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PTQ

Prelims Through Questions

for

ESE 2021

Mechanical Engineering

Day 9 of 11

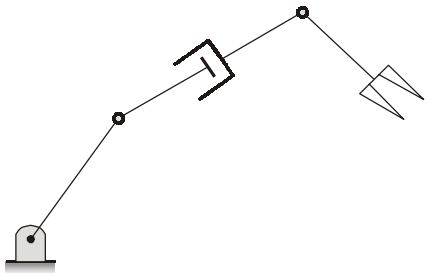
Q.361 - Q.410

(Out of 500 Questions)

Robotics + Mechatronics + Heat Transfer

Robotics + Mechatronics + Heat Transfer

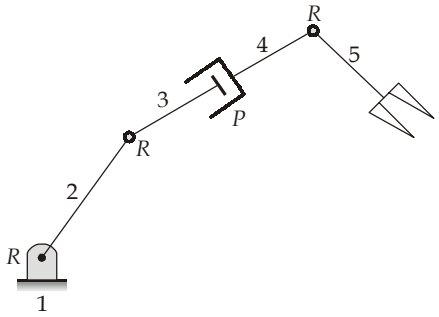
Q.361 What will be the degree of freedom for the given serial planar manipulator?



(a) 3 (b) 4
(c) 5 (d) 6

361. (b)

As shown below for serial manipulator



n = Number of link = 5
C_i = Connectivity of i-th joint i = 1, 2, 3, ... m
$(3 - C_i)$ = Number of constraints by i-th joint
$C_1 = 1, C_2 = 1, C_3 = 1, C_4 = 1$

So, from Grubler's criterion for planar manipulator.

$$\text{DOF} = 3(n-1) - \sum_{i=1}^{i=m}(3 - C_i)$$

$$= 3(5 - 1) - (3 - C_1) - (3 - C_2) - (3 - C_3) - (3 - C_4)$$

$$= 3 \times 4 - 2 - 2 - 2 - 2 = 12 - 8 = 4$$

Q.362 Consider the following statements regarding function of Register Array in Microprocessor.

1. They act as small storage devices that are available to CPU or processors.
2. They act as temporary storage for processing of intermediate data by mathematical or logical operations.

Which of the above statements is(are) correct?

(a) 1 only (b) 2 only
(c) Both 1 and 2 (d) Neither 1 nor 2

362. (c)

Register Array:

- Registers are small storage devices that are available to CPU or processors.
- They act as temporary storage for processing of intermediate data by mathematical or logical operations.

Q.363 Consider the following statements regarding sensors:

1. It is an element which produces signal relating to the quantity being measured.
2. A device which provides a usable output in response to a specified measurand.
3. It is a device that converts a signal from one form of energy to another form of energy.

Which of the above statements is(are) correct?

(a) 2 and 3 (b) 1 and 3 only
(c) 3 only (d) 1 and 2 only

363. (d)

Sensor is defined as an element which produces signal relating to the quantity being measured. According to the Instrument Society of America, sensor can be defined as "A device which provides a usable output in response to a specified measurand."

Transducer can be defined as a device that converts a signal from one form of energy to another form of energy.

Q.364 Consider the following statements regarding mechatronics based systems:

1. These systems certainly ensure to supply better quality, well packed and reliable products in the market.
2. Use of CAD–CAE tools saves significant time in comparison with that required in the conventional sequential design process.
3. Control engineering helps in the development of various electronics-based control systems to enhance or replace the mechanics of the mechanical systems.

Which of the above statements is(are) correct?

(a) 1, 2 and 3 (b) 1 and 3 only
(c) 3 only (d) 1 and 2 only

364. (a)

Mechatronics based automated systems such as automatic inspection and quality assurance, automatic packaging, record making, and automatic dispatch help to expedite the entire manufacturing operation. These systems certainly ensure a supply better quality, well packed and reliable products in the market.

Automation in the machine tools has reduced the human intervention in the machining operation and improved the process efficiency and product quality.

CAD-CAE generated final designs are then sent to the production and process planning section. Mechatronics based systems such as computer aided manufacturing (CAM): automatic process planning, automatic part programming, manufacturing resource planning, etc. uses the design data provided by the design team.

Q.365 Rotation matrix ROT (x, θ) is represented as:

(a) $\begin{bmatrix} \cos\theta & -\sin\theta & 0 \\ \sin\theta & \cos\theta & 0 \\ 0 & 0 & 1 \end{bmatrix}$

(b) $\begin{bmatrix} \cos\theta & 0 & \sin\theta \\ 0 & 1 & 0 \\ -\sin\theta & 0 & \cos\theta \end{bmatrix}$

(c) $\begin{bmatrix} 1 & 0 & 0 \\ 0 & \cos\theta & -\sin\theta \\ 0 & \sin\theta & \cos\theta \end{bmatrix}$

(d) None of the above

365. (c)

Q.366 According to Denavit-Hartenberg notations, length of link is defined as the

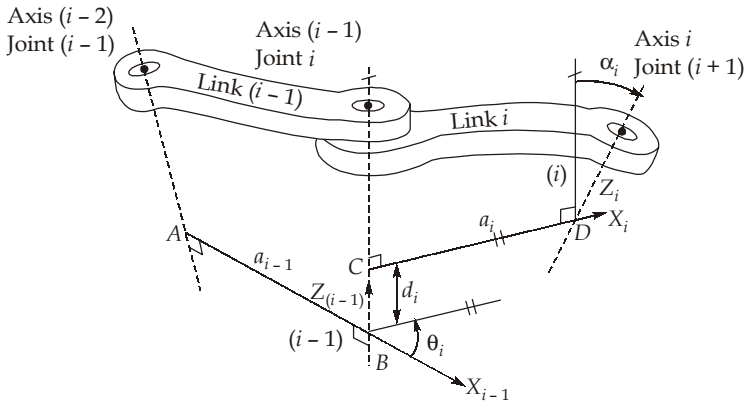
(a) Mutual perpendicular distance between two X axes measured along Z axis.

