SECTION - A

There are FOUR questions in this section. Answer any THREE.

1. (a) In Figure for Question 1(a), a cable system maintains a cylinder in equilibrium at the position shown. If tension in cable $AB$ is 1000 N, determine the mass of the cylinder.

![Figure for Question 1(a)](image)

(b) Four forces are applied to the machine component ABDE as shown in Figure for Question 1(b). Replace these forces with an equivalent force-couple system at A.

![Figure for Question 1(b)](image)

2. (a) Neglecting friction and the radius of the pulley (see Figure for Question 2(a)), determine (i) the tension in cable ADB, (ii) the reaction at C.

Contd .......... P/2
(b) A 2.4-m boom is held by a ball-and-socket joint at C and by two cables AD and AE, as shown in Figure for Question 2(b). Determine the tension in each cable and the reaction at C.

3. (a) The frame supports the 400-kg load in the manner shown in Figure for Question 3(a). Radius of the pulley $\Phi$ is 0.5 m. Neglect the weights of the members compared with the forces induced by the load and compute all forces acting on each of the members.

(b) The system shown in Figure for Question 3(b) starts from rest, and each component moves with a constant acceleration. If the relative acceleration of block C with respect to collar B is $60 \text{ mm/s}^2$ upward and the relative acceleration of block D with respect to block A is $110 \text{ mm/s}^2$ downward, determine (i) the velocity of block C after 3 s, (ii) the change in position of block D after 5 s.
4. (a) A 1 kg collar can slide on a horizontal rod, which is free to rotate about a vertical
shaft as shown in Figure for Question 4(a). The collar is initially held at A by a cord
attached to the shaft. A spring of constant 30 N/m is attached to the collar and to the shaft
and is un-deformed when the collar is at A. As the rod rotates at the rate of 16 rad/s, the
cord is cut and the collar moves out along the rod. Neglecting friction and the mass of the
rod, determine (i) the radial and transverse components of the acceleration of the collar at
A, (ii) the acceleration of the collar relative to the rod at A, (iii) the transverse component
of the velocity of the collar at B.

(b) Block A (see Figure for Question 4(b)) has a mass of 40 kg, and block B has a mass
of 8 kg. The coefficients of friction between all surfaces of contact are \( \mu_s = 0.2 \) and
\( \mu_k = 0.15 \). If \( P = 40 \) N, determine (i) the acceleration of block B, (ii) the tension in the
cord.
ME 165 (CSE)

SECTION – B

There are FOUR questions in this section. Answer any THREE.

5. (a) What is a Robot? Mention the names and functions of Robot accessories. (10)
   (b) Derive the matrix that represents a pure rotation about the y-axis of the reference frame. (10)
   (c) In a robotic setup, a camera is attached to the fifth link of a robot with six degrees of freedom. The camera observes an object and determines its frames relative to the camera's frame. Using the following information, determine the necessary motion the end effector has to make to get to the object: (15)

\[
T_{com} = \begin{bmatrix}
0 & 0 & -1 & 3 \\
0 & -1 & 0 & 0 \\
-1 & 0 & 0 & 5 \\
0 & 0 & 0 & 1 \\
\end{bmatrix}, \quad T_H = \begin{bmatrix}
0 & -1 & 0 & 0 \\
1 & 0 & 0 & 0 \\
0 & 0 & 1 & 4 \\
0 & 0 & 0 & 1 \\
\end{bmatrix}
\]

\[
P_{com} = \begin{bmatrix}
0 & 0 & 1 & 2 \\
1 & 0 & 0 & 4 \\
0 & 0 & 0 & 1 \\
0 & 0 & 0 & 1 \\
\end{bmatrix}, \quad P_E = \begin{bmatrix}
1 & 0 & 0 & 0 \\
0 & 1 & 0 & 0 \\
0 & 0 & 1 & 4 \\
0 & 0 & 0 & 1 \\
\end{bmatrix}
\]

