{dt^2} + 2\gamma\frac{dx}{dt} + \omega_0^2 x = 0.$$

The general solution for displacement is

$$x(t) = e^{\gamma t}\left(A e^{\sqrt{\gamma^2 - \omega_0^2}\,t} + B e^{\sqrt{\gamma^2 - \omega_0^2}\,t}\right)$$

Case (i) Over damped (Heavy damping)

$$\gamma > \omega_0.$$

Condition:- Damping force is high

$$b^2 > 4mk.$$

Behaviour → The system does not oscillate if displaced, it returns to the equilibrium position very slowly.

Example: Door closers, heavy fluid dampers

Case (2) Critically damped [$\gamma = \omega_0$]

Condition:- Damping force is just enough to prevent oscillation ($b^2 = 4mk$).

Behaviour → The system returns to the equilibrium position in the shortest possible time without overshooting.

Example:- Pointer of a galvanometer car shock absorbers.

case (3):- Under damped (Light damping)
[$\gamma < \omega_0$]

Condition:- Damping force is small ($b^2 < 4mk$)

Behaviour → The system performs oscillations with a frequency slightly less than the natural frequency, but the amplitude decays exponentially over time until it stops

Example:- A simple pendulum swinging in air.

Q.2(b) what are different types of springs? Mention its application — (06) M.

Soln:- A spring is an elastic object that stores mechanical energy & exerts a restoring force when deformed. Springs are classified on how the load force is applied to them

① Helical springs:-
Designed to operate with a compression load. The coils are not touching in the unloaded state

Application:- car suspension systems, mattresses

② Torsion springs:-
These springs work by twisting (torque). They exert a force in a circular of rotary direction.

Application:- clothespins, clipboard

③ Leaf springs:-
These consist of one or more flat, slender plates stacked on top of each other.
Application: Suspension system for heavy vehicle

④ Spiral springs
These are made of flat metal strips wound into to a flat spiral. They store energy when wound up.
Application:- Mechanical clocks, measuring tapes.

Q.2 © A car has a spring system that supports the in-built mass 1000 kg. when a person with a weight 980 N sits at the center of gravity, the spring system sinks by 2.8 cm. when a car hits a bump, it starts oscillating vertically. Find period & frequency of oscillation.

Soln:-

$$M = 1000 \text{ kg}$$

$$W_p = 980 \text{ N}$$

Compression $(x) = 2.8 \text{ cm} = 0.028 \text{ m}$

$$g = 9.8 \text{ ms}^2$$

w.k.t $F = kx$

$$k = \frac{F}{x} = \frac{980}{0.028}$$

$$k = 35,000 \text{ N m}^{-1}$$

mass of the person

$$m = \frac{W}{g} = \frac{980}{9.8} = 100 \text{ kg}$$

Total mass $= 1000 + 100 = 1100 \text{ kg}$

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

$$T = 2 \times 3.142 \times \sqrt{\frac{1100}{35000}}$$

$$= 6.283 \times 0.1772$$

$$T = 1.113 \, s$$

Now, $f = \frac{1}{T}$

$$f = \frac{1}{1.113}$$

$$f = 0.898 \, Hz$$

Q.3 (a) Define ground motion & list its key parameters. Explain the structural response & soil structure interaction — (8m).

Soln.   Definition of Ground motion

   Earthquake ground motion is the vibrational motion of the ground near the earth's surface caused by seismic waves generated due to an earthquake.

   Its a complex phenomenon influenced by
   • Dynamics of source breakage
   • Details of the transmitting medium

   Key parameters of the ground motion

   Ground motion at a site is mainly influenced by four elements

1. Source - Size & nature of the earth quake source that controls wave generation.

2. Directivity - Direction in which seismic energy is radiated.

3. Travel path - Effect of the earth materials through which waves travel.

4. Local site conditions → Effect of upper soil layers & surface topography on ground motion.

5. Structural response.

Structures respond dynamically to earthquake ground motion depending on their
- Natural period
- Damping characteristics.

Resonance occurs when the dominant period of ground motion matches the natural period of the structure, resulting in large amplification of vibrations & severe damage.

Soil structure interaction (SSI)

Soil structure interaction is the coupled behaviour in which soil motion influences the structure & the structures inertial forces affect the soil

SSI consists of two main components.

1. Kinematic Interaction
2. Inertial interaction.

Significance

SSI modifies seismic demand &
is important for
- Structures on soft soils
- Heavy & large-foot print buildings

Q.3 (b) Enumerate the causes and adverse
effects of tsunami waves — (8M)

Soln.   Causes of Tsunami

—Tsunami is caused by the sudden
large scale displacement of a large
volume of water in oceans/seas.