(b) Mutual perpendicular distance between two Y axes measured along Z axis.

(c) Mutual perpendicular distance between two Z axes measured along X axis

(d) Mutual perpendicular distance between two Z axes measured along Y axis

366. (c)



DH convention for assigning frames to links and identifying joint-link parameters

Link length (a_i) - distance measured along X_i-axis from the point of intersection of X_i-axis with Z_{i-1}-axis (point C) to the origin of frame (i), that is, distance CD. Therefore mutual perpendicular distance between two Z axes measured along X axis.

Q.367 The purpose of Robot Kinematics is to:

(a) Study the nature of robotic joints.

(b) Study the relative motion of different links.

(c) Determine the joint torques of a robot.

(d) Find collision-free path for the robot

367. (b)

The purpose of kinematics is to study the relative motion of the robotic link, but we do not try to find out the reason behind this particular motion.

Q.368 Which one of the following statements is TRUE?

(a) Unimate 2000 is a point-to-point robot but PUMA is a continuous path robot

(b) Unimate 2000 is a continuous path robot but PUMA is a point-to-point robot

(c) Both Unimate 2000 and PUMA are point-to-point robots

(d) Both Unimate 2000 and PUMA are continuous path robots

368. (a)

Unimate 2000 is a point-to-point robot but PUMA is a continuous path robot

Q.369 Consider the following statements regarding functions of Microprocessor.

1. Microprocessor performs a variety of logical and mathematical operations using its ALU.
2. It controls data flow in a system. It can transfer data from one location to another based on the instructions given to it.
3. A microprocessor can take necessary decisions and jump to a new set of instructions based on those decisions.

Which of the statements given above is/ are correct?

(a) 2 only (b) 1, 2 and 3

(c) 2 and 3 only (d) 1 and 2 only

369. (b)

Functions of microprocessor

- Microprocessor performs a variety of logical and mathematical operations using its ALU.
- It controls data flow in a system and hence can transfer data from one location to another based on the instructions given to it.
- A microprocessor can take necessary decisions and jump to a new set of instructions based on those decisions.

Q.370 Consider the following statements regarding Register Array of Internal Architecture of 8085 Microprocessor.

1. 8085 Microprocessor consists of six general purpose registers, one accumulator and a flag register.
2. There are 5 general-purpose registers B, C, E, H, and L each having capacity to store 8 bit data.
3. The 'program counter' is employed to sequence the execution of instructions

Which of the statements given above are correct?

(a) 1 and 3 only (b) 2 only

(c) 1 and 2 only (d) 3 only

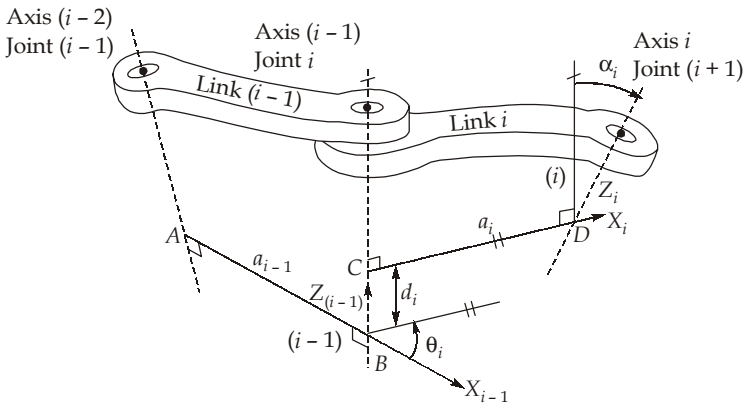
370. (a)

Register Array

8085 Microprocessor consists of six registers, one accumulator and a flag register. There are six general-purpose registers B, C, D, E, H, and L each having capacity to store 8 bit data. They are combined as BC, DE, and HL to perform 16 bit operations. In addition to this Register array, two 16 bit registers viz. stack register and program counter are provided. The 'program counter' is employed to sequence the execution of instructions. It always points to the memory address from which the next byte is to be fetched.

Q.371 According to Denavit-Hartenberg's notations, joint angle can have
(a) positive value only
(b) negative value only
(c) zero value only
(d) either positive or negative or zero value

371. (d)



DH convention for assigning frames to links and identifying joint-link parameters

It is the angle between x_{i-1} and x_i-axes measured about z_{i-1}-axis in the right hand sense. It can have positive or negative or zero value.

Q.372 The coordinate of point P in frame (1) are $[3.0, 2.0, 1.0]^T$. The position vector P is rotated about the z-axis by 45°. What will be the coordinate of point Q, the new position of point P?
(a) $[3.535 \quad 0.707 \quad 1.0]^T$

(b) $\begin{bmatrix} 1.0 \\ 0.707 \\ 3.535 \end{bmatrix}$

(c) $\begin{bmatrix} 0.707 \\ 3.535 \\ 1.0 \end{bmatrix}$

(d) $[3.535 \quad 1.0 \quad 0.707]^T$

372. (c)

The coordinate of the new point Q relative to the frame 1.

$$^1Q = Rz(45°)\,^1P$$

$$^1Q = \begin{bmatrix} \cos 45° & -\sin 45° & 0 \\ \sin 45° & \cos 45° & 0 \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} 3 \\ 2 \\ 1 \end{bmatrix}$$

$$= \begin{bmatrix} 0.707 & -0.707 & 0 \\ 0.707 & 0.707 & 0 \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} 3 \\ 2 \\ 1 \end{bmatrix} = \begin{bmatrix} 0.707 \\ 3.535 \\ 1 \end{bmatrix}$$