6. (a) What are the potential renewable energy sources in Bangladesh? Discuss the challenges and future prospects of renewable energy in Bangladesh. (15)
   (b) Write short notes on the following (any four):
      (i) Solar photovoltaic cell. (ii) Pressurized water nuclear reactor. (iii) Ocean thermal energy conversion. (iv) Pumped hydro storage system. (v) CETO technology. (20)

7. (a) Draw the schematic diagram of a conventional air conditioning system. What is the function of a cooling tower in large air conditioning system? (10)
   (b) What are the factors that affect thermal comfort of human? (5)
   (c) List the key components of a refrigeration system and show them with a suitable sketch. (7)
   (d) A fish cold storage use 5 ton ice per hour at a temperature of – 4°C. The cold storage is operating with vapor compression refrigeration cycle and R134a is used as refrigerant. Water enters the cold storage at 25°C temperature. The pressures of the evaporator and the condenser of the refrigerator are 1 and 10 atm respectively. Determine-
      (i) Refrigerant mass flow rate required to produce the ice. (ii) Compressor work done. (iii) Heat rejected at the condenser. (iv) COP of the refrigeration system. (13)

Contd ............ P/5
8. (a) What are the functions of capillary tube in domestic refrigerator? (5)
(b) How are Robot manipulators classified? Discuss anthropomorphic type manipulator with a suitable notation and sketch. (10)
(c) Show T-v diagram of a pure substance and identify different regions of that diagram. (5)
(d) Air enters an evaporative cooler at 1 atm, 35°C and 20 percent relative humidity. Determine-
   (i) Humidity ratio, enthalpy and specific volume of the intake air. (15)
   (ii) The exit temperature of the air.
   (iii) The lowest temperature to which the air can be cooled by this evaporative cooler.
**p-h Diagram for R134a**

Plotted by: J P M Trusler

Reference state:

- $h/(\text{kJkg}^{-1}) = 200$ and $s/(\text{kJK}^{-1}\text{kg}^{-1}) = 1.00$
- for saturated liquid at $T = 0^\circ\text{C}$

Legend:

- $T/\circ\text{C}$
- $s/(\text{kJK}^{-1}\text{kg}^{-1})$
- $v/(\text{m}^3\text{kg}^{-1})$
- Quality

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1. (a) Is the following code fragment valid? What will be the output if so? State your reason.
   
   ```c
   int a=2, b=5, c;
   c=a+++b;
   printf("%d, %d, %d, a, b, c\n"), a, b, c);
   ```

   (b) As a human being we prefer to read integers in a comma separated readable format
   where a comma is placed after every three digits from the right. Unfortunately print in C
   cannot print it in that way, you need to write your own. Write down a program that will
   take an integer (positive or negative) as input and will print it in a comma separated
   format. See the following example:

<table>
<thead>
<tr>
<th>Sample inputs</th>
<th>Sample outputs</th>
</tr>
</thead>
<tbody>
<tr>
<td>-1234567890</td>
<td>-1,234,567,890</td>
</tr>
<tr>
<td>-123456</td>
<td>-123,456</td>
</tr>
<tr>
<td>-12345</td>
<td>-12,345</td>
</tr>
<tr>
<td>-1000</td>
<td>-1,000</td>
</tr>
<tr>
<td>-999</td>
<td>-999</td>
</tr>
<tr>
<td>-1</td>
<td>-1</td>
</tr>
<tr>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>999</td>
<td>999</td>
</tr>
<tr>
<td>1000</td>
<td>1,000</td>
</tr>
<tr>
<td>12345</td>
<td>12,345</td>
</tr>
<tr>
<td>123456</td>
<td>123,456</td>
</tr>
<tr>
<td>1234567890</td>
<td>1,234,567,890</td>
</tr>
</tbody>
</table>

   (c) Write down a program that will take an English letter in upper case as input and will
   print two letters after it in the alphabet in lower case. For example, if the user enters D
   the output will be f. If the input is Z the output will be b. **You are not allowed to use any if-
   else, switch-case or ternary operator to solve the problem.**

