PhD Admission in Aerospace Engineering, IIT Bombay

Sample Question Paper

The admission to the PhD program in the Department of Aerospace Engineering at IIT Bombay consists of a written test, among other components. Here, we provide a sample of the question paper for such written tests.

The test typically consists of 3 sections – Comprehension, Mathematics and 'Specialization'. The 'Specialization' corresponds to one of the four groups in the department – Aerodynamics (AE1), Dynamics & Controls (AE2), Propulsion (AE3) and Structures (AE4). Students can apply to take the test in any one (and at most one) of these specializations. As an example, a student wishing to take the test in AE2 will see a question paper consisting of three sections – Comprehension, Mathematics, and Dynamics & Controls; she will not see any other section during the exam.

Sample question papers are provided for all the six sections mentioned above.

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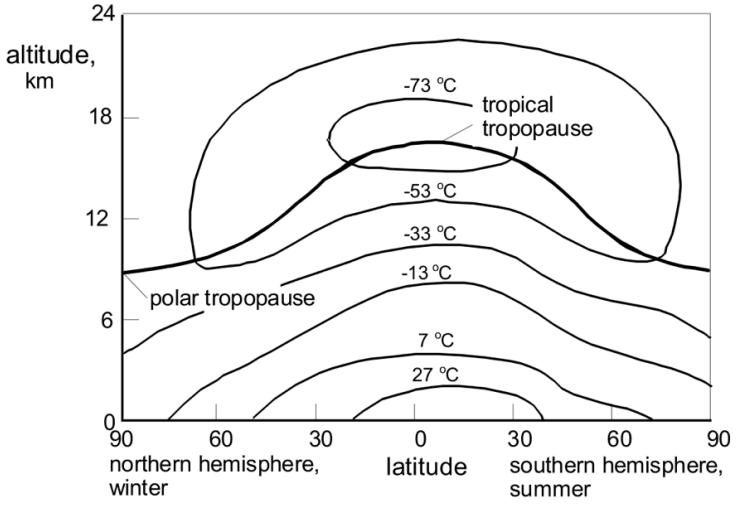
Sample Question Paper – Comprehension Section

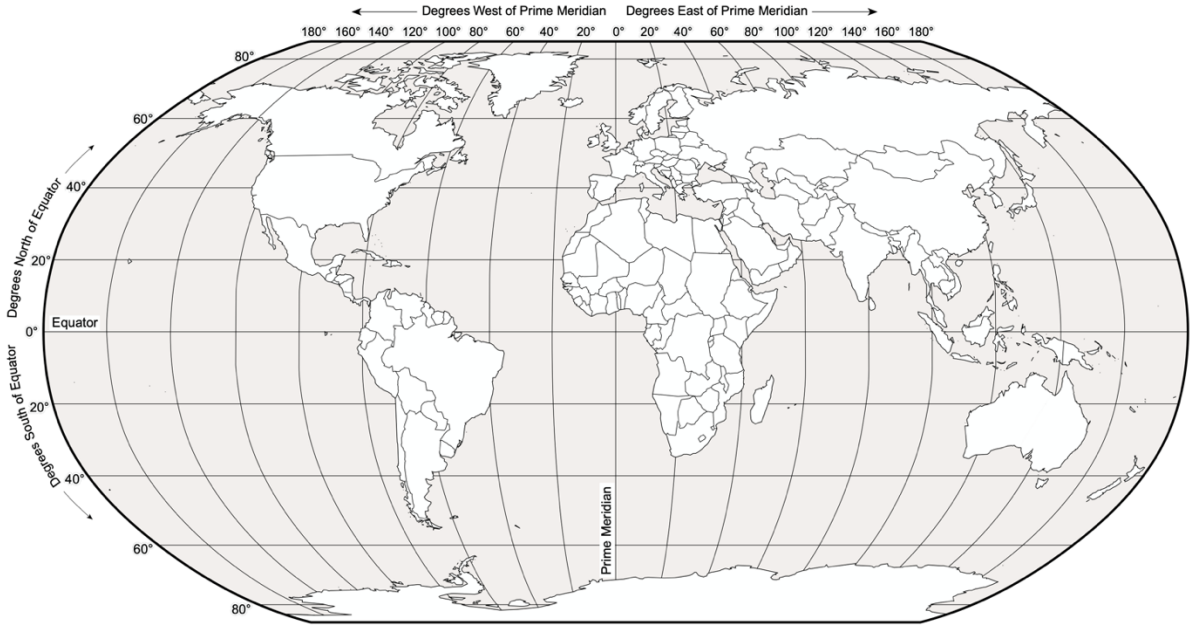
QUESTION= module, COUNT=4, CATEGORY= Comprehension

The following question is from the COMPREHENSION section (consisting of 4 questions worth a total of 5 marks).

