BANGLADESH UNIVERSITY OF ENGINEERING AND TECHNOLOGY, DHAKA

L-1/T-2 B. Sc. Engineering Examinations 2021-2022

Sub: **CSE 105** (Data Structures and Algorithms I)

Full Marks: 210 Time: 3 Hours

The figures in the margin indicate full marks

USE SEPARATE SCRIPTS FOR EACH SECTION

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## SECTION – A

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

1. (a) Derive the time complexity of the following code fragments: **(4×4=16)**

| Code Fragment 1 | Code Fragment 2 |
|---|---|
| `for (i = 0; i < n; ++i) {`<br>`  for (j = 0; j < i; ++j) {`<br>`  sum += i + j;`<br>`  }`<br>`}` | `for (i = 0; i < n; ++i) {`<br>`  for (j = 0; j < i*i; ++j) {`<br>`  sum += i + j;`<br>`  }`<br>`}` |
| **Code Fragment 3** | **Code Fragment 4** |
| `for (i = 0; i < n*n; ++i) {`<br>`  for (t j = 0; j < i; ++j) {`<br>`  sum += i + j;`<br>`  }`<br>`}` | `sum = 0;`<br>`for (k=1; k<=n; k*=2) {`<br>`  for (j=1; j<=k; j++) {`<br>`  sum++;`<br>`  }`<br>`}` |

(b) In an array based implementation of a stack when the array space runs out, the array capacity is increased. Now, analyze and explain the following scenarios through an amortized analysis of the push() function. **(2×7=14)**

(i) Increasing the Capacity of the Array by 1

(ii) Doubling the Capacity of the Array

(c) **(5)**

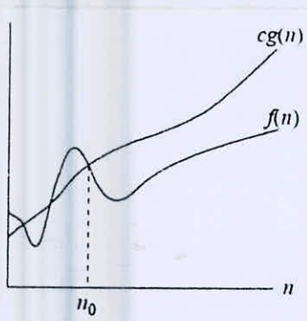


Figure 1(i)

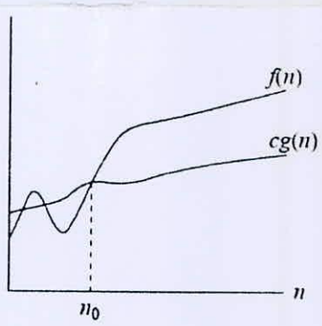


Figure 1(ii)

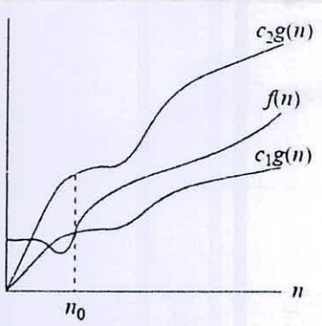


Figure 1(iii)

Explain what do the three figures, i.e., Figure 1(i–iii) signify with respect to asymptotic notations.

Contd ..... P/2

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2. (a) You are given the following numbers to insert into an empty Binary Search Tree (BST): **(5)**

5, 7, 8, 12, 15, 27

Determine which insertion order below would yield the tree with the least height?

(i) 15, 5, 27, 8, 7, 12

(ii) 12, 7, 15, 27, 5, 8

(iii) 8, 27, 7, 5, 15, 12

(iv) 7, 5, 12, 8, 15, 27

(b) A perfect balanced BST requires all interior nodes to contain two children and all leaf nodes to be on the same level. A perfect balanced BST of $h = 0$ would have $n = 1$ node, $h = 1$ would have $n = 3$ nodes, $h = 2$ would have $n = 7$ nodes, and so on. Here, $h$ is tree height and $n$ is the number of nodes in the tree. Providing appropriate arguments, derive the worst-case running time, in terms of $n$, for successfully searching for an element in a perfect balanced BST. **(10)**

(c) Present a recursive method *countInRange(root, low, high)*, without any helper functions, to count, in a BST, all keys that are within a given range. Assume that keys in the BST are unique, i.e., there are no duplicates. For example, suppose that the keys in a BST are 4, 7, 10, 14, 15, 17, 20, 30. Then, *countInRange(root, 8, 17)* returns 4 and *countInRange(root, 21, 29)* returns 0. For your convenience a code snippet in C++ is given below, but, you need not follow any particular programming language. **(10)**

```
public class BSTNode {
    int key;
    Value value;
    BSTNode left;
    BSTNode right;
    ...
}
// counts number of keys in BST that are in the range low to high, inclusive
// i.e. all keys k such that low <= k <= high
public static int countInRange(BSTNode root, int low, int high) {
      // COMPLETE THIS METHOD
}
```

(d) Present an algorithm to delete a full node in a binary search tree. Explain how it works with illustrative examples. **(10)**

3. (a) Suppose the numbers 0, 1, 2, ..., 9 were pushed onto a stack in that order, but that pops occurred at random points between the various pushes. Now you randomly wrote the following two sequences, S1 and S2 as example sequences in which the values in the stack could have been popped: **(5)**

S1: 3, 2, 6, 5, 7, 4, 1, 0, 9, 8

S2: 3, 2, 6, 4, 7, 5, 1, 0, 9, 8

Noticing this, your genius little brother winked at you and said that only one of your sequences is valid! Can you determine why?