   (d) Show a code segment to determine the largest of three fractional numbers a, b, and c.
   You are only allowed to use conditional operators as many as needed to solve this
   problem **(no if-else, no switch-case).**
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2. (a) Write down a program that will take a float x and integer n as input and will calculate the value of the following series. You are not allowed to use any library function(s) except the input output related ones.

\[ x = \frac{x^2}{2!} + \frac{x^3}{3!} + \frac{x^4}{4!} + \ldots + \frac{x^n}{n!} \]

(b) Write down a program that will take a positive integer n as input and display a pyramid pattern. The pattern that needs to be displayed for \( n = 5 \) is shown below.

(c) Write down a function with the following prototype:

\[ \text{int isPowerOfFive(int n);} \]

The function checks whether the number \( n \) passed as parameter is a power of 5 or not. If \( n \) can be expressed as power of 5 the function returns 1; otherwise it returns 0. You are not allowed to use any library functions. Few sample calls and return values are given in the following table:

<table>
<thead>
<tr>
<th>Function call</th>
<th>Return value</th>
</tr>
</thead>
<tbody>
<tr>
<td>isPowerOfFive(5)</td>
<td>1</td>
</tr>
<tr>
<td>isPowerOfFive(10)</td>
<td>0</td>
</tr>
<tr>
<td>isPowerOfFive(25)</td>
<td>1</td>
</tr>
<tr>
<td>isPowerOfFive(33)</td>
<td>0</td>
</tr>
</tbody>
</table>

3. (a) Given two unsorted arrays A and B with size \( m \) and \( n \), write down two other functions \( \text{void union(int A[], int B[], int C[], int m, int n);} \) to implement \( C = A \cup B \) and \( \text{void intersect(int A[], int B[], int D[], int m, int n);} \) to implement \( D = A \cap B \). As an example, suppose \( A = \{7, 1, 5, 2, 3, 6, 1\} \) and \( B = \{3, 8, 6, 20\} \). Then \( C = \{7, 1, 5, 2, 3, 6, 8, 20\} \), and \( D = \{3, 6\} \).

(b) Suppose an array has \( n \) positive integers \( (n \geq 2) \). Show a code segment to find GCD of all numbers in the array.

(c) Discuss the problem and solution of the following parameterized macros:

(i) \#define square(x) \( x^2 \)
(ii) \#define swap(t,x,y) \( t = x; x = y; y = t; \)
(iii) \#define swap(t,x,y) \( t = x; x = y; y = t; \)

Contd ............ P/3
CSE 101

4. (a) Write down the following functions. You are not allowed to use logical operators, relational operators, if-else or loop. You can only use bitwise operators and arithmetic operators as needed. 

<table>
<thead>
<tr>
<th>i</th>
<th>ii</th>
<th>iii</th>
<th>iv</th>
<th>v</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>int isNotEqual(int x, int y)</strong> returns 0 if x is equal to y and nonzero if x is not equal to y.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>int copyABit(int x, int n)</strong> copies nth bit to all bit positions, where 1 ≤ n ≤ 32.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>copyABit(5,3)</strong> returns -1 (i.e., 1 in all bit positions)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>copyABit(5,2)</strong> returns 0 (i.e., 0 in all bit positions)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>int isNegative(int x)</strong> returns a if x is positive and 1 otherwise</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>int isSmaller(int x, int y)</strong> returns 0 if x is not smaller than y and nonzero otherwise</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>int invertBits(int x, int p, int n)</strong> inverts n bits starting from position p of x and returns.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Assume that, 1 ≤ n ≤ 32 and 0 ≤ p ≤ 31 

(b) Write down a function that will take an integer x as parameter and returns after interchanging all pairs of consecutive bits. Assume the size of integers is 32 bits. Here is an example: 

\[ x = 1011 1111 1110 1010 1001 0000 1000 0001 \]

return value = 0111 1111 1101 0101 0110 0000 0100 0010

SECTION – B

There are FOUR questions in this Section. Answer any THREE questions.