Please see the two graphics below and answer the questions that follow.



The above figure shows the variation of the yearly average temperature variation of the Earth's atmosphere with altitude and latitude (reproduced from Torenbeek, E. and Wittenberg, H., 'Flight Physics', Springer, 2009). The below figure is the world map.



Answer the following question based on the above information.

QUESTION= singlecorrect, MARKS=1

The yearly average temperature of the following city is nearly 27 degree Celsius at this time of the year (assuming they are all at nearly the same altitude)

OPTIONS=

A. Delhi
B. Kanyakumari
C. Mumbai
D. Patna

QUESTION= singlecorrect, MARKS=1

The region closest to Mumbai in terms of latitude is

OPTIONS=

A. Pakistan
B. Israel
C. West Indies
D. Bangladesh

QUESTION= singlecorrect, MARKS=1.5

Approximate variation in the altitude of tropopause across India is

OPTIONS=

A. 3 km
B. 6 km
C. 9 km
D. 12 km

QUESTION=numeric, MARKS=1.5

The International Standard Atmosphere assumes a sea-level temperature of 288.15 K. For the time of the year shown in the figure, what latitude in the Southern Hemisphere does this correspond to? Give your answer correct up to 5 degrees of latitude.

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Sample Question Paper – Mathematics Section

QUESTION= module, COUNT=6, CATEGORY= Maths

The following question is from MATHEMATICS (consisting of 8 questions worth a total of 10 marks).

QUESTION=numeric, MARKS=2

Solve the following equation for *x*, correct up to 3 significant digits: $4^{x-2} = 3^{x+4}$.

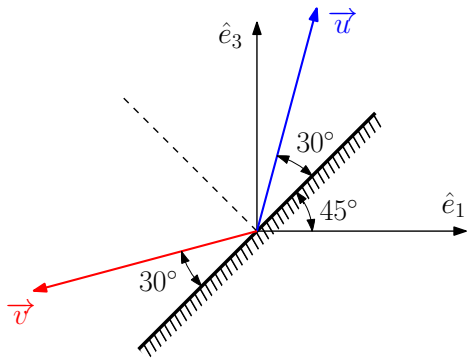
QUESTION=numeric, MARKS=2

Compute the ratio of the largest to the smallest eigenvalues of the following matrix, correct up to 3 significant digits:

$$\begin{bmatrix} 3 & 4 \\ 2 & 1 \end{bmatrix}.$$

QUESTION= singlecorrect, MARKS=2

Let $\hat{e}_1$, $\hat{e}_2$, $\hat{e}_3$ represent a right-handed coordinate system. Consider a plane mirror whose normal $\hat{n}$ is in the plane of $\hat{e}_1$ and $\hat{e}_3$, and makes an angle of $45°$ with $\hat{e}_1$, as shown in the figure. Consider the vector $\vec{u}$ in the plane of $\hat{e}_1$ and $\hat{e}_3$ that makes an angle of $30°$ with the mirror. What is the matrix **T** that transforms $\vec{u}$ into its mirror image $\vec{v}$ with respect to the mirror? Use $\hat{e}_1$, $\hat{e}_2$ and $\hat{e}_3$ as the basis for constructing **T**.



OPTIONS=

A. $[0,0,-1;\ 0,1,0;\ -1,0,0]$

B. $\left[1/\sqrt{2}\,, 0, -1/\sqrt{2}\,; 0,1,0; 1/\sqrt{2}\,, 0, 1/\sqrt{2}\right]$
C. $\left[1/\sqrt{2}\,, 0, 1/\sqrt{2}\,; 0,1,0; -1/\sqrt{2}\,, 0, 1/\sqrt{2}\right]$
D. $[-1, 0, 0; 0,1,0; 0,0,1]$

QUESTION= setcorrect, MARKS=1

For real *a* and *b*, which all of the following statements is/are not always true:

OPTIONS=
A. $|a| + |b| \geq |a + b|$
B. $\big||a| - |b|\big| \leq |a - b|$
C. $a^2 + b^2 \geq (a + b)^2$
D. $a^2 + b^2 \geq (a - b)^2$

QUESTION=numeric, MARKS=1

If the shadow of a building increases by 20 meters when the angle of elevation of the sun rays decreases from $60°$ to $45°$, what is the height of the building, correct up to 3 significant digits?

