

**MECHANICAL ENGINEERING**

**Q. No. 1 – 25 Carry One Mark Each**

1. A motor driving a solid circular steel shaft transmits 40kW of power at 500 rpm. If the diameter of the shaft is 40 mm, the maximum shear stress in the shaft is \_\_\_\_\_MPa.

**Answer: (60 to 61)**

2. Consider the following partial differential equation for  $u(x,y)$  with the constant  $c > 1$  :

$$\frac{\partial u}{\partial y} + c \frac{\partial u}{\partial x} = 0$$

Solution of this equation is

(A)  $u(x,y) = f(x + cy)$

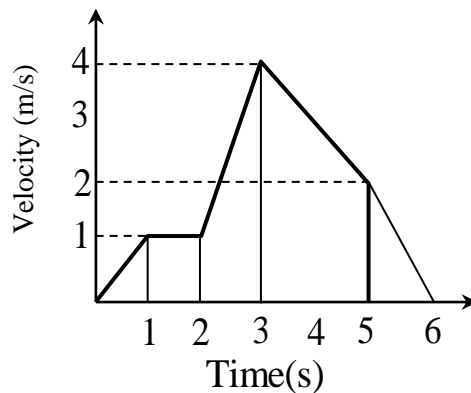
(B)  $u(x,y) = f(x - cy)$

(C)  $u(x,y) = f(cx + y)$

(D)  $u(x,y) = f(cx - y)$

**Answer: (B)**

3. The following figure shows the velocity- time plot for a particle traveling along a straight line. The distance covered by the particle from  $t = 0$  to  $t = 5$  s is \_\_\_\_\_m.



**Answer: (10 to 10)**

4. The damping ratio for a viscously damped spring mass system, governed by the relationship

$$m \frac{d^2x}{dt^2} + C \frac{dx}{dt} + kx = F(t), \text{ is given by}$$

- (A)  $\sqrt{\frac{c}{mk}}$                       (B)  $\frac{c}{2\sqrt{km}}$                       (C)  $\frac{c}{\sqrt{km}}$                       (D)  $\sqrt{\frac{c}{2mk}}$

**Answer: (B)**

5. The differential equation  $\frac{d^2y}{dx^2} + 16y = 0$  for  $y(x)$  with the two boundary conditions

$$\left. \frac{dy}{dx} \right|_{x=0} = 1 \text{ and } \left. \frac{dy}{dx} \right|_{x=\frac{\pi}{2}} = -1 \text{ has}$$

- (A) no solution    (B) exactly two solutions  
(C) exactly one solution                                      (D) infinitely many solutions

**Answer: (A)**

6. Metric thread of 0.8 mm pitch is to be cut on a lathe. Pitch of the lead screw is 1.5 mm. If the spindle rotates at 1500 rpm, the speed of rotation of the lead screw (rpm) will be \_\_\_\_\_

**Answer: (800 to 800)**

7. The molar specific heat at constant volume of an ideal gas is equal to 2.5 times the universal gas constant (8.314 J/mol.K). When the temperature increases by 100K, the change in molar specific enthalpy is \_\_\_\_\_ J/mol.

**Answer: (2908 to 2911)**

8. A particle of unit mass is moving on a plane. Its trajectory, in polar coordinates, is given by  $r(t) = t^2$ ,  $\theta(t) = t$ , where  $t$  is time. The kinetic energy of the particle at time  $t = 2$  is
- (A) 4                      (B) 12                      (C) 16                      (D) 24

**Answer: (C)**

9. The Poisson's ratio for a perfectly incompressible linear elastic material is
- (A) 1                      (B) 0.5                      (C) 0                      (D) infinity

**Answer: (B)**

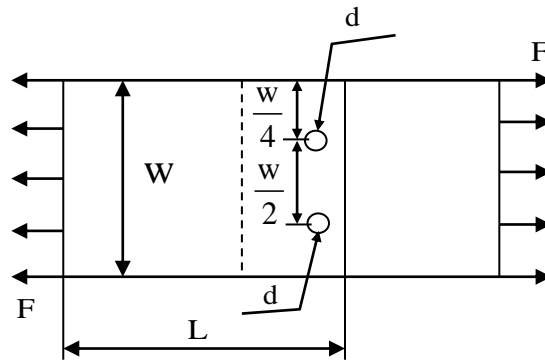
10. A heat pump absorbs 10 kW of heat from outside environment at 250 K while absorbing 15 kW of work. It delivers the heat to a room that must be kept warm at 300K. The Coefficient of Performance (COP) of the heat pump is \_\_\_\_\_.