5. (a) Consider the following declaration:

\[ \text{int } p[2][3][2] =\{1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12\}; \]

the first element of p located at address 12040 and an integer is represented by 2 bytes, then show the addresses of each of the integers in the list. Write down the values of the following expressions:

(i) **p  
(ii) *((*p+1)+2)  
(iii) **(*)*(p+2)  
(iv) **(*p+1)+1 

(b) Explain the declaration of the following function prototype:

\[ \text{char } (*(*funct[])(int(*a)[]))) []; \]

(c) Re-declare the following using pointer and malloc() function. Do not use [ ] operator.

\[ \text{double A[10][20][30];} \]

(d) Write down a C function that will return the index of first occurrence of a substring in a string. The string and substring will be passed as the first and the second argument of the function respectively. You must write down your program codes using pointer and avoiding array. The prototype of the function is as follow:

\[ \text{int findSubStrIndex (const char *str, const char *substr);} \]

For example findSubStrIndex("This is a pen.", "is") will return 2, while findSubStrIndex("This is a pen.", "ball") will return -1.

Contd ........... P/4
6. (b) A hall management system records information of all students who are either resident or attached to that hall. The record has the following fields:

<table>
<thead>
<tr>
<th>Fields</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>name</td>
<td>Name of the student</td>
</tr>
<tr>
<td>stdID</td>
<td>Student number</td>
</tr>
<tr>
<td>DoB</td>
<td>Death of birth of the student</td>
</tr>
<tr>
<td>enrolDate</td>
<td>Date of admission into the hall</td>
</tr>
<tr>
<td>Room No</td>
<td>Room number of the residential student</td>
</tr>
<tr>
<td>GPA</td>
<td>An array contains semester-wise GPA</td>
</tr>
</tbody>
</table>

(a) Write down a suitable data structure to store the above mentioned information of all students associated with the hall.

(b) Assume that studentList is a pointer to the list of all students as declared below:

```c
Student *StudentList;
```

Write down a C function to list all the students (containing name, stdID and roomNo) whose CGPA is less than 3.0 and occupied seats in the hall.

Write a C function that will retrieve information of all students stored in the hard-disk into the variable `studentList` as declared in (b). At the end of the program, you are required to replace the information stored in the hard-disk with the information recorded in `studentList`, which is referred as save operation. Write another C function for save operation. Both of the function must be written in such a way that a student's information is considered as a single entity. (Hints: You are not allowed to use fscanf() or fprintf() functions in your program.)

7. (a) Define three two dimensional, 100 x 100 integer arrays. Please note that number of rows and columns are same for all three arrays. Prompt for number of rows and columns and read the values of m and n respectively. Read mn integers for first two arrays, perform matrix multiplication and store the results in third array. Print the elements in third array.

(b) Write a C function to calculate the transpose of a square matrix. The function prototype is as follows:

```c
void transpose(int *list, int n); // list represents the matrix

// n is the number of rows/columns
```

(c) A gray scale image is represented by a 2-dimensional integer array where value of each pixel represented by a number ranges from 0 to 255. A sample gray image is given below:

```
231 187 178 194 203 190
202 195 198 195 204 192
214 197 179 196 200 197
230 190 180 198 201 187
224 219 193 200 201 186
231 123 189 201 203 197
```
CSE 101

Contd ... Q. No.7(c)

An error matrix is calculated as follows. At first average of all the pixels are calculated and then error of each pixel is calculated by subtracting the average from the pixel value.

Write a C function to calculate error matrix of a given image. Also write a C function to calculate the error frequency list, which represents how many times each error occurs. Arrange the list in ascending order on error values.

8. (a) A binary search tree, abbreviated as BST, is a binary tree where all the element in the left subtree of a node are less than or equal to the element at that node and all the elements at the right subtree are higher than it.