QUESTION= singlecorrect, MARKS=1

Simplify i^{231}, where i is the imaginary unit and is defined as: $i = \sqrt{-1}$:

OPTIONS =
A. $+i$
B. $-i$
C. $+1$
D. -1

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QUESTION=module, COUNT=2, CATEGORY= Maths

The following question is from MATHEMATICS (consisting of 8 questions worth a total of 10 marks).

It is given that *m* and *n* are integers in the equation $4^m/125 = 5^n/16$.

QUESTION=numeric, MARKS=0.5

What is *m*?

QUESTION=numeric, MARKS=0.5

What is *n*?

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Sample Question Paper – Aerodynamic Specialization

QUESTION = module, COUNT = 9, CATEGORY = Aerodynamics

The following question is from the AERODYNAMICS specialization (consisting of 11 questions worth a total of 15 marks).

QUESTION=singlecorrect, MARKS=1

An appropriate non-dimensional speed for a viscous flow is

OPTIONS=

A. vx/U_∞
B. vU_∞/x
C. $U_\infty x/v$
D. $\sqrt{vU_\infty x}$

QUESTION=singlecorrect, MARKS=1

For 2-D freestream flow in the *x*-direction, boundary layer separation starts when

OPTIONS=

A. $\left(\frac{\partial u}{\partial y}\right)_{y=0} > 0$ and $\left(\frac{\partial P}{\partial x}\right) < 0$
B. $\left(\frac{\partial u}{\partial y}\right)_{y=0} < 0$ and $\left(\frac{\partial P}{\partial x}\right) > 0$
C. $\left(\frac{\partial u}{\partial y}\right)_{y=\delta} = 0$ and $\left(\frac{\partial P}{\partial x}\right) < 0$
D. $\left(\frac{\partial u}{\partial y}\right)_{y=0} = 0$ and $\left(\frac{\partial P}{\partial x}\right) > 0$

QUESTION=numeric, MARKS=1

An aircraft is flying at sea level (air density is 1.225 kg/m^3) with wing loading of 100 N/m^2 and maximum C_L of 2.5. Find the speed in m/s (accurate to two significant digits) below which the aircraft will stall.

QUESTION=numeric, MARKS=1

An object of mass 100 kg is dropped from an aircraft flying at a velocity of 270 km/h at an altitude of 5.5 km. Within 30 seconds, it has been found to attain a terminal velocity of 450 km/h. What is the drag force acting on this object 40 seconds after leaving the aircraft in Newtons, correct up to 3 significant digits? [Take acceleration due to gravity as 9.81 m/s^2.]

QUESTION=numeric, MARKS=1

A spherical balloon filled with Helium remains steady at an altitude where the density of air is 1.2 kg/m^3, while the density of Helium is 0.2 kg/m^3. If the material of the balloon is 1 mm thick, and has a density of 300 kg/m^3, what is the radius of the balloon (correct to 2 significant digits)? Assume that the radius is very large in comparison to the thickness, and ignore any ambient wind.

QUESTION=numeric, MARKS=2

At the entrance of a square duct of cross-section 40 x 40 cm^2, airflow velocity is a uniform U_0 = 2 m/s, density is 1.2 kg/m^3, and pressure is 1 atm. At the section 3 m downstream from the entrance, the displacement thickness on each wall is 0.0082 m. What is the mean pressure *drop* in Pa at the core of the flow at that section compared to the entrance? Your answer must be accurate to two significant digits.