Contd ..... P/3

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**Contd.... for Q. No. 3**

(b) Consider the following C++ fragment. A stack is being used to parse the matching parentheses / brackets / braces- (,[, and {. Show the state of the stack at the end of this fragment. **(5)**

```
1 #include <iostream>
2 using namespace std;
3
4 int main() {
5 const int M = 30;
6 int N = 1024;
7 int parent[N], height[N], depth[N];
8 int maxheights[100];
9
10 for ( int i = 0; i < 100; ++i ) {
11 maxheights[i] = 0;
12 }
13
14 double minmeandepth = 1e300;
15 double meandepths = 0;
16 double maxmeandepth = 0;
17
18 for ( int j = 0; j < M; ++j ) {
19 for ( int i = 0; i < N; ++i ) {
20 parent[i] = -1;
21 height[i] = 0;
22 }
23
24 for ( int i = 0; i < N - 1; ++i ) {
25 while ( true ) {
26 int p1 = rand() & (N - 1);
27 int p2 = rand() & (N - 1);
28
28 int s1 = p1;
30 int s2 = p2;
31
32 while ( parent[s1
```

(c) You are given access to the following functions of a list data structure: **(25)**

- *init*(*n*) /* Initialize an array $L[0..n-1]$ of length $n$ for integers. Current position 'points to' $L[0]$. All the functions below are applied on this array which is not accessible directly. */
- *insert*(*item*) /* Inserts an element at the current position and current position is 'incremented' (so if current position pointed to $L[k]$ before the call, after the call it points to $L[k+1]$). Here, *item* is the element to be inserted. In case the list is full, it returns ERR (a large negative constant). */
- *remove*() /* Removes the element at the current position and current position is 'decremented' (so if current position pointed to $L[k]$ before the call, after the call it points to $L[k-1]$). In case the list is empty, it returns ERR (a large negative constant). */
- *value*() /*Returns the value of the element at the current position. Current position remains unchanged. In case the list is empty, it returns ERR (a large negative constant). */

Contd ..... P/4

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**Contd.... for Q. No. 3(c)**

- *moveToStart*() /*Sets the current position to $L[0]$.*/
- *moveToEnd*() /*Sets the current position to $L[n-1]$*/
- *next*() /*Increments the current position (so if current position pointed to $L[k]$ before the call, after the call it points to $L[k+1]$). If $k = n-1$, it returns ERR (a large negative constant).*/
- *prev*() /*Decrements the current position (so if current position pointed to $L[k]$ before the call, after the call it points to $L[k-1]$). If $k = n-1$, it returns ERR (a large negative constant).*/

Now you have to build one queue and one stack in one List data structure as defined above. The queue should grow from the beginning of the list (i.e., first element of the queue should be at $L[0]$) and the stack should grow from the end of the list (i.e., the first element of the stack should be at $L[n-1]$). You have no access to the code of the above implementation and can only call these functions in your code. You need to write appropriate codes (no specific programming language is required; pseudo code is fine) for implementing the queue and stack simultaneously as described above. Please explain your code by giving appropriate comments. In particular, you need to implement the following four functions:

- *push*(*item*) /* push a positive integer, *item* in the stack. If there is an error (e.g., no more space available for growing the stack in the list, it should output an appropriate error message and returns with -1.*/
- *pop*() /* pop an element from the stack. If there is an error, it should output an appropriate error message and returns with -1.*/
- *enqueu*(*item*) /* enqueue a positive integer, *item* in the queue. If there is an error (e.g., no more space available for growing the queue in the list, it should output an appropriate error message and returns with -1.*/
- *dequeue*() /* dequeue an element from the queue. If there is an error, it should output an appropriate error message and returns with -1. */

4. (a) Compute the best alignments (i.e., alignments with the minimum edit distance) of two DNA sequences, ATCGGT and ACCGT using dynamic programming. Use 2 as the gap penalty, 1 as the mismatch penalty, and 0 as the penalty for a match. If there are multiple optimal alignments, find all of them. You do not need to write the algorithm, just show the dynamic programming (DP) table. Show the alignments and mark the paths (which correspond to the alignments), in the DP table. **(18)**