![Figure 8(a)-1: BST](image)

A BST can be stored in a 1D array where the root of the tree is stored at index 1. node(i) represent the element stored in the index i. Left child of node(i) is node(2*i) and the right child of node(i) is node(2*i+1). The value of an element -1 in an index means there is no element at that index. The BST in the Figure is represented in the following array. For example, 15 is root and hence it is placed in index 1. Left child of 15 is 9, which is placed in index 2*1 = 2 and the right child of 15 is 19 which is placed in index 2*1+1 = 3 and so on.

<table>
<thead>
<tr>
<th>Index</th>
<th>0</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
<th>11</th>
<th>12</th>
</tr>
</thead>
<tbody>
<tr>
<td>Value</td>
<td>-1</td>
<td>15</td>
<td>9</td>
<td>19</td>
<td>-1</td>
<td>12</td>
<td>17</td>
<td>21</td>
<td>-1</td>
<td>-1</td>
<td>-1</td>
<td>-1</td>
<td>-1</td>
</tr>
</tbody>
</table>

(i) Write a recursive C function that will insert a node in the given tree. If the tree does not exist, inserting a node means that the done become the root of tree. Use the following function prototype

```c
void BST_insert( int *node, int x); // element x to be inserted into the BST
```

// and node is name of array.

(ii) The height of a node of the tree is defined as follows: the height of the root is zero. If a node is at a height of n, then its left and right child are at the height of n+1. Write a recursive C function that will return the height of a given node. The function prototype is as follows:

```c
int BST_height(int *node, int x); // element x is the element whose height
// need to be determined
// and node is the name of the array
```

If the element x is not present in the tree, then −1 will be return.

Contd ............ P/S
(b) Write down a recursive C function for binary search within a sorted list that returns the index of the array if the element is found otherwise returns -1. The prototype of the function is as follows:

```c
int binSearch( int *list, int low, int high, int value);
```

where `list` is the name of the sorted array and `value` is the element to be searched. Variables `low` and `high` represent the searching range.

------------------------------------------------------------------
BANGLADESH UNIVERSITY OF ENGINEERING AND TECHNOLOGY, DHAKA
L-1/T-1  B. Sc. Engineering Examinations 2016-2017
Sub: MATH 145 (Differential Calculus, Integral Calculus and Co-ordinate Geometry)
Full Marks : 210 Time : 3 Hours
The figures in the margin indicate full marks.
Symbols have their usual meaning.
USE SEPARATE SCRIPTS FOR EACH SECTION

SECTION - A
There are FOUR questions in this Section. Answer any THREE.

1. (a) Let, \( f(x) = \begin{cases} 
4 + x^2, & 0 < x \leq 4 \\
4, & -1 \leq x < 0 \\
1 + x, & -4 \leq x < -1 
\end{cases} \)
Discuss the continuity and differentiability of \( f(x) \) at \( x = 0, -1 \). Also sketch the curve of \( f(x) \).

(b) If \( x = \sin \left( \frac{\ln y}{m} \right) \), then show that \( (1 - x^2)y_{n+2} - (2n+1)xy_{n+1} - (n^2 + m^2)y_n = 0 \). Also find \( (y_n)_0 \).

(c) Evaluate: \( \lim_{x \to 1} (1 - x^2) \sqrt[n]{y_n(x)} \).

2. (a) Expand \( \ln x \) in powers of \( (x - 2) \). Also find Lagrange and Cauchy’s form of remainder.

(b) Verify Rolle’s theorem for the function \( f(x) = \ln \frac{x^2 + ab}{(a + b)x} \) in \( (a, b) \); where \( a \) and \( b \) are positive constants.

(c) If \( u = \ln \left( x^2 + y^2 + z^2 \right) \), then prove that \( \frac{\partial u}{\partial x} + y \frac{\partial u}{\partial y} + z \frac{\partial u}{\partial z} = 2 \).