QUESTION=numeric, MARKS=2

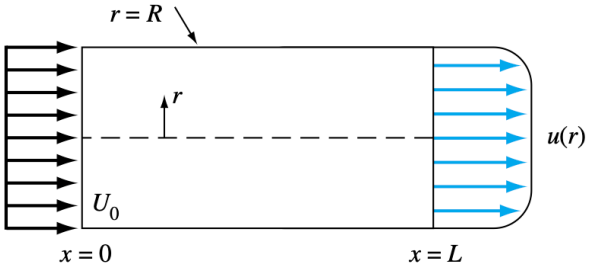
A siphon consisting of a 3 cm diameter tube is used to drain water from a tank. The outlet end of the tube is 1.8 m below the water surface in the tank. Neglect friction. If the peak point of the siphon is 1.2 m above the water surface in the tank, estimate the absolute pressure of fluid (in Pa) at the peak point of siphon. (Density of water = 1000 kg/m^3, gravitational acceleration = 9.81 m/s^2, ambient pressure = 101325 Pa.) Give your answer correct up to 4 significant digits.

QUESTION=numeric, MARKS=2

Experiments have determined that in the low-Reynolds-number laminar-flow regime over a circular cylinder of diameter *d*, the shedding frequency *f* is inversely proportional to the 1.5 power of *d* (i.e., $f \propto d^{-3/2}$). Two cylinders (cylinder 1 and cylinder 2) are immersed in air (same density and viscosity). Cylinder 1 has 3.5 times the flow velocity and 0.7 times the diameter as cylinder 2. What will the ratio of shedding frequencies be for cylinder 1 to cylinder 2? Your answer should be correct up to 2 significant digits.

QUESTION=numeric, MARKS=2

Water, assumed incompressible, flows steadily through the round pipe in the below figure. The entrance velocity is constant, $u = U_o$, and the exit velocity approximates turbulent flow,$u = u_{max}(1 - r/R)^{1/7}$. Determine the ratio U_o/u_{max} for this flow, correct up to 2 significant digits.



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QUESTION = module, COUNT = 2, CATEGORY = Aerodynamics

The following question is from the AERODYNAMICS specialization (consisting of 11 questions worth a total of 15 marks).

The *x*, *y* and *z* (Cartesian) components of the velocity field in a steady flow are $u = -x$, $v = 4x^2y^2$, $w = 2x - y$? Consider the point $P = (x = 0.5, y = 3, z = 0.25)$.

QUESTION=numeric, MARKS=1

What is the *y*-component of the Lagrangian acceleration field at point *P* (correct to 3 significant digits)?

QUESTION=numeric, MARKS=1

What is the *z*-component of the Lagrangian acceleration field at point *P* (correct to 3 significant digits)?

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Sample Question Paper – Dynamics & Controls Specialization

QUESTION= module, COUNT=9, CATEGORY= DynamicsControls

The following question is from the DYNAMICS & CONTROLS specialization (consisting of 9 questions worth a total of 15 marks).

QUESTION= singlecorrect, MARKS=1

Suppose that a PD controller is designed to compensate a system. Compared to the uncompensated system, the compensated system has

OPTIONS=

A. a higher type number
B. reduced damping
C. higher noise amplification
D. larger transient overshoot

QUESTION=numeric, MARKS=1

Consider the transfer function $G(s) = \frac{5}{s+10}$. What is the steady-state value of the system response to a unit step input, correct up to 2 significant digits?

QUESTION=numeric, MARKS=1

For the system with transfer function $\frac{2}{s+1}$, the approximate time taken for a step response to reach 98% of the final value (correct to 2 significant digits) is _____.

QUESTION=numeric, MARKS=2

How many open right half plane poles are there for $G(s) = \frac{10}{s^5+2s^4+3s^3+6s^2+5s+3}$?

QUESTION=numeric, MARKS=2

Consider a unity negative feedback configuration system with open loop transfer function $G(s) = \frac{100}{s(s+10)^2}$. How much is the gain margin (expressed in dB) of the system under closed loop unity negative feedback? You may use $\log_{10}2 = 0.3$ whenever required. Your answer should be correct to 3 significant digits.

QUESTION=numeric, MARKS=2

The unit impulse response of a second order under-damped system starting from rest is given by $c(t) = 12.5\, e^{-6t} \sin 8t$, $t > 0$. What would be the steady-state value of the unit step response of the system, correct up to 3 significant digits?

QUESTION=numeric, MARKS=2

The open loop transfer function of a unity feedback control system is given as $G(s) = \frac{as+1}{s^2}$. For what value of the parameter *a*, the phase margin will be 45 deg? Your answer should be correct to 2 significant digits.