Q.373 Consider the following statements about Denavit-Hartenberg (DH) notation:

1. An n-DOF manipulator will have (n) frames with the frame {0} or base frame acting as the reference inertial frame and frame {n} being the "tool frame".
2. There are four DH parameters: two link parameters (a_i, α_i) and two joint parameters (d_i, θ_i)

Select the correct answer using the codes given below:

(a) 1 only (b) 2 only
(c) Both 1 and 2 (d) Neither 1 nor 2

373. (b)

- An n-DOF manipulator will have (n + 1) frames with the frame {0} or base frame acting as the reference inertial frame and frame {n} being the "tool frame".
- There are four DH-Parameters.
  (a) Link length (a_i)
  (b) Link twist angle (α_i)
  (c) Joint distance (d_i)
  (d) Joint angle (θ_i)

Q.374 Consider the following statements about variable reluctance stepper motor:

1. It has a permanent magnet on the rotor.
2. The large difference in magnetic reluctances that exist between the direct and quadrature axes develop torque.

Select the correct answer using the codes given below:

(a) 1 only (b) 2 only
(c) Both 1 and 2 (d) Neither 1 nor 2

374. (b)

- A variable- reluctance stepper motor has no permanent magnet on the rotor and the rotor employed is a ferro-magnetic multi-toothed one.
- The stationary field developed by the direct current in some stator coils tends to develop a torque which causes the rotor to move to the position where the reluctance of the flux path is minimum. It has low torque.

Q.375 Consider the following statements about manipulator in robotics:

1. A manipulator with 6-DOF is called a spatial manipulator.
2. A spatial manipulator with more than 6-DOF is known as redundant manipulator.
3. A planer manipulator can only sweep a 2-D space or a plane and can have any number of degree of freedom.

Select the correct answer using the codes given below:

(a) 1 and 2 (b) 2 and 3
(c) 1 and 3 (d) 1, 2 and 3

375. (d)

- A manipulator with less than 6-DOF has constrained motion in 3-D space.
- Spatial manipulator with more than 6-DOF having surplus joints are known as redundant manipulators. The extra DOF may enhance the performance by addition to its dexterity.

Q.376 Consider the following statements about robot programming:

1. In on-line programming, the manipulator executes the commands as soon as it is entered and the programmer can verify whether robot executes the desired task.
2. In off-line programming, the robot is not tied-up and can continue doing its task i.e. there is no loss of production.

Select the correct answer using the codes given below:

(a) 1 only (b) 2 only

(c) Both 1 and 2 (d) Neither 1 nor 2

376. (c)

- One of the advantage of on-line programming is that if any discrepancy is found, then it can be corrected immediately.
- In off-line and on-line programming after the program is complete, it is saved and the robot executes it in the 'run' mode relentlessly.

Q.377 In homogeneous transformation matrix

$$^{2}T_{1} = \left[\begin{array}{c|c} {}^{2}R_{1} & {}^{2}D_{1} \\ \hline 0\ 0\ 0 & 1 \end{array}\right]$$

Where $^{2}R_{1}$ and $^{2}D_{1}$ is rotational transformation matrix and translation vector respectively. Then $^{1}T_{2}$ is represented by

(a) $\left[\begin{array}{c|c} {}^{2}R_{1}^{T} & {}^{2}R_{1}^{T}\,{}^{2}D_{1} \\ \hline 0\ 0\ 0 & 1 \end{array}\right]$ (b) $\left[\begin{array}{c|c} {}^{2}R_{1}^{T} & -{}^{2}R_{1}^{T}\,{}^{2}D_{1} \\ \hline 0\ 0\ 0 & 1 \end{array}\right]$

(c) $\left[\begin{array}{c|c} {}^{1}R_{2}^{T} & -{}^{1}R_{2}^{T}\,{}^{1}D_{2} \\ \hline 0\ 0\ 0 & 1 \end{array}\right]$ (d) $\left[\begin{array}{c|c} {}^{1}R_{2}^{T} & {}^{1}R_{2}^{T}\,{}^{1}D_{2} \\ \hline 0\ 0\ 0 & 1 \end{array}\right]$

377. (b)

Q.378 Consider the following statements regarding robotics:

1. All rotational transformation matrix are orthogonal matrix.
2. For any rotational transformation matrix ($R^{-1} = R^{T}$)
3. For any rotational transformation matrix ($RR^{T} = I$)
4. Scale factor (σ) > 1 is used for enlarging and σ < 1 is used for reducing.

Which of the above statement is/are correct?

(a) 1 and 2 (b) 1, 2 and 3

(c) 2, 3 and 4 (d) 1, 2, 3 and 4

378. (b)

Q.379 Consider 2 frames x, y, z and u, v, w with a common origin. Let there be a point P in the space such that ^1P and ^2P represent position vector of point P with respect to x, y, z and u, v, w frame respectively.

Given: $^2P = {}^2R_1[^1P]$

Where $^2R_1$ is the rotation matrix. Then $^2R_1$ can be written as

(a) $\begin{bmatrix} \hat{u}\cdot\hat{x} & \hat{u}\cdot\hat{y} & \hat{u}\cdot\hat{z} \\ \hat{v}\cdot\hat{x} & \hat{v}\cdot\hat{y} & \hat{v}\cdot\hat{z} \\ \hat{w}\cdot\hat{x} & \hat{w}\cdot\hat{y} & \hat{w}\cdot\hat{z} \end{bmatrix}$ (b) $\begin{bmatrix} \hat{x}\cdot\hat{u} & \hat{x}\cdot\hat{v} & \hat{x}\cdot\hat{w} \\ \hat{y}\cdot\hat{u} & \hat{y}\cdot\hat{v} & \hat{y}\cdot\hat{w} \\ \hat{z}\cdot\hat{u} & \hat{z}\cdot\hat{v} & \hat{z}\cdot\hat{w} \end{bmatrix}$