3. (a) Show that the condition that the curves \( \frac{x^2}{a^2} + \frac{y^2}{b^2} = 1 \) may touch the curve \( x^2 + y^3 = c^3 \) is \( a + b = c \).

(b) Sketch the graph of the function \( y = x^3 - 3x + 2 \) and identify the locations of the intercepts, relative extrema and inflection points. Also find the interval where \( f(x) \) is increasing or decreasing.

(c) Find the pedal equation of \( r^m = a^m \cos m \theta \); where \( m \) is constant.

Contd ............ P/2
MATH 145(CSE)

4. (a) Evaluate: \[ \int_0^\frac{\pi}{2} x \ln(\sin x) \, dx. \] (12)

(b) Evaluate: \[ \int_0^\frac{\pi}{2} \frac{x \, dx}{\sin x + \cos x}. \] (12)

(c) Derive Walli’s formula for \[ \int_0^\frac{\pi}{2} \cos^n x \, dx \] and hence evaluate \[ \int_0^\frac{\pi}{2} \cos^9 x \, dx. \] (11)

SECTION - B

There are FOUR questions in this Section. Answer any THREE questions.

5. (a) Evaluate: \[ \int_0^\infty \frac{\sqrt{x}}{(1 + x)^2} \, dx. \] (11)

(b) Show that \[ \beta(m, n) = \frac{r(m)r(n)}{r(m + n)} \] . (12)

(c) Evaluate: (i) \[ \int_0^\infty e^{-y/3} \, dy \] (ii) \[ \int \left( -\frac{3}{2} \right) \]. (12)

6. (a) Find the area bounded by cardioid \( r = c(1 + \cos \theta) \). (11)

(b) Find the volume of the solid generated by revolving the ellipse \( b^2x^2 + a^2y^2 = a^2b^2 \) about the minor axis. (12)

(c) Find the length of the semi cubical parabola \( ay^2 = x^3 \) from the vertex to the point \((a, a)\). (12)

7. (a) Through what angle should the axes be rotated so that the equation \[ 9x^2 - 2\sqrt{3}xy + 7y^2 = 10 \] may be changed to \[ 3x^2 + 5y^2 = 5 \] ? (12)

(b) If \( ax^2 + 2hxy + by^2 + 2gx + 2fy + c = 0 \) represents a pair of straight lines, show that the area of the triangle formed by these lines and the axis of \( x \) is \[ \frac{g^2 - ac}{a\sqrt{h^2 - ab}} . \] (12)

(c) Prove the necessary and sufficient condition that two of the lines represented by the equation \[ ay^4 + bxy^3 + cx^2y^2 + dx^3y + ex^4 = 0 \] should be at right angles is \( (b + d)(ad + be) + (e - a)^2(a + c + e) = 0 \). (11)

Contd .......... P/3
MATH 145(CSE)

8. (a) Find the common external tangents to the two circles $x^2 + y^2 = 16$ and $x^2 + y^2 + 6x - 8y = 0$.

(b) Reduce the equation $x^2 - 6xy + 9y^2 - 2x - 3y + 1 = 0$ to its standard form.

(c) Show that the tangents to the ellipse $\frac{x^2}{a^2} + \frac{y^2}{b^2} = 1$ at the ends of a chord which subtends a right angle at the center intersect on the ellipse $\frac{x^2}{a^2} + \frac{y^2}{b^2} = \frac{1}{a^2} + \frac{1}{b^2}$.
SECTION A

There are FOUR questions in this Section. Answer any THREE.

1. (a) Find the equivalent resistance $R_{eq}$ in Fig. 1(a)

(b) For the circuit in Fig. 1(b):

(i) Find the gain $\frac{V_0}{V_s}$.

(ii) If $V_s = 1V$, find $V_{ab}$.

2. (a) Using mesh current analysis, find the power delivered/absorbed by the 5A current source in Fig. 2(a).
(b) Find the node voltages and current $I_0$ using nodal analysis in Fig. 2(b).