**Answer: (1.66 to 1.70)**

11. Which one of the following is NOT a rotating machine?
- (A) Centrifugal pump                      (B) Gear pump  
(C) Jet pump                      (D) Vane pump

**Answer: (C)**

12. Consider the schematic of a riveted lap joint subjected to tensile load  $F$ , as shown below. Let  $d$  be the diameter of the rivets, and  $S_f$  be the maximum permissible tensile stress in the plates. What should be the minimum value for the thickness of the plates to guard against tensile failure of the plates? Assume the plates to be identical.



- (A)  $\frac{F}{S_f(W-2d)}$       (B)  $\frac{F}{S_f W}$       (C)  $\frac{F}{S_f(W-d)}$       (D)  $\frac{2F}{S_f W}$

**Answer: (A)**

- 13.** Water (density =  $1000 \text{ kg/m}^3$ ) at ambient temperature flows through a horizontal pipe of uniform cross section at the rate of  $1 \text{ kg/s}$ . If the pressure drop across the pipe is  $100 \text{ kPa}$ , the minimum power required to pump the water across the pipe, in watts, is \_\_\_\_\_.

**Answer: (100 to 100)**

- 14.** For steady flow of a viscous incompressible fluid through a circular pipe of constant diameter, the average velocity in the fully developed region is constant. Which one of the following statements about the average velocity in the developing region is TRUE?

- (A) It increases until the flow is fully developed.  
 (B) It is constant and is equal to the average velocity in the fully developed region.  
 (C) It decreases until the flow is fully developed.  
 (D) It is constant but always lower than the average velocity in the fully developed region.

**Answer: (B)**

15. Cylindrical pins of diameter  $15^{\pm 0.020}$  mm are being produced on a machine. Statistical quality control tests show a mean of 14.995 mm and standard deviation of 0.004mm. The process capability index  $C_p$  is
- (A) 0.833                      (B) 1.667                      (C) 3.333                      (D) 3.750

Answer: (B)

16. The product of Eigen values of the matrix P is  $P = \begin{bmatrix} 2 & 0 & 1 \\ 4 & -3 & 3 \\ 0 & 2 & -1 \end{bmatrix}$

(A) -6                      (B) 2                      (C) 6                      (D) -2

Answer: (B)

17. Match the processes with their characteristics.

Process	Characteristics
P: Electrical Discharge machining	1. No residual stress
Q: Ultrasonic machining	2. Machining of electrically conductive materials
R: Chemical machining	3. Machining of glass
S: Ion Beam Machining	4. Nano-machining

(A) P – 2, Q – 3, R – 1, S – 4                      (B) P – 3, Q – 2, R – 1, S – 4  
 (C) P – 3, Q – 2, R – 4, S – 1                      (D) P – 2, Q – 4, R – 3, S – 1

Answer: (A)

18. The Value of  $\lim_{x \rightarrow 0} \frac{x^3 - \sin(x)}{x}$  is

(A) 0                      (B) 3                      (C) 1                      (D) -1

Answer: (D)

**19.** In an arc welding process, welding speed is doubled. Assuming all other process parameters to be constant, the cross sectional area of the weld bead will

- (A) Increase by 25% (B) Increase by 50%  
(C) Reduce by 25% (D) Reduce by 50%

**Answer: (D)**

**20.** A six-face fair dice is rolled a large number of times. The mean value of the outcomes is \_\_\_\_\_.

**Answer: (3.5 to 3.5)**

**21.** Consider the two dimensional velocity field given by  $\vec{V} = (5 + a_1x + b_1y)\hat{i} + (4 + a_2x + b_2y)\hat{j}$ , where  $a_1, b_1, a_2$  and  $b_2$  are constants. Which one of the following conditions needs to be satisfied for the flow to be incompressible?

- (A)  $a_1 + b_1 = 0$  (B)  $a_1 + b_2 = 0$  (C)  $a_2 + b_2 = 0$  (D)  $a_2 + b_1 = 0$

**Answer: (B)**

**22.** Consider a beam with circular cross-section of diameter  $d$ . The ratio of the second moment of area about the neutral axis to the section modulus of the area is.