Main Causes
1. Seismic activity (undersea earthquake)
2. Land slides
3. Volcanic eruptions
4. Large meteoroid impacts.

Adverse effects of Tsunami
1. Severe flooding
2. Destruction of human settlements, roads & infrastructure
3. Withdrawal damage
4. Damage to ports.
5. Loss of Life.
6. Public health issues
7. Economic & environmental losses

Q.3 © The intensity of one earthquake is 100 times the intensity of the others of the magnitude of the first earthquake is 8.9, estimate the magnitude of the other. —(4m)

Soln:-

$$M = \log\left(\frac{I}{10^4}\right) \qquad \begin{array}{l} M - \text{Magnitude} \\ I - \text{Intensity} \end{array}$$

for two earthquakes.

$$M_1 - M_2 = \log\left(\frac{I_1}{I_2}\right)$$

$$\frac{I_1}{I_2} = 100 \quad \& \quad M_1 = 8.9$$

$$M_1 - M_2 = \log(100)$$
$$M_1 - M_2 = 2$$
$$8.9 - M_2 = 2$$
$$M_2 = 8.9 - 2$$
$$M_2 = 6.9$$

Magnitude of the other earthquake = 6.9

Q.4 @ Mention the types of waves. Explain wave propagation in beams, rods and slabs ——(8m).

Soln: A wave is a vibratory disturbance that transfers energy from one point to another without actual movement of the medium.

Main types of waves

① Mechanical waves
     Require material medium

② Electromagnetic waves
     Do not require a medium

③ Matter waves → Associated with moving particles.

Types of Mechanical waves
1. Longitudinal waves →
2. Transverse waves
3. Torsional waves.

Wave propagation in structural members

1. Wave propagation in Rods
   - waves are longitudinal
   - Particles vibrate along the length of the rod.
   - Common in bars subjected to impact loading

2. Wave propagation in Beams.
   1. Beams carry transverse waves.
   2. The Beam bends as the wave passes
   3. Flexural waves are dispersive.

3. Wave propagation in slabs
   - Lamb waves propagate
   - They exist in symmetric & anti-symmetric modes
   - Used in non-destructive testing of plates.

Q4(5) Discuss the engineering structures to with stand earthquake & tsunami waves   — (8M).

Soln. Earthquake-resistant design focusses on strength, flexibility & energy dissipation.

a) Structural elements:-
   - Use of diaphragm, shear walls, cross bracing & moment-resisting frames to resist lateral forces.

(b) Flexibility & Damping:
  • Structures are designed to sway & dissipate energy in stead of collapsing.
(c) Material Quality
  • Use of reinforced concrete, steel & high quality materials to resist seismic stresses.
(d) Site & code compliance.
    Proper site selection
(e) Architectural planning
    Balanced building shapes & proper foundation design.

• Engineering structures to withstand Tsunamic waves
  (1) site Selection
  (2) Elevated structures
  (3) water Breakers & Barriers
  (4) Land use Planning
  (5) Community Shelters

Q.4 (c) the earthquake in city A registered 8.3 on Richter scale. In the same year another earthquake was recorded in city B that was four times stronger. what was the magnitude of the earthquake in city B.

Soln.

$$M = \log \left(\frac{I}{10^{-4}} \right)$$

$$M_2 - M_1 = \log \left(\frac{I_2}{I_1} \right)$$

$$M_A = 8.3$$

City B is 4 times stronger $\Rightarrow I_B = 4 I_A$

So

$$M_B - M_A = \log(4)$$
$$M_B = 8.3 + \log(4)$$
$$\log(4) = 0.602$$
$$M_B = 8.3 + 0.602$$
$$M_B = 8.9$$

Magnitude of earthquake in city B = 8.9

Q.5(a). Mention the conditions for good acoustics — (6m)

Soln: For a hall of auditorium to have good acoustics, the following conditions must be satisfied.

1. Adequate Loudness
2. Optimum Reverberation time
3. Absence of Echoes
4. No focusing of sound
5. Freedom from Echelon effect
6. Proper sound insulation
7. uniform distribution of sound.

Q.5(b) Define & explain Lambert's cosine law & Inverse Square law — (9m)

Soln: Lambert's cosine law

Lambert's cosine law states that the illumination (E) on a surface is directly proportional to the cosine of the angle (θ) between the direction of incident light & the normal to the surface

$$E \propto \cos\theta$$
$$E = E_0 \cos\theta$$

SCORE

where
θ = angle between incident light &
 normal to the surface.
E_0 = illumination when light falls
 normally.