QUESTION=numeric, MARKS=2

Let a unity feedback control system with the open loop transfer function be $G(s) = \frac{s+1}{s^p(s+2)(s+3)}$, where *p* is an integer. If the steady state errors are 0 and 6 for unit step input and unit ramp input, respectively, the value of the parameter *p* is _____.

QUESTION=numeric, MARKS=2

A unity feedback control system is characterized by the open-loop transfer function $G(s) = \frac{2(s+1)}{s^3+Ks^2+2s+1}$. The value of *K* (correct up to 2 significant digits) for which the system oscillates at 2 rad/sec is ____.

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Sample Question Paper – Propulsion Specialization

QUESTION = module, COUNT = 10, CATEGORY = Propulsion

The following question is from the PROPULSION specialization (consisting of 10 questions worth a total of 15 marks).

QUESTION= singlecorrect, MARKS=1

An appropriate non-dimensional speed for a viscous flow is

OPTIONS=

A. vx/U_∞
B. vU_∞/x
C. $U_\infty x/v$
D. $\sqrt{vU_\infty x}$

QUESTION= singlecorrect, MARKS=1

Bernoulli's theorem is not valid when the flow is

OPTIONS=

A. Irrotational
B. Rotational
C. Steady
D. Unsteady

QUESTION= singlecorrect, MARKS=1

For 2-D freestream flow in the *x*-direction, boundary layer separation starts when

OPTIONS=

A. $\left(\frac{\partial u}{\partial y}\right)_{y=0} > 0$ and $\left(\frac{\partial P}{\partial x}\right) < 0$
B. $\left(\frac{\partial u}{\partial y}\right)_{y=0} < 0$ and $\left(\frac{\partial P}{\partial x}\right) > 0$
C. $\left(\frac{\partial u}{\partial y}\right)_{y=\delta} = 0$ and $\left(\frac{\partial P}{\partial x}\right) < 0$
D. $\left(\frac{\partial u}{\partial y}\right)_{y=0} = 0$ and $\left(\frac{\partial P}{\partial x}\right) > 0$

QUESTION= singlecorrect, MARKS=1

The properties of mercury at 300 K are: density = 13529 kg/m^3, specific heat at constant pressure = 0.1393 kJ/kg-K, dynamic viscosity = 0.1523x10^{-2} Ns/m^2 and thermal conductivity = 8.54 W/m-K. The Prandtl number of the mercury at 300 K is

OPTIONS=

A. 0.0248
B. 0.248
C. 248
D. 24.8

QUESTION= singlecorrect, MARKS=1

For the following cycles operating between the same temperature limits, the cycle that will have the maximum efficiency is _____

OPTIONS=

A. Brayton cycle
B. Rankine cycle
C. Otto cycle
D. Carnot cycle

QUESTION = numeric, MARKS = 2

The stagnation temperatures at the inlet and exit of a combustion chamber are 600 K and 1200 K, respectively. If the heating value of the fuel is 44 MJ/kg and specific heat at constant pressure for air and hot gases are 1.005 kJ/kg.K and 1.147 kJ/kg.K respectively, the fuel-to-air ratio is ____ (correct up to 3 significant digits).

QUESTION = numeric, MARKS = 2

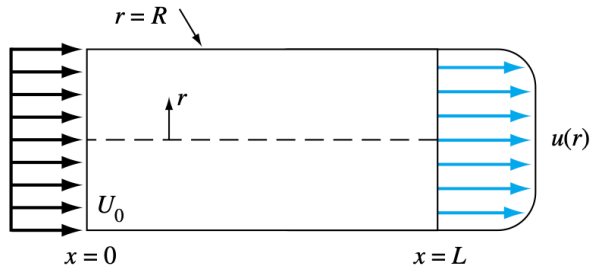
A siphon consisting of a 3 cm diameter tube is used to drain water from a tank. The outlet end of the tube is 1.8 m below the water surface in the tank. Neglect friction. If the peak point of the siphon is 1.2 m above the water surface in the tank, estimate the absolute pressure of fluid (in Pa) at the peak point of siphon. (Density of water = 1000 kg/m^3, gravitational acceleration = 9.81 m/s^2, ambient pressure = 101325 Pa.) Give your answer correct up to 4 significant digits.