(c) $\begin{bmatrix} \hat{x}\cdot\hat{w} & \hat{x}\cdot\hat{v} & \hat{x}\cdot\hat{u} \\ \hat{y}\cdot\hat{w} & \hat{y}\cdot\hat{v} & \hat{y}\cdot\hat{u} \\ \hat{z}\cdot\hat{w} & \hat{z}\cdot\hat{v} & \hat{z}\cdot\hat{u} \end{bmatrix}$ (d) $\begin{bmatrix} \hat{x}\cdot\hat{u} & \hat{x}\cdot\hat{w} & \hat{x}\cdot\hat{v} \\ \hat{y}\cdot\hat{u} & \hat{y}\cdot\hat{w} & \hat{y}\cdot\hat{v} \\ \hat{z}\cdot\hat{u} & \hat{z}\cdot\hat{w} & \hat{z}\cdot\hat{v} \end{bmatrix}$

379. (a)

$$^1R_2 = \begin{bmatrix} \hat{x}\cdot\hat{u} & \hat{x}\cdot\hat{v} & \hat{x}\cdot\hat{w} \\ \hat{y}\cdot\hat{u} & \hat{y}\cdot\hat{v} & \hat{y}\cdot\hat{w} \\ \hat{z}\cdot\hat{u} & \hat{z}\cdot\hat{v} & \hat{z}\cdot\hat{w} \end{bmatrix}$$

$$^2R_1 = [^1R_2]^T = [^1R_2]^{-1} = \begin{bmatrix} \hat{u}\cdot\hat{x} & \hat{u}\cdot\hat{y} & \hat{u}\cdot\hat{z} \\ \hat{v}\cdot\hat{x} & \hat{v}\cdot\hat{y} & \hat{v}\cdot\hat{z} \\ \hat{w}\cdot\hat{x} & \hat{w}\cdot\hat{y} & \hat{w}\cdot\hat{z} \end{bmatrix}$$

Q.380 Which of the following is a 16-bit register used to hold the memory address of the next instruction to be executed?

(a) Stack pointer (b) Program counter
(c) Accumulator (d) Flag register

380. (b)

The program counter (PC) holds the address of the next instruction to be executed, while the instruction register (IR) holds the encoded instruction

Q.381 Consider the following statements for PLC:

1. The interfacing for inputs and outputs is inside the controller.
2. They are hard to program.
3. They are usually programmed with 'Ladder logic'.
4. Input/output must be in digital signal.

Which of the above statements is incorrect?

(a) 1, 3 and 4 (b) 2, 3 and 4
(c) 1, 2 and 4 (d) 2 and 4 only

381. **(d)**

Ladder logic has evolved into a programming language that represents a program by a graphical diagram based on the circuit diagrams of relay logic hardware. Ladder logic is used to develop software for programmable logic controllers (PLCs) used in industrial control applications.

- PLC are easier to programme.
- Input/output can be both analog and digital signals.

Q.382 Which of the following can be matrix representation of a frame?

(a) $\begin{bmatrix} 0.707 & 0 & 1 & 5 \\ 1 & 0 & -0.707 & 3 \\ 0 & 1 & 0 & 2 \\ 0 & 0 & 0 & 1 \end{bmatrix}$ (b) $\begin{bmatrix} 0.707 & 0 & 0.707 & 5 \\ 0.707 & 0 & -0.707 & 3 \\ 0 & 0.707 & 0 & 2 \\ 0 & 0 & 0 & 1 \end{bmatrix}$

(c) $\begin{bmatrix} 0.707 & 0 & 0.707 & 5 \\ 0.707 & 0 & -0.707 & 3 \\ 0 & 1 & 0 & 2 \\ 0 & 0 & 0 & 1 \end{bmatrix}$ (d) $\begin{bmatrix} 0.707 & 0 & -0.707 & 5 \\ 0.707 & 0 & -0.707 & 3 \\ 0 & 1 & 0 & 2 \\ 0 & 0 & 0 & 1 \end{bmatrix}$

382. **(c)**

$$F = \begin{bmatrix} n_x & o_x & a_x & p_x \\ n_y & o_y & a_y & p_y \\ n_z & o_z & a_z & p_z \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

$$n = \begin{bmatrix} n_x \\ n_y \\ n_z \end{bmatrix}, \quad o = \begin{bmatrix} o_x \\ o_y \\ o_z \end{bmatrix}, \quad a = \begin{bmatrix} a_x \\ a_y \\ a_z \end{bmatrix}$$

For a frame the following condition must be satisfied,

$n.o = n.a = a.o = 0$

and $|n| = |a| = |o| = 1$

Only c satisfies these conditions.

Q.383 Consider the following statements regarding sensors:

1. This is a device which responds to a change in physical phenomena.
2. Sensors are transducers when they sense one form of energy as input and produce output in a different form of energy

Select the correct statement using codes given below:

(a) 1 only (b) 2 only

(c) both 1 and 2 (d) neither 1 nor 2

383. **(c)**

Sensor is a device that when exposed to a physical phenomenon (temperature, displacement, force, etc.) produces a proportional output signal (electrical, mechanical, magnetic, etc.). The term transducer is often used synonymously with sensors.

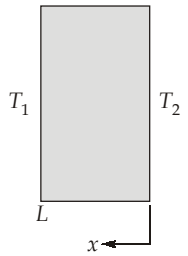
Q.384 A programmable logic controller (PLC) normally replaces which one of the following in control applications?

(a) Computer numerical control
(b) Distributed process control
(c) Industrial robots
(d) Relay control panel

384. (d)

Programming a PLC is easier than wiring a relay control panel.