![Fig. 2(b)](image)

3. (a) In Fig. 3(a), Use superposition principle to find the voltage $V_{ab}$. Then, find the Thevenin and Norton equivalent of the circuit between terminals $a$ and $b$.

![Fig. 3(a)](image)

(b) Design an active bandpass filter to pass frequencies between 250 Hz and 3000 Hz with $k = 10$ and $R = 20 \, \text{k}\Omega$.

![Fig. 4(a)](image)

4. (a) Find the value of resistance $R$ so that maximum power is transferred to the 3 kΩ resistance. Find the value of that maximum power.
(b) In Fig. 4(b), find $V_x$ by applying a series of source transformation.

(c) Solve the op-amp circuit in Fig. 4(c) and find the current $i_0$.

SECTION - B
There are FOUR questions in this Section. Answer any THREE questions.

5. (a) Using the phasor approach, find the voltage $v(t)$ in a circuit described by the following equation:

$$2 \frac{dv}{dt} + 5v + 10 \int v dt = 20 \cos(5t - 30^\circ)$$

(b) For the circuit shown in Fig. for Q. 5(b), $R_1 = 80 \ \Omega$, $|V_1| = 50 \ V$, $|V_s| = 145 \ V$, $|V_o| = 110 \ V$. Voltage measurements are taken with an AC voltmeter when the circuit is at steady state and operating at 60 Hz frequency. Find the values of $R_2$ and $L$. 

Contd ........... P/4
5. (a) For the circuit shown in Fig. for Q. 5(c), find the magnitude and phase of $V_o$ as the resistance $R$ is varied from zero to infinity. Given that, source voltage $V_s = V_m \sin \omega t$ and the amplitude and phase angle of the source voltage are kept constant as $R$ is varied. 

(b) For the circuit shown in Fig. for Q. 5(b), find $V_1$. 

6. (a) For the circuit shown in Fig. for Q. 6(a), find $v_o(t)$ (use any method).

(b) For the circuit shown in Fig. for Q. 6(b), use a phasor diagram to find the value of $R$ that will cause the current through resistor $R$ to lag the source current $I$ by 45 degree. Given that, $L = 0.2 \text{ mH}$, $C = 800 \mu \text{F}$ and angular frequency $\omega = 5 \text{ krad/s}$.
7. (a) For the circuit shown in Fig. for Q. 7(a), find the frequency for which input and output voltages are in phase. [Find your result in terms of circuit components C, R, R₁, R₂.]

(b) The device shown in Fig. Q. 7(b) is represented by a Norton equivalent circuit. When a resistor having an impedance of 5 kΩ is connected across the device, then the value of $V₀$ is 5-j15 V. When a capacitor having an impedance of $-j3$ is connected across the device, the value of $I₀$ is 4.5-j6 mA. Find the Norton current $I_N$ and the Norton impedance $Z_N$.

8. (a) A 2000 kW turbine-generator operates with a power factor of 0.85 at rated load and is connected to 220 V rms 50 Hz line. An additional load of 300 kW with 0.8 power factor is added. Find the value of the capacitor required to operate the turbine-generator system at constant Volt-Amp(s).

(b) One of the line voltages of a balanced Y connected source is $V_{ab} = 240\angle20^\circ$. If the source is connected to a delta connected load of $20\angle40^\circ$ Ω, find the line currents and phase currents. Assume abc sequence.
1. (a) Discuss the deficiencies of the perfect gas equation and obtain the following Vander Waal’s equation of state for real gases using the pressure connection and volume connection.

\[ \left( \frac{\rho + a}{v^2} \right) (v-b) = RT \]  

(b) Deduce expressions for critical temperature, critical pressure and critical volume in terms of the Van der Waal’s constants and universal gas constant. 

(c) Calculate the number of molecules per c.c of a gas if the mean free path of the molecules is \( 3.4 \times 10^{-6} \) cm and the molecular diameter is equal to \( 2.0 \times 10^{-8} \) cm. What will be collision frequency if the r.m.s. speed of the molecules under the given condition is of the order of \( 1 \times 10^5 \) cm/sec?