- (A)  $\frac{d}{2}$  (B)  $\frac{\pi d}{2}$  (C)  $d$  (D)  $\pi d$

**Answer: (A)**

**23.** Saturated steam at 100°C condenses on the outside of a tube. Cold fluid enters the tube at 20° C and exists at 50°C. The value of the Log Mean Temperature Difference (LMTD) is \_\_\_\_\_°C.

**Answer: (63.5 to 64)**

24. In a metal forming operation when the material has just started yielding, the principal stresses are  $\sigma_1 = +180 \text{ MPa}$ ,  $\sigma_2 = -100 \text{ MPa}$ ,  $\sigma_3 = 0$ . Following Von Mises criterion, the yield stress is \_\_\_\_\_ MPa.

Answer: (245 to 246)

25. In the engineering stress-strain curve for mild steel, the Ultimate Tensile Strength (UTS) refers to
- (A) Yield stress (B) Proportional limit
- (C) Maximum stress (D) Fracture stress.

Answer: (C)

Q. No. 26 to 55 Carry Two Marks Each

26. A parametric curve defined by  $x = \cos\left(\frac{\pi u}{2}\right)$ ,  $y = \sin\left(\frac{\pi u}{2}\right)$  in the range  $0 \leq u \leq 1$  is rotated about the X – axis by 360 degrees. Area of the surface generated is.

- (A)  $\frac{\pi}{2}$  (B)  $\pi$  (C)  $2\pi$  (D)  $4\pi$

Answer: (C)

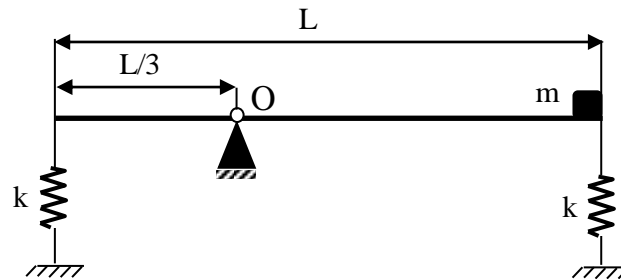
27. Assume that the surface roughness profile is triangular as shown schematically in the figure. If the peak to valley height is  $20 \mu\text{m}$ , The central line average surface roughness  $R_a$  (in  $\mu\text{m}$ ) is



- (A) 5 (B) 6.67 (B) 10 (D) 20

Answer: (A)

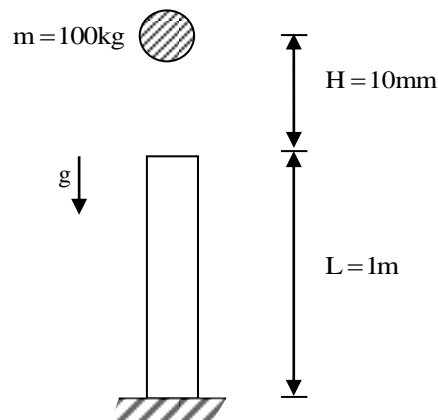
28. A thin uniform rigid bar of length  $L$  and mass  $M$  is hinged at point  $O$ , located at a distance of  $\frac{L}{3}$  from one of its ends. The bar is further supported using springs, each of stiffness  $k$ , located at the two ends. A particle of mass  $m = \frac{M}{4}$  is fixed at one end of the bar, as shown in the figure. For small rotations of the bar about  $O$ , the natural frequency of the systems is



- (A)  $\sqrt{\frac{5k}{M}}$  (B)  $\sqrt{\frac{5k}{2M}}$  (C)  $\sqrt{\frac{3k}{2M}}$  (D)  $\sqrt{\frac{3k}{M}}$

**Answer: (B)**

29. A point mass of 100 kg is dropped onto a massless elastic bar (cross-sectional area = 100 mm<sup>2</sup>, length = 1m, Young's modulus = 100 GPa) from a height  $H$  of 10mm as shown in the figure. (Figure is not to scale).



If  $g = 10\text{m/s}^2$ , the maximum compression of the elastic bar is \_\_\_\_\_ mm.