(b) Given two strings, the longest common subsequence problem is to find the longest subsequence present in both strings. A common subsequence is a sequence that appears in both string in the same relative order, but not necessarily contiguous. For example, for two strings S1 = "ALGORITHM" and S2 = "LITHIUM", the longest common subsequence is "LITHM". Present a dynamic programming algorithm to find the length of the longest common subsequence of two strings. Derive a proof of correctness of the algorithm and also derive its running time. **(8+6+3=17)**

Contd ..... P/5

## SECTION – B

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

5. (a) Consider the following array ($A$) of integers. **(20)**

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|---|
| A: | 16 | 4 | 10 | 7 | 14 | 9 | 3 | 2 | 8 | 1 |

Verify whether the array is a max heap. Derive the complexity of your verification algorithm. Justify whether the algorithm max_heapify ($A$, $i$) will establish the max heap property of the array, if you apply algorithm with index $i = 2$. Analyze the time complexity of max_heapify algorithm.

(b) Explain why topological sort algorithm cannot run on a directed graph that cycle(s). Derive the component graph of the directed graph $G$ represented by the adjacency matrix give in **Fig. for Q. No. 5(b) and 6.** Then find the topological sorting of the vertices of the component graph. Show every steps. **(15)**

6. (a) Consider the adjacency matrix representation of a directed graph $G$ given in **Fig. for Q. No. 5(b) and 6**. Draw the graph and find its adjacency list representation considering the vertices in ascending order. Find the shortest path distance of every vertex from vertex **1** using BFS. Show the queue status when the vertex **10** is just enqueued. Prove that the distance of the most recent vertex (tail in the queue) is at most one larger than the distance of the oldest vertex (head in the queue). **(20)**

(b) Classify the edges of the graph $G$ represented by the adjacency matrix given in **Fig. for Q. No. 5(b) and 6** after you run DFS on the graph considering the vertices in ascending order. Prove that an edge ($u$, $v$) is a tree edge. **(15)**

$$\text{if } u.d < v.d < v.f < u.f.$$

Notations bear their usual meaning.

7. (a) Given a set $U = \{x_1, x_2, \cdots, x_n\}$ of $n$ integers and an integer $k\,(k < n)$, give an optimal greedy algorithm to find a subset $S$ of size $k$ in $U$ such that the summation of the numbers in $S$ is maximum (over all the subsets of size $k$ in $U$). Prove the correctness of your algorithm, and analyze the running time. **(15)**

(b) Given a sequence of $n$ numbers $a_1, \ldots, a_n$, which we assume are all distinct, we define an inversion to be a pair $i < j$ such that $a_i > a_j$. Present an $O(n \log n)$ divide-and-conquer algorithm to count the number of inversions between two orderings. One might feel that this measure of inversion is too sensitive and may want to change it. Let's call a pair a modified-inversion if $i < j$ and $a_i > 2a_j$. What modifications do you need to make in the divide-and-conquer algorithm (for counting inversion) to count the number of modified-inversions? **(20)**

Contd ..... P/6

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8. (a) Given $n$ points $(x_1, y_1), (x_2, y_2), \cdots, (x_n, y_n)$ in the plane, give an efficient divide-and-conquer algorithm to find the pair of points that is closest together. Prove the correctness and analyze the running time of your algorithm. **(18)**

(b) Calculate the number of swap operations (data interchanges) required if you apply Build_Max_Heap algorithm on the array $A = \{5, 3, 17, 10, 84, 19, 6, 22, 9\}$. Justify whether the max heap you produced can be used as a priority queue. Show that **Heap_Extract_Max** algorithm is essentially a part of **Heapsort** algorithm. Derive and compare the time complexities of these two algorithms. (Heapsort and Heap_Extract_Max). **(17)**

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| | **1** | **2** | **3** | **4** | **5** | **6** | **7** | **8** | **9** | **10** |
|---|---|---|---|---|---|---|---|---|---|---|
| **1** | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 1 | 0 |
| **2** | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 |
| **3** | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 |
| **4** | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 |
| **5** | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 |
| **6** | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 |
| **7** | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| **8** | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| **9** | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 1 |
| **10** | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 |

**Fig. for Q. No. 5(b) and 6**

**L-1/T-2/CSE** **Date: 02/10/2023**

BANGLADESH UNIVERSITY OF ENGINEERING AND TECHNOLOGY, DHAKA

L-1/T-2 B. Sc. Engineering Examinations 2021-2022

Sub: **CSE 107** (Object Oriented Programming Language)

Full Marks: 210 Time: 3 Hours

The figures in the margin indicate full marks

USE SEPARATE SCRIPTS FOR EACH SECTION

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## SECTION – A

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

1. (a) Discuss the difference between a class and an object. Describe how C++ supports inheritance. **(11)**