Q.385 Consider steady-state conditions for one-dimensional conduction in a plane wall having a thermal conductivity of 25 W/mK and a thickness L as 0.5 m, with no internal heat generation. When the temperature at both surfaces are T_1 = 400 K and T_2 = 300 K, then the heat flux will be:



(a) 200 W/m^2
(b) +5000 W/m^2
(c) –200 W/m^2
(d) –5000 W/m^2

385. (d)

Given: $T(0) = T_2 = 300$ K, $T(L) = T_1 = 400$ K

By Fourier's law of conduction,

$$\text{Heat flux, } q'' = -k\frac{dT}{dx}$$

where, $$\frac{dT}{dx} = \frac{T(L)-T(0)}{L}$$

Now, $$\frac{dT}{dx} = \frac{T_1 - T_2}{L} = \frac{400-300}{0.5} = \frac{100}{0.5} = 200 \text{ K/ m}$$

$$q'' = -25 \times 200 = -5000 \text{ W/m}^2$$

Q.386 A furnace of spherical shape is losing heat steadily and uniformly from its outer surface of radius R to the very near ambient at temperature T_∞ with convection coefficient of h and to the surrounding surfaces at temperature T_{surr}. Which of following is the correct boundary condition at the outer surface of furnace maintained at the temperature T_o?

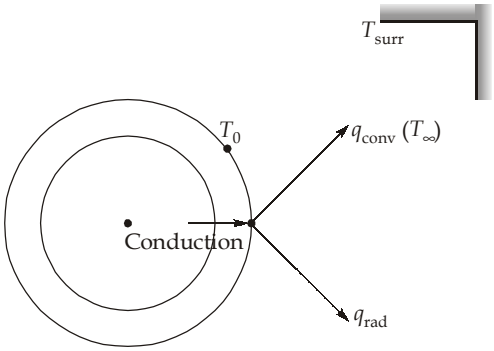
(a) $$-k\frac{dT}{dr}\bigg|_{r=R} = h(T_o - T_\infty) + \in \sigma\left(T_o^4 - T_{surr}^4\right)$$

(b) $$-k\frac{dT}{dr}\bigg|_{r=R} = h(T_o - T_\infty) - \in \sigma\left(T_o^4 - T_{surr}^4\right)$$

(c) $k\left.\frac{dT}{dr}\right|_{r=R} = h(T_o - T_\infty) + \in \sigma\left(T_o^4 - T_{surr}^4\right)$

(d) $-k\left.\frac{dT}{dr}\right|_{r=R} = h(T_o - T_\infty) + \in \sigma\left(T_o^4 - T_\infty^4\right)$

386. (a)



$$(q_{cond})_{at\ surface} = q_{conv.} + q_{rad.}$$

$$-k\left.\frac{dT}{dr}\right|_{r=R} = h(T_o - T_\infty) + \in \sigma\left(T_o^4 - T_{surr}^4\right)$$

Q.387 Two finned surfaces with long fins are identical, except that the convection heat transfer coefficient for first fin is half that of second fin. Which statement below is accurate for efficiency and effectiveness of the first finned surface relative to second one?

(a) Higher efficiency and higher effectiveness.
(b) Higher efficiency but lower effectiveness.
(c) Lower efficiency but higher effectiveness.
(d) Equal efficiency but higher effectiveness.

387. (a)

$$h_1 = \frac{h_2}{2}$$

$\therefore$ $h_1 < h_2$

$$\text{Effectiveness, } \varepsilon_f = \left(\frac{kP}{hA}\right)^{1/2}$$

$$\text{Efficiency, } \eta_f = \frac{1}{mL} = \frac{1}{\left(\frac{hP}{kA}\right)^{1/2} \times L}$$

$\therefore$ Both $\in_f$ and η_f is inversely proportional to $h^{1/2}$.

$\therefore (\in_{f1} > \in_{f2})$ and $(\eta_{f1} > \eta_{f2})$

Q.388 A flat plate is suspended in a room, and is subjected to air flow parallel to its surface with free stream temperature and velocity are 20°C and 7 m/s respectively. The average friction coefficient is 0.0025. What will be the value of average convection heat transfer coefficient for the plate when Prandtl number is 0.729? (For air, assume ρ = 1.2 kg/m^3 and c_p = 1.005 kJ/kgK)

(a) 13 W/m^{2}K (b) 10 W/m^{2}K

(c) 15 W/m^{2}K (d) 17 W/m^{2}K

388. (a)

Given: $\rho = 1.2\ \text{kg/m}^3, c_p = 1.005\ \text{kJ/kgK}$

From modified Reynolds analogy

$$\frac{\bar{C}_f}{2} = \overline{St} \times \text{Pr}^{2/3}$$

$$\overline{St} = \frac{\bar{C}_f}{2\text{Pr}^{2/3}}$$

$$\frac{\bar{h}}{\rho V c_p} = \frac{\bar{C}_f}{2\text{Pr}^{2/3}}$$

$$\bar{h} = \frac{\bar{C}_f}{2} \times \frac{\rho V c_p}{\text{Pr}^{2/3}} = \frac{0.0025 \times 1.2 \times 7 \times 1.005 \times 10^3}{2 \times (0.729)^{2/3}}$$

$$= \frac{0.01055 \times 10^3}{(0.9)^{3\times 2/3}} = \frac{0.01055 \times 10^3}{0.81}$$

$$\bar{h} = 13.027\ \text{W/m}^2\text{K}$$

Q.389 Considering a wall that consists of three layers A, B and C are in series with the following values:

k_A = 1.2 W/mK, L_A = 8 cm, k_B = 0.2 W/mK, L_B = 5 cm, k_C = 0.1 W/mK, L_C = 1.9 cm.

If the temperature drop across the wall is 21°C, then what will be the rate of heat transfer through the wall per unit area of the wall?