**Answer: (1.50 to 1.52)**



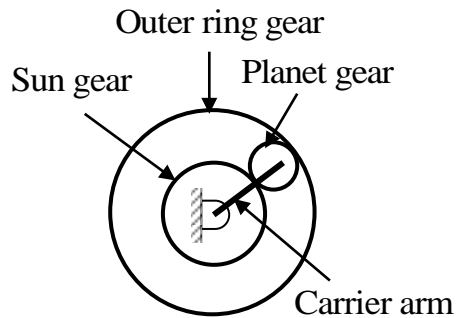
30. One kg of an ideal gas (gas constant,  $R = 400 \text{ J/kg.K}$ ; specific heat at constant volume,  $c_v = 1000 \text{ J/kg.K}$ ) at 1 bar, and 300 K is contained in a sealed rigid cylinder. During an adiabatic process, 100kJ of work is done on the system by a stirrer. The increase in entropy of the system is \_\_\_\_\_ J/K.

Answer: (286 to 288)

31. For an inline slider-crank mechanism, the lengths of the crank and connecting rod are 3m and 4m, respectively. At the instant when the connecting rod is perpendicular to the crank, if the velocity of the slider is 1m/s, the magnitude of angular velocity (upto 3 decimal points accuracy) of the crank is \_\_\_\_\_ radian/s.

Answer: (0.26 to 0.27)

32. In an epicyclic gear train, shown in the figure, the outer ring gear is fixed, while the sun gear rotates counterclockwise at 100rpm. Let the number of teeth on the sun, planet and outer gears to be 50, 25, and 100, respectively.



The ratio of magnitudes of angular velocity of the planet gear to the angular velocity of the carrier arm is \_\_\_\_\_.

Answer: (3 to 3)

- 33.** Moist air is treated as an ideal gas mixture of water vapor and dry air (molecular weight of air = 28.84 and molecular weight of water = 18). At a location, the total pressure is 100 kPa, the temperature is 30°C and the relative humidity is 55%. Given that the saturation pressure of water at 30°C is 4246 Pa, the mass of water vapor per kg of dry air is \_\_\_\_\_ grams.

**Answer:** (14.7 to 15.1)

- 34.** Following data refers to the jobs (P, Q, R, S) which have arrived at a machine for scheduling. The shortest possible average flow time is \_\_\_\_\_ days.

Job	Processing Time (days)
P	15
Q	9
R	22
S	12

**Answer:** (31) (not matching with IIT key)

- 35.** Two models, P and Q, of a product earn profits of Rs. 100 and Rs. 80 per piece, respectively. Production times for P and Q are 5 hours and 3 hours, respectively, while the total production time available is 150 hours. For a total batch size of 40, to maximize profit, the number of units of P to be produced is \_\_\_\_\_.

**Answer:** (15 to 15)

36. Circular arc on a part profile is being machined on a vertical CNC milling machine. CNC part program using metric units with absolute dimensions is listed below:

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N60 G01 X 30 Y 55 Z -5 F 50
N70 G02 X 50 Y 35 R 20
N80 G01 Z 5
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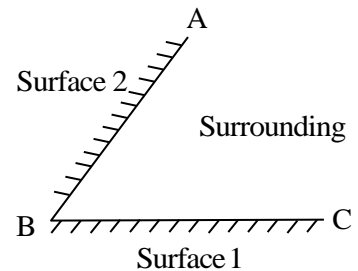
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The coordinates of the centre of the circular arc are:

- (A) (30, 55)                      (B) (50, 55)                      (C) (50, 35)                      (D) (30, 35)

**Answer: (D)**

37. Two black surfaces, AB and BC, of lengths 5m and 6m, respectively, are oriented as shown. Both surfaces extend infinitely into the third dimension. Given that view factor  $F_{12}=0.5$ ,  $T_1=800\text{K}$ ,  $T_2=600\text{K}$ ,  $T_{\text{surrounding}}=300\text{K}$  and Stefan Boltzmann constant,  $\sigma=5.67 \times 10^{-8} \text{ W / (m}^2\text{K}^4\text{)}$ , the heat transfer rate from Surface 2 to the surrounding environment is \_\_\_\_\_ kW.



**Answer: (13.7 to 13.9) (Marks to all)**

38. Consider the matrix  $P = \begin{bmatrix} \frac{1}{\sqrt{2}} & 0 & \frac{1}{\sqrt{2}} \\ 0 & 1 & 0 \\ -\frac{1}{\sqrt{2}} & 0 & \frac{1}{\sqrt{2}} \end{bmatrix}$ .