   (b) Demonstrate the order of execution of constructor functions for multilevel inheritance with an example program. **(11)**

   (c) Differentiate between 'new' operator and 'malloc()' function? Design "Class A" so that the following code inside the main function does not produce any error: **(13)**

```
int main()
{
   A obj(10);
   A *array = new A[10];
   return 0;
}
```

2. (a) Describe the differences between function overloading and function overriding. **(10)**

   (b) Design your custom inserter in the program below to generate the following output:

   x: 120, y: 130 **(10)**

```
#include <iostream>
using namespace std;
class myclass{
        int x, y;
public:
        myclass(int x, int y){
                this->x=x;
                this->y=y;
        }
};
```

```
int main(){
        myclass ob(120, 130);
        cout<<ob;
        return 0;
}
```

Contd ..... P/2

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**Contd.... for Q. No. 2**

(c) Consider the following class: **(15)**

```
class strtype {
  char *p;
  int len;
public:
  strtype(char *s) {
    len = strlen(s) + 1;
    p = new char[len];
    strcpy(p, s);
  }
  ~strtype() {
    delete [ ] p;
  }
};
```

Identify the problem that may arise if we want to execute the following instructions from the main function:

**strtype s1("LEVEL"), s2("TERM");**
**s1 = s2;**

Without changing the constructor and the destructor function, write the code to solve the problem.

3. (a) Describe the use of a virtual base class. Explain why it is not possible to create an object of an abstract class? **(12)**

(b) Write an example program to demonstrate the use of forward declaration of a class. **(11)**

(c) Consider the following overloaded functions and develop the equivalent function using default arguments: **(6)**

```
void f2( ) { int a = 0, b = 0; ... }
void f2( int a ) { int b = 0; ... }
void f2( int a, int b ) { ... }
```

(d) Evaluate the output of the following program: **(6)**

```
#include <iostream>
using namespace std;
class circle{
 int r;
public:
 circle(int a=0)
 {
   r=a;
 }
 void show(){
   cout << r << endl;
 }
 friend circle operator++(circle &ob);
};
circle operator++(circle &ob)
{
   ob.r++;
   return ob;
}
int main() {
   circle c1(10);
   ++c1;
   c1.show();
   return 0;
}
```

Contd ..... P/3

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4. (a) "Generic functions are similar to overloaded functions except that they are more restrictive"— Do you agree? Justify your answer. **(5)**

(b) Using an example scenario, demonstrate the use of a static member variable and a static member function for a class. **(8)**

(c) Design a template function 'myfunc' which takes two numbers (both of them are integers or both of them are real numbers) and an operator as a character ('+', '-', '*' or any other value). The function prints the summation, subtraction and product of the two numbers for '+', '-' and '*', respectively. For any other value in operator, the function prints Invalid Input. A sample main function and its corresponding output is shown below: **(10)**

```
#include <iostream>
using namespace std;
int main()
{
   myfunc(10.5, 4.3, '+');
   myfunc(4, 8, '*');
   myfunc(10.5, 4.5, '-');
   myfunc(3, 6, 'a');
   return 0;
}
```

Output:

```
14.8
32
6
Invalid Input
```

(d) Discuss different types of containers that are available in C++ Standard Template Library (STL). Describe their differences with an example class for each type of container. **(12)**

## SECTION – B

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

5. (a) Explain three uses of the final keyword with short examples. Describe the fundamental differences between an interface and an abstract class. **(10)**

(b) Consider the following code segment: **(10)**

```
interface x1 {
   void f1();
   static void f2() {}
   default void f3() {}
}

interface x2 {
   void f4();
   private void f5() {}
}
```

```
abstract class A implements x1 {
   final void f6() {}
   abstract void f7();
}

public class B extends A implements x2 {
   // your code
}
```

Demonstrate successful compilation of class B by writing the minimum code. You can't define class B as abstract.

Contd ..... P/4

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**Contd.... for Q. No. 5**

(c) Consider the following code segment: **(15)**

```
class Point {
   private int x, y;

   Point(int x, int y) {
      this.x = x;
      this.y = y;
   }
}

class Circle {
   Point center;
   int radius;

   Circle(int x, int y, int r) {
      center = new Point(x, y);
      this.radius = r;
   }
}
```

```
public class Test {
   public static void main(String[] args) {
      Circle c1 = new Circle(10, 20, 5);
      Circle c2 = new Circle(10, 20, 5);
      System.out.println(c1);
      System.out.println(c2);
      System.out.println(c1.equals(c2));
      HashMap<Circle, String> m = new HashMap<>();
      m.put(c1, "I am a Circle");
      System.out.println(m.get(c2));
   }
}
```

The expected output of the main method:

```
Circle: center (10, 20), radius: 5
Circle: center (10, 20), radius: 5
true
I am a Circle
```

Construct the Point and Circle class to achieve the expected output. Please note that the Point class's getter methods for x and y are private.