(a) 44.2 W/m^2 (b) 41.5 W/m^2

(c) 39.2 W/m^2 (d) 37 W/m^2

389. (b)

$$\text{Heat transfer, } Q = \frac{\Delta T}{\frac{L_A}{k_A A} + \frac{L_B}{k_B A} + \frac{L_C}{k_C A}}$$

$$\therefore \quad \text{Heat flux, } q = \frac{Q}{A} = \frac{\Delta T}{\frac{L_A}{k_A} + \frac{L_B}{k_B} + \frac{L_C}{k_C}} = \frac{21}{\frac{0.08}{1.2} + \frac{0.05}{0.2} + \frac{0.019}{0.1}}$$

$$= \frac{21}{0.0667 + 0.25 + 0.19} = \frac{21}{0.5067}$$

$$q = 41.44\ \text{W/m}^2$$

Q.390 A 3 cm long, 2 mm × 2 mm rectangular cross-section aluminium fin (k = 237 W/mK) is attached to a surface. If the fin efficiency is 71 percent, then what is the value of effectiveness of fin?

(a) 40.5 (b) 42.6
(c) 43.6 (d) 44.3

390. (b)

We know that,Effectiveness, $\varepsilon_f = \dfrac{q_f}{hA_{c,b}\theta_b}$

$$\text{Efficiency, } \eta_f = \frac{q_f}{hA_f\theta_b}$$

where, $A_{c,b}$ = Cross sectional area of fin
A_f = Total area of fin

$$\frac{\varepsilon_f}{\eta_f} = \frac{A_f}{A_{c,b}} = \frac{4\times(2\times30)}{2\times2}$$

[Neglecting end cross-section area in A_f]

$$\frac{\varepsilon_f}{0.71} = 60$$

$$\varepsilon_f = 42.6$$

Q.391 Consider the following statements regarding Nusselt number.

1. Nusselt number represents the enhancement of heat transfer through a fluid layer as a result of convection relative to conduction across the same fluid layer.
2. Nusselt number can be greater than, equal to or less than one.
3. A Nusselt number equal to one for a fluid layer represents heat transfer across the layer by pure conduction.
4. A larger value of Nusselt number means convection heat transfer is more effective.

Which of the above statements are correct?

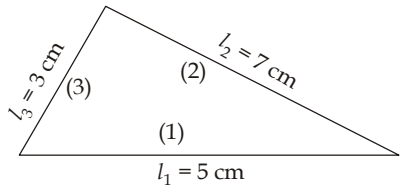
(a) 1, 2 and 3 (b) 2, 3 and 4
(c) 1, 3 and 4 (d) 1, 2 and 4

391. (c)

$$\text{Nusselt number, Nu} = \frac{\dot{q}_{conv}}{\dot{q}_{cond}} = \frac{\dot{q}_{cond}+\dot{q}_{advection}}{\dot{q}_{cond}} = 1+\frac{\dot{q}_{advection}}{\dot{q}_{cond}}$$

$$\therefore \quad \text{Nu} \geq 1$$

Q.392 For the three sided enclosure shown below. The shape factor F_{23} is



(a) 0.36 (b) 0.32
(c) 0.38 (d) 0.50

392. (a)

For three-sided enclosure, $F_{i\text{-}j} = \dfrac{l_i + l_j - l_k}{2l_i}$

$$F_{23} = \frac{l_2 + l_3 - l_1}{2l_2} = \frac{7+3-5}{2\times 7} = \frac{5}{14}$$

$$F_{23} = 0.357$$

Q.393 A thin Aluminium sheet with an emissivity of 0.1 on both sides is placed between two very large parallel plates that are maintained at uniform temperature of T_1 = 800 K and T_2 = 500 K and have emissivity of 0.2 each. What is the net rate of radiation heat transfer between the two plates?

(a) 650 W/m^2 (b) 800 W/m^2
(c) 750 W/m^2 (d) 700 W/m^2

393. (d)

$$\dot{q}_{12} = \frac{\dot{Q}_{12,\text{with shield}}}{A} = \frac{\sigma\left(T_1^4 - T_2^4\right)}{\left(\frac{1}{\varepsilon_1} + \frac{1}{\varepsilon_2} - 1\right) + \left(\frac{1}{\varepsilon_{3,1}} + \frac{1}{\varepsilon_{3,2}} - 1\right)}$$

where, $\varepsilon_1 = \varepsilon_2 = 0.2$ (Emissivity of plate)

$\varepsilon_{3,1} = \varepsilon_{3,2} = 0.1$ (Emissivity of shield)

$$\therefore \quad \dot{q}_{12} = \frac{5.67\times 10^{-8}\left(800^4 - 500^4\right)}{\left(\frac{1}{0.2} + \frac{1}{0.2} - 1\right) + \left(\frac{1}{0.1} + \frac{1}{0.1} - 1\right)} = \frac{5.67\times\left(8^4 - 5^4\right)}{9+19}$$

$$= \frac{5.67(4096-625)}{28} = 702.87 \text{ W/m}^2$$

Q.394 Consider a counter flow heat exchanger with hot oil entering at a temperature of 250°C and leaving at 150°C. The cooling water receiving heat from hot oil flowing at a rate of 2 kg/s has the inlet and outlet temperature of 40°C to 140°C. What is the value of NTU for the heat exchanger?