Which one of the following statements about P is INCORRECT?

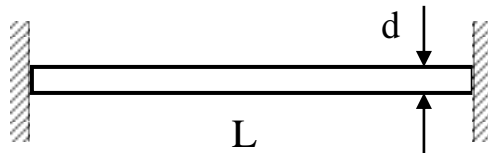
- (A) Determinant of P is equal to 1.  
 (B) P is orthogonal.  
 (C) Inverse of P is equal to its transpose.  
 (D) All Eigen values of P are real numbers

**Answer: (D)**

39. The Pressure ratio across a gas turbine (for air, specific heat at constant pressure,  $c_p = 1040 \text{ J/kg.K}$  and ratio of specific heats,  $\gamma = 1.4$ ) is 10. If the inlet temperature to the turbine is 1200K and the isentropic efficiency is 0.9, the gas temperature at turbine exit is \_\_\_\_\_ K.

Answer: (675 to 684)

40. An initially stress-free massless elastic beam of length  $L$  and circular cross-section with diameter  $d$  ( $d \ll L$ ) is held fixed between two walls as shown. The beam material has Young's modulus  $E$  and coefficient of thermal expansion  $\alpha$ .



If the beam is slowly and uniformly heated, the temperature rise required to cause the beam to buckle is proportional to

- (A)  $d$  (B)  $d^2$  (C)  $d^3$  (D)  $d^4$

Answer: (B)

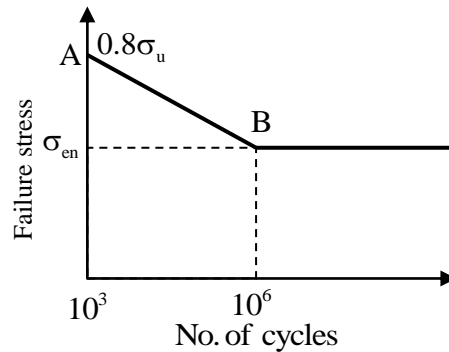
41. For the vector  $\vec{V} = 2yz\hat{i} + 3xz\hat{j} + 4xy\hat{k}$ , the value of  $\nabla \cdot (\nabla \times \vec{V})$  is \_\_\_\_\_

Answer: (0 to 0)

42. A 10 mm deep cylindrical cup with diameter of 15mm is drawn from a circular blank. Neglecting the variation in the sheet thickness, the diameter (upto 2 decimal points accuracy) of the blank is \_\_\_\_\_ mm.

Answer: (28.71 to 28.73)

43. A machine element has an ultimate strength ( $\sigma_u$ ) of 600 N/mm<sup>2</sup>, and endurance limit ( $\sigma_{en}$ ) of 250 N/mm<sup>2</sup>. The fatigue curve for the element on log-log plot is shown below.



If the element is to be designed for a finite of 10000 cycles, the maximum amplitude of a completely reversed operating stress is \_\_\_\_\_ N/mm<sup>2</sup>.

**Answer: (370 to 390)**

44. A sprue in a sand mould has a top diameter of 20mm and height of 200mm. The velocity of the molten metal at the entry of the sprue is 0.5m/s. Assume acceleration due to gravity as 9.8 m/s<sup>2</sup> and neglect all losses. If the mould is well ventilated, the velocity (upto 3 decimal points accuracy) of the molten metal at the bottom of the sprue is \_\_\_\_\_ m/s.

**Answer: (2.04 to 2.07)**

45. Air contains 79% N<sub>2</sub> and 21% O<sub>2</sub> on a molar basis. Methane (CH<sub>4</sub>) is burned with 50% excess air than required stoichiometrically. Assuming complete combustion of methane, the molar percentage of N<sub>2</sub> in the products is \_\_\_\_\_

**Answer: (73 to 74)**

**46.** P(0,3), Q(0.5, 4), and R (1,5) are three points on the curve defined by f(x). Numerical integration is carried out using both Trapezoidal rule and Simpson's rule within limits  $x = 0$  and  $x = 1$  for the curve. The difference between the two results will be.

- (A) 0                      (B) 0.25                      (C) 0.5                      (D) 1

**Answer: (A)**

**47.** Heat is generated uniformly in a long solid cylindrical rod (diameter = 10mm) at the rate of  $4 \times 10^7 \text{ W/m}^3$ . The thermal conductivity of the rod material is  $25 \text{ W/m.K}$ . Under steady state conditions, the temperature difference between the centre and the surface of the rod is \_\_\_\_\_  $^{\circ}\text{C}$ .