Explanation:-
- when light falls normally ($\theta = 0$)
  $\rightarrow \cos 0 = 1$, illumination is
  maximum.
- As the angle increases, $\cos \theta$ decreases
  hence illumination decreases.
- when light falls at $90°$, $\cos 90° = 0$,
  illumination becomes zero.

⟵Thus illumination reduces as the surface
tilts away from the light source.

Inverse Square law:
    The inverse square law states
that illumination at a point is
inversely proportional to the square
of the distance from the light source.

$$E \propto \frac{1}{r^2}$$

$$E = \frac{1}{r^2}$$

where r = distance from source
       I = luminous intensity.
Explanation:-
- If the distance is doubled → illumina-
  tion becomes $1/4^{th}$
- If the distance is tripled → illumination
  becomes $1/9^{th}$.

Q.5 (C) The volume of room is $1500 \, m^3$. The wall area of the room is $260 \, m^2$, the floor area is $140 \, m^2$ & the ceiling area is $140 \, m^2$. The average sound absorption coefficient for wall is 0.03, for the ceiling is 0.8 & for the floor is 0.06. Calculate the average absorption coefficient & the reverberation time — (05) M

Soln.

Given

volume $v = 1500 \, m^3$

Areas walls $= 260 \, m^2$

floor $= 140 \, m^2$

Ceiling $= 140 \, m^2$

Absorption coefficient

$\alpha_w = 0.03$

$\alpha_f = 0.06$

$\alpha_c = 0.8$

$$A = \sum \alpha_i \, S_i$$

(i) walls

$Aw = 0.03 \times 260 = 7.8$

(2) floor $A_f = 0.06 \times 140 = 8.4$

(3) ceiling $A_c = 0.8 \times 140 = 112$

$A = 7.8 + 8.4 + 112 = 128.2 \, sabins$

Average absorption coefficient α

$$\alpha = \frac{A}{S}$$

$S = 260 + 140 + 140 = 540 \, m^2$

$$\bar{\alpha} = \frac{A}{S} = \frac{128.2}{540}$$

$$\bar{\alpha} = 0.237.$$

Reverberation time T (Sabine's formula)

$$T = \frac{0.161\,V}{A} = \frac{0.161 \times 1500}{128.2}$$

$$= \frac{241.5}{128.2} = 1.88s.$$

Q.6 (a) Elucidate the impact of noise in multi-storied buildings & explain the noise-control measures — (8m).

Soln. Impact of noise in Multi-storied Building.

① speech privacy is affected

② Noise from fans, Ac, generators. disturb workspaces.

③ Blending of building systems noise & exterior noise affects clarity

④ Rooms perpendicular to roadways experience more disturbing noise.

⑤ Traffic, emergency vehicles, disturb occupants

Noise control measures

① sound Insulation.
Prevents transmission of sound between rooms or from outside.

Types of Sound Insulation
① Air borne Sound insulation
② Impact sound insulation

Practical Measures.

: Use of thick walls, double glazing insulated doors.
· Proper sealing to avoid leakage.
· Use vibration isolation for machinery.
· Proper building orientation to reduce road noise.

8.6(b) Define Photometry & explain any three photometric quantities — (8m).

Soln: Photometry is the science of measurement of light as perceived by the human eye interms of brightness. It deals with the measurement of intensity of light emitted by a source & the illuminating power of a surface.

3 photometric quantities
① Luminous flux, (Φ)

· It is the light energy emitted per second from a light source
unit is lumen (lm)

② Luminous Intensity (I)
It is the luminous flux emitted per unit solid angle in given direction
$$I = \frac{\Phi}{\Omega}$$
Ω - solid angle
unit - Candela (cd)

③ Illumination: (E)
It is the luminous flux incident per unit area of a surface

$$E = \frac{\phi}{A}$$

unit lux (lm/m^2)

Q 6 (c) For an empty assembly hall of size $20 \times 15 \times 10$ cubic meter with absorption coefficient 0.106, calculate reverberation time. — (4 m)

Soln: Reverberation time

$$T = \frac{0.167 V}{\bar{\alpha} S}$$

$V \rightarrow$ volume of the hall

$S \rightarrow$ total surface area

$\bar{\alpha} \rightarrow$ average absorption coefficient

Hall size $20 \times 15 \times 10$

$$V = 3000 \, m^3$$

Total surface area

$$S = 2(lb + bh + lh)$$

$$S = 2[20 \cdot 15 + 15 \cdot 10 + 20 \cdot 10]$$

$$S = 1300 \, m^2$$

absorption coefficient $\bar{\alpha} = 0.106$

$$\therefore T = \frac{0.167 \times 3000}{0.106 \times 1300}$$

$$T = 3.64 s$$

Q 7 (a) Describe the principle & process involved in Liquid Penetration test.