6. (a) Describe two different ways of creating threads in Java with short examples. Which one is better and why? Explain the difference between a synchronized method and a synchronized statement. **(10)**

(b) Consider a Java program that copies a binary file named "src.mkv" to another binary file named "dst.mkv" using chunks of 8 KB (8092 bytes). Implement this Java program using try with resources to close the files automatically. Please note that you are not allowed to throw Exception anywhere in your program. **(10)**

(c) The following Java code (incomplete) is required to find the minimum of a 1000 integers array using an array of 5 threads in parallel. **(15)**

```
class ParallelMin implements Runnable {
   // your code
}
class Main {
   public static void main(String[] args) {
      Random random = new Random();
      int [] numbers = new int[1000];
      for (int i = 0; i < numbers.length; i++) {
         numbers[i] = random.nextInt();
      }
      ParallelMin [] parallelMin = new ParallelMin[5];
      // your code
   }
}
```

You need to construct the complete Java code. You cannot write any more classes, but you can add variables, constructors, and other methods.

Contd ..... P/5

**CSE 107**

7. (a) Describe 3 (three) different ways to convert an int value to a String. Explain the major differences between an ArrayList and a Vector. **(10)**

(b) Consider the following code segment and its output. **(10)**

```
public class Q {
  public static void main (String [] args) {
    Integer [] n1 = {10, 20, 30, 40, 50};
    MyAvg<Integer> s1 = new MyAvg<>(n1);
    System.out.println(s1.average());
    Integer [] n2 = {50, 20, 40, 10, 30};
    MyAvg<Integer> s2 = new MyAvg<>(n2);
    System.out.println(s2.average());
    System.out.println(s1.sameAvg(s2));
    Double [] n3 = {50.0, 40.0, 30.0, 20.0, 10.0};
    MyAvg<Double> s3 = new MyAvg<>(n3);
    System.out.println(s3.average());
    System.out.println(s2.sameAvgAny(s3));
  }
}
```

```
The output of the main method is as follows:
30.0
30.0
true
30.0
true
```

Implement the MyAvg class to achieve the provided output for the main method. Please note that the MyAvg class can only be created for Java number classes.

(c) Consider the following class where getter methods are available for all attributes: **(15)**

```
public class Employee {
  private int id;
  private String name;
  private int age;

  Employee (int id, String name, int age) {
    this.id = id;
    this.name = name;
    this.age = age;
  }
}
```

Develop Java code for the following:

(i) Declare an ArrayList named employeeList that can store a list of employees and add the following employees to the list.

| Id | Name | Age |
|---|---|---|
| 1 | Eric | 10 |
| 2 | Brown | 25 |
| 3 | Ben | 15 |
| 4 | Peter | 10 |
| 5 | Jack | 30 |
| 6 | Stewart | 15 |

(i) Store only the name of the employee whose age is greater than 15 in an ArrayList named nameList.

(ii) Sort the list based on the ascending order of the age. If the age is the same, then sort based on the ascending order of the name. You can't use your own sorting technique. However, you can change the Employee class if necessary.

Contd ..... P/6

**CSE 107**

8. (a) Describe boxing and unboxing in Java. Give examples with primitive int and Integer. Explain the difference between boxing/unboxing and autoboxing/unboxing with code. When you shouldn't use autoboxing/unboxing? **(10)**

(b) Consider the following countries, their number of FIFA World Cup titles, and the year of the last title in the FIFA World Cup: **(10)**

| Country | Number of Titles | Year of the Last Title |
|---|---|---|
| Argentina | 3 | 2022 |
| France | 2 | 2018 |
| Uruguay | 2 | 1950 |
| England | 1 | 1966 |
| Spain | 1 | 2010 |

Implement the following using Java code for the above scenario:

(i) Declare a single Enumeration named FWCWinners for the above countries

(ii) Write Java code to print all the countries with their number of titles and the year of the last title

(iii) Write Java code to print the most recent winner (you can't simply write Argentina)

(c) A server program can accept multiple clients. The client program will send two integers to the server. The server will calculate the number of prime numbers between the two integers and send it to the client. The client will show the number as output. **(15)**

Develop a complete Java server-client program to handle the above scenario.