QUESTION = numeric, MARKS = 2

A balloon behaves such that the pressure is $P = C \times V^{1/3}$ where V is the volume of the balloon and C = 100 kPa/m. The balloon is blown up with air from a starting volume of 1 m^3 to a volume of 3 m^3. Find the work done by the air (in kJ) assuming it is at 25°C, correct up to 3 significant digits.

QUESTION = numeric, MARKS = 2

Water, assumed incompressible, flows steadily through the round pipe in the below figure. The entrance velocity is constant, $u = U_o$, and the exit velocity approximates turbulent flow,$u = u_{max}(1 - r/R)^{1/7}$. Determine the ratio U_o/u_{max} for this flow, correct up to 2 significant digits.



QUESTION = numeric, MARKS = 2

Ethanol is proposed as a fuel for an engine. What is the fuel-air ratio (mass flowrates) needed for stoichiometric combustion? Note that air has 3.76 moles of Nitrogen for every mole of Oxygen. Give your answer correct up to 2 significant digits.

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Sample Question Paper – Structures Specialization

QUESTION= module, COUNT=8, CATEGORY= Structures

The following question is from the STRUCTURES specialization (consisting of 8 questions worth a total of 15 marks).

QUESTION=numeric, MARKS=2

Given the following stress field in a thick cylinder

$$\sigma_{rr} = A + \frac{B}{r^2}, \qquad \sigma_{\theta\theta} = A - \frac{B}{r^2}$$

where *r* represents the radius and *A*, *B* are two arbitrary constants. All other stress components are zero. If the surface traction on the inner surface *r* = 1 is a uniform pressure 0.6 and the outer surface *r* = 2 is a free surface, find the constant *A*.

QUESTION= singlecorrect, MARKS=1

Which one is correct?

OPTIONS=

A. If displacements are given, compatibility conditions are required.
B. If strains are given, compatibility conditions are required.
C. Compatibility conditions are always required.
D. All are true.

QUESTION=numeric, MARKS=2

A rectangular parallelepiped is oriented such that its edges are parallel to the principal directions of strain. The strain tensor with respect to the Cartesian system is given by

$$\varepsilon_{ij} = \begin{bmatrix} 0.020 & -0.015 & 0.023 \\ -0.015 & -0.011 & 0.001 \\ 0.023 & 0.001 & 0.001 \end{bmatrix}$$

Find the dilatation (change in volume/initial volume) of the parallelepiped.

QUESTION= singlecorrect, MARKS=2

In a composite laminate subjected to a temperature rise of 30 deg Celsius during its operation, we would like to avoid the generation of moment forces [Mx, My, Mxy]. Which type of laminate would best suit the purpose?

OPTIONS=

A. [90/45/30/45/90]
B. [90/90/0/0]
C. [45/0/0/45]
D. [0/30/-30/90]

QUESTION= singlecorrect, MARKS=2

A beam with clamp support at one end and a roller support at the other end is subjected to a uniform through thickness temperature gradient with the top surface being at 75 deg Celsius and bottom surface being at 25 deg Celsius temperature. Assume the end face of the beam at the roller support end to be constrained to be flat. The beam will be

OPTIONS=

A. Stress free and strain free
B. Finite stress and finite strain
C. Stress free and a finite strain
D. Stress free and insufficient information to comment on strain state

QUESTION= singlecorrect, MARKS=2

Four planks of same material are simply placed on top of each other (assuming no friction between plank surfaces). This stack of planks is subjected to transverse loading at the midspan and the two ends are simply supported. Which of the following are TRUE?

OPTIONS=

A. Plank set will deform less than the case when they are bonded
B. The endfaces of the beam would not remain flat
C. Both the options of A and B are true

QUESTION= singlecorrect, MARKS=2

In pure torsion test of a cylindrical sample, as a test engineer, you have been asked to strain gage the cylindrical sample. You will place the strain gage

OPTIONS=

A. Along the longitudinal axis of the cylinder
B. Along the circumference of the cylindrical sample
C. At 45 deg angle to the longitudinal axis of the cylinder
D. All of A, B and C.

QUESTION= singlecorrect, MARKS=2

In an elastic-perfectly plastic material, beyond yield point, the material could be considered to be

OPTIONS=

A. Incompressible with Poisson ratio = 0.5
B. Not incompressible with Poisson ratio = 0.25
C. Not incompressible with Poisson ratio = 0
D. Compressible with Poisson ratio = 0

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