Soln:- Principle:-

Liquid Penetrant testing (LPT) is a low cost NDT method used to detect surface defects by the seepage of a liquid dye into open surface discontinuities through capillary action.

It is suitable for non-porous metallic/ non metallic surfaces but not suitable for rough/dirty/porous surfaces

Process:-

(1) Surface cleaning :- remove dust, paint, oil ..etc

(2) Apply penetrant:- apply dye/ fluoresent penetrant by brush/ spray

(3) Dwell time:- allow time for pene-tration (20-30 min)

(4). Remove acces penetrant from surface

(5) Apply develop:- dry powder/ water soluble

(6) Inspection:- developer draws penetrant out of cracks

Q7(b) Discuss the methods of producing ultrasound. Describe the role of probes used in ultrasonic & mention the types of probes — (8M).

Soln:- Methods of Producing ultrasound.

(a) Piezoelectric method.
  • Based on piezoelectric effect
  • Certain crystals produce mechanical vibrations when an alternating voltage is applied.

• These high frequency vibration generate ultrasonic waves.

(b) Magnetostriction Method.
   • A ferromagnetic rod changes its length when placed in an alternating magnetic field.
• This produces ultrasonic vibration.

(2) Role of Probes in Ultrasonics.
   • The probe (transducer) converts electrical energy into ultrasonic waves & also converts reflected ultrasonic waves back into electrical signals.
• It acts as both transmitter & receiver.
• Probes help detect internal defects based on reflected echo signals.

   Types of Probes
   (1) Normal Beam probe.
   (2) Angle Beam probe
   (3) Dual probe
   (4) Immersion probe.

Q.7(c) Find the depth of a submarine, if an ultrasonic pulse reflected from the submarine is received 0.33s after sending out the ultrasonic waves. Given the sound velocity in sea water is 1440 ms⁻¹.

Soln: Time for echo received $t = 0.33s$
               $v = 1440 \, ms^{-1}$
   Total distance $= v \times t$
                       $= 1440 \times 0.33$

Total dist = 475.2 m

Depth (one way distance) is half of
this =
$$d = \frac{475.2}{2} = 237.6 m.$$

depth of submarine is 238m.

Q8(a) Describe the eddy current inspection
probes & display methods in eddy
current testing ———— (8M).

Soln   In Eddy current testing (ECT),
probes contain coils that produce
alternating magnetic fields. When placed
near a conductive material, eddy currents
are induced. Defects disturb these
currents, changing coil impedence

— Types of Probes
(1). Absolute probe - contains single coil
(2) Differential probe - contains 2 coils.
(3) Reflection probe - Has separate
          transmitter & receiver coils
(4) Surface probe - for surface crack detn
(5) Encircling probe-
(6) Internal probe

Display methods in ECT.
the changes in impedence are
displayed using instruments.
Common display methods
(1) Meter display
(2) Digital display
(3) CRT - display
(4) Impedence plane display.

SCORE

Q.8(b) Discuss the shadow formation & distortion in radiography. — (8m)

Soln. .Shadow formation in Radiography.

Radiography is based on the penetration of x-rays & γ-rays through a material. When radiation passes through an object.

. Some radiation is absorbed & some is transmitted.
• Dense regions absorb more radiation.
• Less dense & defective regions allow more radiation to pass.
• The transmitted radiation falls on a film/detector, forming a shadow image

Key points :
• Defects appear as darker regions.
• Thicker or denser areas appear lighter
• Dosage contrast depends on material thickness, density & radiation intensity.

Thus the radiographic image is essentially a shadow picture of internal structure.

Distortion in Radiography
Causes of distortion
① Geometric distortion
② Magnification
③ Shape distortion
④ Source size effect

Q.8 (b) Speed of sound in a steel block is 5900 m/s. The observed front wall echo is at 2μs & back wall echo at 26μs. Find the thickness of the specimen.

Soln.

Velocity in steel $v = 5900$ m/s^{-1}

Front wall echo time $t_f = 2 μs$

Back wall echo time $t_b = 26 μs$.

$$\Delta t = t_b - t_f$$
$$= 24 \times 10^{-6} s$$

In pulse - echo method
$$\Delta t = \frac{2d}{v} \implies d = \frac{v \Delta t}{2}$$

$$d = \frac{5900 \times 24 \times 10^{-6}}{2}$$

$$= 0.0708 m$$

Q.9 (a) Explains different types of smart materials — (8M)

Soln. Smart / intelligent materials are the materials whose properties can be significantly changed in a controlled way by external stimuli such as stress, tempr, moisture, electric field, magnetic field ..etc.