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L-1/T-2/CSE **Date: 12/10/2023**

BANGLADESH UNIVERSITY OF ENGINEERING AND TECHNOLOGY, DHAKA

L-1/T-2 B. Sc. Engineering Examinations 2021-2022

Sub: **CHEM 113** (Chemistry)

Full Marks: 210 Time: 3 Hours

The figures in the margin indicate full marks

USE SEPARATE SCRIPTS FOR EACH SECTION

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## SECTION – A

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

1. (a) Define boiling-point elevation and freezing-point depression of a dilute solution. Explain why molality is used for boiling-point elevation and freezing-point depression calculations and molarity is used in osmotic pressure calculations. **(13)**

   (b) A 7.85 g sample of a compound with the empirical formula $C_5H_4$ is dissolved in 301 g of benzene. The freezing point of the solution is 1.05°C below that of pure benzene. What are the molar mass and molecular formula of this compound? (The value of the constant $K_f = 5.12$ °C/m) **(12)**

   (c) What is Henry's Law? Explain the law in terms of the kinetic molecular theory of gases. Give an exception to Henry's law. **(10)**

2. (a) What do you mean by Torus and Carbon nanobuds? How do the colloidal particles acquire electrical charge? **(6+7=13)**

   (b) Define gold number. The gold numbers of A, B, C and D are 0.005, 0.05, 0.5 and 5 respectively. Which of these has the greatest protective action. Explain your answer. **(12)**

   (c) What do you understand by cadmium-free quantum dots? Discuss the applications of quantum dot. **(10)**

3. (a) Discuss the salient features of phase diagram of sulphur system. Why can four phases of heterogeneous system not exist at equilibrium? **(13)**

   (b) Aluminum hydroxide forms a positively charged sol. Which of the following ionic substances should be most effective in coagulating the sol and why? NaCl, $CaCl_2$, $Fe_2(SO_4)_3$ and $K_3PO_4$. **(12)**

   (c) "The accuracy of a calculation is dependent on both the model and the type of basis set applied to it" — explain. **(10)**

Contd ..... P/2

4. (a) Enthalpy is a state function — Justify. **(5+8=13)**

A lead (Pb) pellet having a mass of 26.47 g at 89.98°C was placed in a constant-pressure calorimeter of negligible heat capacity containing 100.0 mL of water. The water temperature rose from 22.50°C to 23.17°C. What is the specific heat of the lead pellet?

(b) What is Fuel? Describe three fuel-oxidizer systems used in rockets. **(12)**

(c) Ammonia will burn in the presence of a platinum catalyst to produce nitric oxide, NO.

$$4NH_3(g) + 5O_2(g) \rightarrow 4NO(g) + 6H_2O(g)\,.$$ **(10)**

What is the heat of reaction at constant pressure? Use the following thermochemical equations:

$$N_2(g) + O_2(g) \rightarrow 2NO(g); \quad \Delta H = 180.6\,\text{kJ}$$
$$N_2(g) + 3H_2(g) \rightarrow 2NH_3(g); \quad \Delta H = -91.8\,\text{kJ}$$
$$2H_2(g) + O_2(g) \rightarrow 2H_2O(g); \quad \Delta H = -483.7\,\text{kJ}$$

## SECTION – B

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

5. (a) Demonstrate the relationship between blackbody radiation and Planck's quantum theory. **(10)**

(b) Apply the concept of 'Linear Combination of Atomic Orbitals' to illustrate the creation of molecular orbitals, and then contrast the characteristics of bonding and antibonding molecular orbitals. **(10)**

(c) Consider a $Ca^{19+}$ ion with its electron in the $5^{th}$ excited state. (i) Calculate the longest wavelength of light that could be emitted when the $Ca^{19+}$ electron transitions to a lower energy state. (ii) Suppose the same transition as in part (i) took place in a hydrogen atom. Would the wavelength of emission be longer than, shorter than, or the same as your answer. **(10)**

(d) Concisely describe the physical significance of $\Psi^2$ for a hydrogen atom. **(5)**

6. (a) Draw the Lewis structure of (NNO) (atom order as indicated) including all relevant resonance forms. Determine which resonance form contributes more to the resonance hybrid by calculating formal charges. **(10)**

(b) Plot the radial probability distribution for a 2*s* orbital (as a solid line) and a 2*p* orbital (as a dashed line). (i) For each orbital indicate any radial nodes with an arrow. (ii) Compare the shielding experienced by a 2*s* electron to that of a 2*p* electron and provide a brief explanation. **(10)**

Contd ..... P/3

**CHEM 113/CSE**
**Contd.... for Q. No. 6**

(c) Given that the standard reduction potentials for vitamin $B_{12}$ and the protein flavodoxin are: **(10)**

Vitamin $B_{12}$ $E° = -0.526$ V

Flavodoxin $E° = -0.230$ V

(i) Calculate $\Delta G°$ in kJ for the one-electron reduction of vitamin $B_{12}$ by flavodoxin.