**Answer: (10 to 10)**

**48.** Two disks A and B with identical mass (m) and radius (R) are initially at rest. They roll down from the top of identical inclined planes without slipping. Disk A has all of its mass concentrated at the rim, while Disk B has its mass uniformly distributed. At the bottom of the plane, the ratio of velocity of the center of disk A to the velocity of the center of disk B is.

- (A)  $\sqrt{\frac{3}{4}}$                       (B)  $\sqrt{\frac{3}{2}}$                       (C) 1                      (D)  $\sqrt{2}$

**Answer: (A)**

**49.** A block of length 200mm is machined by a slab milling cutter 34mm in diameter. The depth of cut and table feed are set at 2mm and 18mm/minute, respectively. Considering the approach and the over travel of the cutter to be same, the minimum estimated machining time per pass is \_\_\_\_\_ minutes.

**Answer: (12 to 12)**

- 50.** A horizontal bar, fixed at one end ( $x = 0$ ), has a length of 1 m, and cross-sectional area of  $100\text{mm}^2$ . Its elastic modulus varies along its length as given by  $E(x) = 100e^{-x}$  GPa, Where  $x$  is the length coordinate (in m) along the axis of the bar. An axial tensile load of 10 kN is applied at the free end ( $x=1$ ). The axial displacement of the free end is \_\_\_\_\_ mm.

**Answer:** (1.70 to 1.72)

- 51.** Consider steady flow of an incompressible fluid through two long and straight pipes of diameters  $d_1$  and  $d_2$  arranged in series. Both pipes are of equal length and the flow is turbulent in both pipes. The friction factor for turbulent flow through pipes is of the form,  $f = K(\text{Re})^{-n}$  where  $K$  and  $n$  are known positive constants and  $\text{Re}$  is the Reynolds number. Neglecting minor losses, the ratio of the frictional pressure drop in pipe 1 to that in pipe 2,  $\left(\frac{\Delta P_1}{\Delta P_2}\right)$ , is given by

(A)  $\left(\frac{d_2}{d_1}\right)^{(5-n)}$       (B)  $\left(\frac{d_2}{d_1}\right)^5$       (C)  $\left(\frac{d_2}{d_1}\right)^{(3-n)}$       (D)  $\left(\frac{d_2}{d_1}\right)^{(5+n)}$

**Answer:** (A)

- 52.** The velocity profile inside the boundary layer for flow over a flat plate is given as  $\frac{u}{U_\infty} = \sin\left(\frac{\pi y}{2\delta}\right)$ , where  $U_\infty$  is the free stream velocity and  $\delta$  is the local boundary layer thickness. If  $\delta^*$  is the local displacement thickness, the value of  $\frac{\delta^*}{\delta}$  is

(A)  $\frac{2}{\pi}$       (B)  $1 - \frac{2}{\pi}$       (C)  $1 + \frac{2}{\pi}$       (D) 0

**Answer:** (B)

53. For a steady flow, the velocity field is  $\vec{V} = (-x^2 + 3y)\hat{i} + (2xy)\hat{j}$ . The magnitude of the acceleration of a particle at (1, -1) is
- (A) 2                      (B) 1                      (C)  $2\sqrt{5}$                       (D) 0

**Answer: (C)**

54. Two cutting tools with tool life equations given below are being compared:

Tool 1:  $VT^{0.1} = 150$

Tool 2:  $VT^{0.3} = 300$

Where V is cutting speed in m/minute and T is tool life in minutes. The breakeven cutting speed beyond which Tool 2 will have a higher tool life is \_\_\_\_\_ m/minute.

**Answer: (105 to 107)**

55. A rectangular region in a solid is in a state of plane strain. The (x,y) coordinates of the corners of the under deformed rectangle are given by P(0,0), Q (4,0), S (0,3). The rectangle is subjected to uniform strains,  $\epsilon_{xx} = 0.001$ ,  $\epsilon_{yy} = 0.002$ ,  $\gamma_{xy} = 0.003$ . The deformed length of the elongated diagonal, up to three decimal places, is \_\_\_\_\_ units.

**Answer: (5.013 to 5.015)**