Types of smart materials

(1) Piezo electric materials.
Generate electric charge when mechanical stress is applied.

(2) Magnetostrictive materials.
change shape / size when subjected to a mag. field.

③ Electrostrictive Materials:-
A dielectric material shows strain when electric field is applied & strain is proportional to square of electric field.

④ Electro-Rheological Materials:-

~~E.R-mater~~ ER fluids change viscosity/stiffness rapidly when an emf is applied

⑤ Magneto-Rheological materials

⑥ Shape memory Alloys :-
Alloys can be deformed & then return to original shape on heating/cooling

Q.9(b) Deduce the classification of sensors? Explain the working of tempr sensors & mention its application. — 8m

Soln   Sensors are classified based on various criteria.

ⓐ Based on Energy Requirement
   • Active sensors — Generate their own output
   • Inactive sensors → Require external power source

ⓑ Based on output signal
   • Analog sensors
   • Digital sensors.

(c) **Based on Measurand**
- Temp. sensor
- Pressure sensor
- Displacement sensor
- Strain sensor
- Vibration sensors etc

(2) **Working of temperature Sensors**

Temperature sensors measure tempr by converting thermal energy into electrical signals.

Thermo couple :-
- Works on Seebeck effect.
- When two dissimilar metals are joined & heated, a thermoelectric voltage is produced proportional to tempr difference.

Resistance Temperature Detector.
- Based on principle that electrical resistance of metals increases with tempr
- platinum is commonly used.
- Accurate & stable

Q.9 (C) A tensile specimen test uses a strain gauge with a gauge factor of 2.0 & an initial resistance of 120Ω. The measured strain is 300μC. Calculate the change in resistance of the strain gauge.

Soln   Gauge factor GF = 2.0
Initial resistance R = 120 Ω
Strain ε = 3000 × 10^{-6} = 0.003

Gauge factor reln

$$GF = \frac{\Delta R / R}{\varepsilon}$$

$$\therefore \Delta R = GF \cdot \varepsilon \cdot R$$

$$\Delta R = 2.0 \times 0.003 \times 120$$

$$= 0.72 \, \Omega$$

$$= 0.72 \, \Omega$$

Q10 (a) Explain shape memory alloys.
Describe their phase transformation
Behaviour & list their application (8m)

Soln   Shape memory alloys are smart
materials that can recover their
original shape after deformation
when subjected to temp. change.
Phase transformation Behaviour :-
Shape memory alloys exhibit a reversible
martensitic transformation between
Austenite phase (high temperature, strong
phase) and Martensite phase (low tempr,
easily deformable phase)
Two key effects.
① Shape memory effect (SME): Deformed
martensite regains original shape upon
heating.
② Super elasticity : Large strain recovery
upon unloading above transformation tempr.
Transformation is diffusionless &
thermoelastic

Applications:
- structural vibration control devices.
- Seismic dampers & actuators.
- couplings & fasteners
- Biomedical stents & orthodontic wires
- smart reinforcement systems.

Q10 (b) Describe the concept of structural health monitoring — (2M)

Soln. structural health monitoring is a smart sensing based system used to continuously access the condition, performance & safety structures using embedded sensors.

Key features
- uses sensors (piezo electric, fiber optic etc)
- Detects damage such as cracks, corrosion
- Enables real-time monitoring.
- Supports preventive maintenance & life prediction.

objectives:
- Early damage detection
- Improved safety & reliability
- Reduced maintenance cost.
- Increased service life of structures.

Q10 (c) A piezo electric disk has a charge coefficient $d = 200 \times 10^{-12}$ C N^{-1} under an applied compressive force $F = 50.0$ N. of the disk is connected to an input stage with an effective capacitance $C = 50$ pf, compute the open-circuit voltage V.

Sol. Given

$$d = 200 \times 10^{-12} \, C/N$$

$$F = 50 N$$

$$C = 50 \, pF = 50 \times 10^{-12} F$$

charge generated

$$q = d \times F$$

$$q = \left(200 \times 10^{-12} \right) \times 50$$

$$q = 1.0 \times 10^{-8} C$$

Open circuit voltage
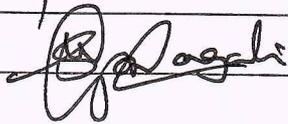
$$V = \frac{q}{c}$$

$$V = \frac{1.0 \times 10^{-8}}{50 \times 10^{-12}}$$

$$V = 200 \, V. //$$

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