(a) 1.1 (b) 1.0
(c) 0.5 (d) 0.9

394. (d)

Heat transfer rate, $q = C_h(T_{hi} - T_{he}) = C_c(T_{ce} - T_{ci})$

$= C_h(250 - 150) = C_c(140 - 40)$

$C_h = C_c$

$$\therefore \quad \frac{C_{\min}}{C_{\max}} = 1$$

$$\varepsilon = \frac{C_h(T_{hi} - T_{he})}{C_{\min}(T_{hi} - T_{ci})} = \frac{250-150}{250-40} = \frac{100}{210} = \frac{10}{21}$$

when, $\dfrac{C_{\min}}{C_{\max}} = 1$

For counter flow heat exchanger, $\varepsilon = \frac{NTU}{1+NTU} = \frac{10}{21}$

$$21\ (NTU) = 10 + 10(NTU)$$

$$NTU = \frac{10}{11} = 0.909 \simeq 0.91$$

Q.395 A heated stainless steel sheet is being conveyed at a constant speed of 1 cm/s into a chamber to be cooled. The stainless steel sheet is 5 mm thick and 2 m wide and it enters and exits the chamber at 500 K and 300 K respectively. What is the rate of heat loss from the stainless steel sheet inside the cooling chamber? Properties of stainless steel at 400 K is $\rho = 7900\ kg/m^3$, $c_p = 515\ J/kgK$.

(a) 79.4 kW (b) 40.4 kW
(c) 81.4 kW (d) 41.4 kW

395. (c)

Mass flow rate of stainless steel, $\dot{m} = (\rho)(v) \cdot (A) = (\rho)(v)(w \times t)$

$= (7900)\ (0.01)\ (0.005 \times 2) = 0.79\ kg/s$

Rate of heat loss from the stainless steel sheet,

$$\dot{Q}_{loss} = \dot{m}c_p(T_{in} - T_{out})$$

$$= 0.79 \times 515\ (500 - 300)$$

$$= 0.79 \times 515 \times 200 = 81.37\ kW \simeq 81.4\ kW$$

Q.396 Match List-I with List-II and select the correct answer using the codes given below the lists:

List–I

1. Heat generation
2. Work
3. Heat
4. Energy
5. Absorption
6. Adsorption

List–II

A. Boundary phenomena
B. Volume phenomena

Codes:

	1	2	3	4	5	6
(a)	A	A	A	A	B	B
(b)	B	A	A	A	B	B
(c)	B	A	A	B	B	A
(d)	B	B	B	B	A	A

396. (c)

Absorption is a phenomenon involving the bulk properties of a solid, liquid or gas. It involves atoms or molecules crossing the surface and entering the volume of the material whereas adsorption is a surface phenomena and in adsorption, there can be physical and chemical absorption.

Q.397 The value of Biot number (Bi) in an ideal situation for validation of lumped heat analysis system is given by:

(a) $Bi = 0.1$ (b) $Bi < 0.1$

(c) $Bi = 0$ (d) None of the above

397. (c)

Ideally the value of Biot no. is equal to zero for validation of lumped heat analysis system. Lumped system analysis assumes a uniform temperature distribution throughout the body, which is the case only when the thermal resistance of the body to heat conduction (the conduction resistance) is zero. Thus lumped system analysis is exact when $Bi = 0$ so in ideal situation of lumped system analysis biot number is equal to zero but in generally accepted that lumped heat analysis valid when $Bi < 0.1$.

Q.398 Which of the following statements are INCORRECT regarding Nusselt number:

1. As the value of Nusselt number increases, the convection heat transfer becomes less effective.
2. A Nusselt number is equal to unity for a fluid layer represents heat transfer across the layer by pure conduction.
3. In general, for geometries in convection heat transfer Nusselt number is less than 1.

(a) 1 and 2 only (b) 1 and 3 only

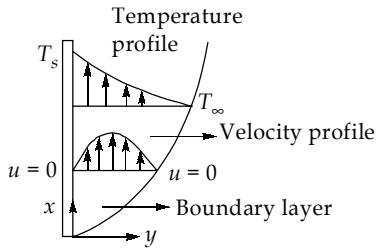
(c) 2 and 3 only (d) 1, 2 and 3

398. (b)

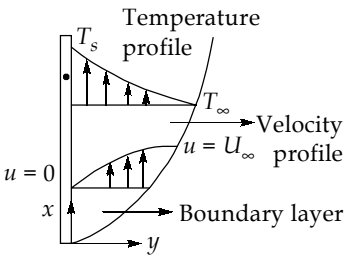
- As Nu increases, h (heat transfer coefficient) also increases so convection becomes more effective.
- The Nusselt number represents the enhancement of heat transfer through a fluid layer as a result of convection relative to conduction across the same fluid layer. The larger Nusselt number leads to the more effective the convection.
- A Nusselt number (Nu) = 1 for a fluid layer represents heat transfer across the layer by pure conduction.
- In general Nu is greater than 1.

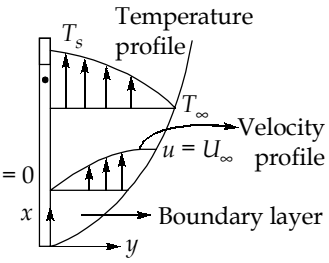
Q.399 Which of the following temperature and velocity profile is correct in case of heated vertical plate natural convection?

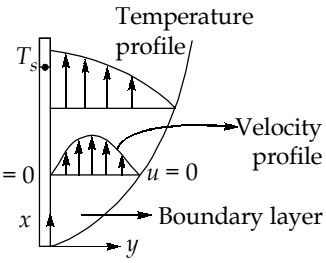
(a)



(b)



(c)


(d)


399. (a)

In natural convection, velocity of fluid = 0 (at the end point of boundary layer thickness)

Q.400 Consider the following statements for heat exchangers:

1. The ratio of heat transfer surface area of a heat exchanger to its volume is called the volume density of a compact heat exchanger.
2. Compact heat exchangers is a type of heat exchangers in which surface area for heat transfer per unit volume is less as compared to other heat exchangers.

Select the correct answer using the codes given below:

(a) 1 only (b) 2 only

(c) 1 and 2 both (d) Neither 1 nor 2

400. (d)

The ratio of the heat transfer surface area of a heat exchanger to its volume is called the area density.