(ii) Which is the superior reducing agent: vitamin $B_{12}$ or flavodoxin? Justify your choice.

(d) Draw a diagram that illustrates how atomic $p$ orbitals can form both $\sigma$ and $\pi$ molecular orbitals. **(5)**

7. (a) Analyze the molecular orbital theory of the oxygen molecule and discuss how it leads to its paramagnetic behavior. **(10)**

(b) Using an example explain the role of conjugation in facilitating the delocalization of electrons and enhancing the stability of molecules. **(10)**

(c) What can be inferred about the structure of DNA in terms of its double helix configuration and the complementary base pairing (A-T, G-C)? **(10)**

(d) What distinguishes thermoplastics from thermosetting plastics? **(5)**

8. (a) Protein is a bio-polymer– explain by showing peptide bond formation. **(10)**

(b) Apply your knowledge of intermolecular forces to explain the thermal transitions in amorphous and crystalline polymers. **(10)**

(c) List the requirements of a conducing polymer for electrical conduction. Discuss a process for improving the conduction of polyacetylene, utilizing the concept of HOMO-LUMO. **(10)**

(d) How would you contrast batteries and supercapacitors as energy storage devices? **(5)**

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**L-1/T-2/CSE** **Date: 18/10/2023**

BANGLADESH UNIVERSITY OF ENGINEERING AND TECHNOLOGY, DHAKA

L-1/T-2 B. Sc. Engineering Examinations 2021-2022

Sub: **MATH 143** (Linear Algebra)

Full Marks: 210 Time: 3 Hours

The figures in the margin indicate full marks

USE SEPARATE SCRIPTS FOR EACH SECTION

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## SECTION – A

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

1. (a) Solve the system of homogeneous linear equations by reducing the coefficient matrix to its canonical form (Gauss-Jordan elimination): **(18)**

$$x+2y+3z+t=0$$
$$2x+4y+7z+4t=0$$
$$3x+6y+10z+5t=0$$

Write down a basis and dimension of the solution space.

(b) Determine the values of '$a$' for which the system **(17)**

$$x+2y-3z=4$$
$$3x-y+5z=2$$
$$4x+y+\left(a^2-14\right)z=a+2$$

has no solution, unique solution, or infinitely many solutions. Justify your answer.

2. (a) Test whether the following sets are subspaces of $\mathbf{R}^3$: **(18)**

   (i) All vectors of the form (a, 1, 1)

   (ii) All vectors of the form (a, b, c), where b = a + c.

(b) Find a subset of vectors $\underline{v_1}=(1,-2,0,3)$, $\underline{v_2}=(2,-5,-3,6)$, $\underline{v_3}=(0,1,3,0)$ $\underline{v_4}=(2,-1,4,-7)$ and $\underline{v_5}=(5,-8,1,2)$ that forms a basis for the space spanned by these vectors. (ii) Express each vector not in the basis as a linear combination of the basis vectors. **(17)**

3. (a) Find the standard matrix for the transformation T on $\mathbf{R}^3$, where T is the composition of a rotation of 45° about y-axis, followed by a reflection about the yz-plane, followed by a dilation with factor k = √2. Then find T(3, –4, 9) using the standard matrix. **(17)**

(b) Find the Kernel and Range of orthogonal projection on the plane x = z. Write down the basis and dimension of the Kernel and Range. **(18)**

Contd ..... P/2

**MATH 143/CSE**

4. (a) Consider the basis $S = \{\underline{v_1}, \underline{v_2}, \underline{v_3}\}$ for $\Re^3$, where $\underline{v_1} = (1, 2, 1)$, $\underline{v_2} = (2, 9, 0)$ and $\underline{v_3} = (3, 3, 4)$. Let T: $\Re^3 \to \Re^2$ be the linear transformation such that $T(\underline{v_1}) = (1, 0)$, $T(\underline{v_2}) = (-1, 1)$, $T(\underline{v_3}) = (0, 1)$. Find a formula for $T(x, y, z)$ and use that formula to find $T(7, 13, 7)$. **(17)**

(b) Consider the vector space $\mathbf{R^3}$ with the Euclidean inner product. Apply *Gram-Schmidt* process to transform the basis vectors, $\underline{u_1} = (1, 1, 1)$, $\underline{u_2} = (0, 1, 1)$, and $\underline{u_3} = (0, 0, 1)$ into an orthogonal basis $\{\underline{v_1}, \underline{v_2}, \underline{v_3}\}$ considering $\underline{v_1} = \underline{u_1}$; then normalize the orthogonal basis to obtain the orthonormal basis $\{\underline{q_1}, \underline{q_2}, \underline{q_3}\}$. **(18)**