2. (a) Distinguish between isothermal and adiabatic processes.

(b) Describe Carnot cycle. Calculate the work done in a cycle of operations. Show that the efficiency of a Carnot engine using an ideal gas as the working substance is

\[ \eta = \frac{T_1 - T_2}{T_1} \]

where \( T_1 \) and \( T_2 \) are the temperatures of the source and the sink, respectively.

(c) Show that for a perfect gas undergoing adiabatic transformation, (i) \( pv^\gamma \) = constant and (ii) \( TV^{\gamma-1} \) = constant, where the symbols have their usual meaning.

(d) Explain why the temperature of a gas drops in adiabatic expression?

3. (a) Show that for a body executing simple harmonic motion, total mechanical energy remains conserved. What is the ratio between its kinetic energy and potential energy at a displacement equal to half its amplitude?

(b) What are lissajous' figures? Derive a general expression for the lissajous' figure, having the same time period but different amplitudes and phase angles.

(c) An oscillating mass-spring system has its energy fully potential at the position 0.1 m from its equilibrium position it's maximum speed is 2.0 m/sec and the energy is 5 Joule at the equilibrium position (i) What is its amplitude? (ii) Calculate the force constant and mass attached to the spring?
4. (a) What are the characteristics of a mechanical wave? Give two examples of Mechanical wave.  
(b) Give the theory of growth of sound intensity inside a room using Sabine’s assumptions.  
(c) Define energy density sound intensity of a plane progressive wave. Obtain expressions for both.  
(d) A sound wave of energy 150 Joule, passes through a medium of volume $10^6$ m$^3$. Calculate the intensity of the sound wave. Velocity of sound = 330 m/sec.  

**SECTION – B**  
There are **FOUR** questions in this Section. Answer any **THREE** questions.  

5. (a) What do you mean by electric charge? What are the basic properties of electric charge? Explain the terms (i) quantization, and (ii) conservation of charge?  
(b) What is an electric dipole? An electric dipole is placed in a uniform external electric field. Find the expression for torque exerted on the dipole and the work needed to change the orientation of the dipole by an angle $\theta$.  
(c) A cube of edge ‘a’ carries a point charge ‘q’ at each corner, (i) show that the magnitude of the resultant electric force on any one of the charge is  
\[ F = \frac{0.261q^2}{\varepsilon_0a^2} \]  
(ii) What is the direction of $F$ relative to the cube edge?  

6. (a) What is a capacitor? Define the capacitance of a capacitor. Mention some applications of capacitors.  
(b) Derive an expression for capacitance of a spherical capacitor. Assume the radius of the inner spherical plate is ‘a’ and the outer plate ‘b’.  
(c) Consider a parallel plate capacitor of plate area $A$ and the distance between the plates is $d$, is filled with two dielectric materials, such that half of the plate area is filled with materials of dielectric constant $k_1$ and the other half is filled with materials of dielectric constant $k_2$. Calculate the capacitance of this capacitor.
7. (a) What do you mean by wave function? Write down the properties of wave function.  
(b) Solve the time-independent Schrödinger equation to derive an expression for the wave  
function when a particle of mass \( m \) is confined inside an infinite square well of width \( a \).  
(c) Show that there is no acceptable solution to the time independent Schrödinger  
equation for the infinite square well with negative energy.  

8. (a) Write down the difference between Classical and Quantum Mechanics.  
(b) State and prove Ehrenfest's theorem. Write down the physical significance of  
Ehrenfest's theorem.  
(c) Consider the wave function,  
\[ \psi(x, t) = Ae^{-\lambda |x|} e^{-i\omega t} \]  
where, \( A \), \( \lambda \), and \( \omega \) are positive real constants,  
(i) Normalize \( \psi \), and  
(ii) determine the expectation value of \( x \) and \( x^2 \).