Compact heat exchangers have high heat transfer surface area per unit volume. Compact heat exchangers enable us to achieve high heat transfer rates between two fluids in a small volume, and they are commonly used in applications with strict limitations on the weight and volume of heat exchangers.

Q.401 Consider the following statements regarding the fins in heat exchanger:

1. Fins are commonly placed on the air side to enhance the product (UA). Where, U is overall heat transfer coefficient and A is heat transfer area.
2. Due to use of fins, thermal resistance decreases in the path of heat flow.
3. Fins are commonly used to increase the conductive heat transfer area.

Select the correct answer using the codes given below:

(a) 1, 2 only (b) 1, 3 only

(c) 2, 3 only (d) 1, 2 and 3

401. (a)

The smaller heat transfer coefficient creates a bottle-neck in the path of heat transfer and seriously impedes heat transfer. This situation arises frequently when one of the fluids is a air and the other is a liquid. In such cases, fins are commonly used on the gas side to enhance the product UA, which reduces the overall thermal resistance.

Hence fins are commonly used to increase convective heat transfer area.

Q.402 Consider the following statements:

1. Absorptivity of a body depends on the temperature of its absorbing surface.
2. Monochromatic emissivity of a grey body is independent of the wave length of incident radiation.

Which of the above statement is/are correct?

(a) 1 only (b) 2 only

(c) Both 1 and 2 (d) Neither 1 nor 2

402. (b)

- Absorptivity of a surface depends on the temperature of incident radiation waves.
- Absorptivity is independent of surface temperature but emissivity is strongly temperature dependent.

Direction (Q.403 to Q.410): The following questions consists of two statements, one labelled as **Statement (I)** and the other labelled as **Statement (II)**. You have to examine these two statements carefully and select your answers to these items using the codes given below:

Codes:

(a) Both Statement (I) and Statement (II) are true and Statement (II) is the correct explanation of Statement (I).

(b) Both Statement (I) and Statement (II) are true but Statement (II) is not a correct explanation of Statement (I).

(c) Statement (I) is true but Statement (II) is false.

(d) Statement (I) is false but Statement (II) is true.

Q.403 **Statement (I):** The degree of freedom of a robotic system is the minimum number of independent parameters, variables, or coordinates needed to describe a robotic system completely.

Statement (II): According to International Organization for Standardization (ISO), the robot is an automatically controlled, reprogrammable, multifunctional manipulator, programmable in three or more axes, which can be either fixed in place or mobile for use in industrial automation applications.

403. (b)

According to Robot Institute of America (RIA): It is a reprogrammable, multi-functional manipulator designed to move materials, parts, tools or specialized devices through variable programmed motions for the performance of a variety of tasks.

And according to ISO, that is, International Organization for Standardization, the robot has been defined as follows: the robot is an automatically controlled, reprogrammable, multifunctional manipulator, programmable in three or more axes, which can be either fixed in place or mobile for use in industrial automation applications.

Q.404 **Statement (I):** The dextrous workspace is the volume of space that the robot's end-effector can reach with different combinations of the joint angles.

Statement (II): The reachable workspace is that volume of space that the end-effector can reach with one orientation.

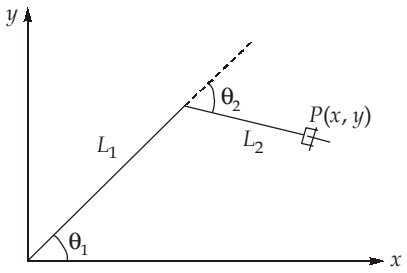
404. (b)

Q.405 Statement (I): The inverse kinematics problem is to determine the joint angles, given the position and orientation of the end-effector.

Statement (II): Computing the position and orientation of end-effector of manipulator when the joint angles are known, is known as forward kinematics problem.

405. (b)

The 2-DOF two link planar manipulator.



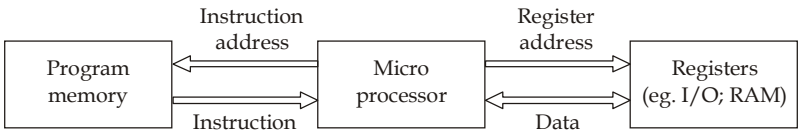
The problem faced in inverse kinematics is that the solution for joint angles may not be unique, there may be multiple solutions.

Q.406 Statement (I): The microchip microcontroller uses a form of architecture termed as Harvard architecture.

Statement (II): Harvard architecture enables faster execution speeds to be achieved for a given clock frequency.

406. (b)

With the help of harvard architecture, instructions are fetched from program memory using accessible variables.



Harvard architecture

Q.407 Statement (I): Reach is the maximum distance a robot can reach within its work envelope.

Statement (II): Reach is a function of Robot's joints and length and its configuration.

407. (b)

Q.408 Statement (I): Even robots do not provide good repeatability.

Statement (II): Errors due to mechanical sources decrease repeatability.

408. (a)

Q.409 **Statement (I):** Boiling and condensation heat transfer coefficients are generally smaller than those of convection heat transfer coefficients without phase change.
Statement (II): Combined latent heat and buoyancy driven flow effects are there in boiling and condensation.

409. **(d)**
Boiling and condensation heat transfer coefficients are generally much larger than those of convection heat transfer coefficients without phase change.

Q.410 **Statement (I):** In mixed convection involving both forced and natural convection, the relative importance of each mode of heat transfer is determined by value of coefficient $\left(\frac{Gr}{Re^2}\right)$.

Statement (II): If $\frac{Gr}{Re^2} << 1$, then natural convection is of greater importance than forced convection.

410. **(c)**

When $\frac{Gr}{Re^2} << 1$, then buoyancy forces are negligible and inertia forces are dominant therefore, forced convection must be considered.

■■■■