## SECTION – B

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

5. (a) Find the least squares solutions, the least squares error vector, and the least squares error of the linear system **(18)**

$$\begin{aligned} 3x_1 + 2x_2 - x_3 &= 2 \\ x_1 - 4x_2 + 3x_3 &= -2 \\ x_1 + 10x_2 - 7x_3 &= 1 \end{aligned}$$

(b) Write down the properties of triangular matrices with examples. Find an *LU*-decomposition of the matrix **(17)**

$$A = \begin{bmatrix} 6 & -2 & 0 \\ 9 & -1 & 1 \\ 3 & 7 & 5 \end{bmatrix}.$$

6. (a) Find a matrix $P$ that diagonalizes **(20)**

$$A = \begin{bmatrix} 0 & 0 & -2 \\ 1 & 2 & 1 \\ 1 & 0 & 3 \end{bmatrix}.$$

and verify $P^{-1}AP$ is a diagonal matrix. Also find $A^{13}$.

(b) (i) Write down the following system in matrix form **(15)**

$$\begin{aligned} y_1' &= y_1 + 4y_2 \\ y_2' &= 2y_1 + 3y_2 \end{aligned}$$

(ii) Use diagonalization to solve the system and find the solution that satisfies the initial condition $y_1(0) = 0, y_2(0) = 0$.

Contd ..... P/3

**MATH 143/CSE**

7. (a) (i) Explain principal sub-matrix. Working with principal sub-matrix, classify the matrix as positive definite, negative definite, or indefinite. **(17)**

$$A = \begin{bmatrix} 3 & 1 & 2 \\ 1 & -1 & 3 \\ 2 & 3 & 2 \end{bmatrix}.$$

(ii) Identify all values of $k$ for which the quadratic form is positive definite.

$$5x_1^2 + x_2^2 + kx_3^2 + 4x_1x_2 - 2x_1x_3 - 2x_2x_3.$$

(b) Find a singular value decomposition (SVD) of the matrix. **(18)**

$$A = \begin{bmatrix} 1 & 1 \\ 0 & 1 \\ 1 & 0 \end{bmatrix}.$$

8. (a) Find a matrix $P$ that unitarily diagonalizes the Hermitian matrix **(12)**

$$A = \begin{bmatrix} 2 & 1+i \\ 1-i & 3 \end{bmatrix}.$$

Also, verify that $P^*AP$ is a diagonal matrix.

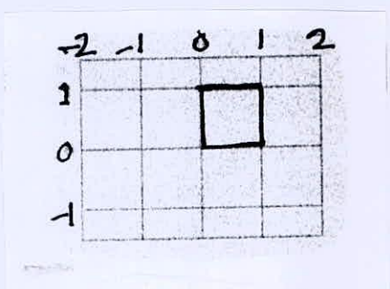
(b) Use the enciphering matrix $\begin{bmatrix} 1 & 3 \\ 2 & 1 \end{bmatrix}$ to obtain the Hill cipher of the plaintext message **(10)**

*'DARK NIGHT'*

(c) (i) Write down the coordinate matrix of View 1. **(13)**

(ii) Write down coordinate matrix of View 1 after it is scaled by a factor $-\frac{3}{2}$ in the $x$ direction and $\frac{1}{2}$ in the $y$=-direction and draw a sketch of the scaled view.

(iii) Write down the coordinate matrix of View 1 after it is rotated through an angle of –60° about the z-axis? Draw a sketch of the rotated view.




View 1: Square with vertices (0, 0, 0), (1, 0, 0), (1, 1, 0), and (0, 1, 0).

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**L-1/T-2/CSE** **Date: 07/10/2023**

BANGLADESH UNIVERSITY OF ENGINEERING AND TECHNOLOGY, DHAKA

L-1/T-2 B. Sc. Engineering Examinations 2021-2022

Sub: **ME 165** (Basic Mechanical Engineering)

Full Marks: 210 Time: 3 Hours

The figures in the margin indicate full marks

USE SEPARATE SCRIPTS FOR EACH SECTION

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## SECTION – A

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

Symbols have their usual meaning and interpretations. Necessary charts are attached.

1. (a) With a neat sketch, briefly describe the working principle of hydroelectric power plant. **(15)**

   (b) Write down advantages and disadvantages of fossil fuels. **(10)**

   (c) A refrigerator uses R134a as working fluid and operates on an ideal vapor compression refrigeration cycle between 0.10 MPa and 1.10 MPa. If the refrigerator removes heat from refrigerated space at a rate of 3.5 kW, calculate the mass flow rate of the refrigerant. **(10)**

2. (a) Air at 35°C dry bulb temperature and 60% relative humidity flowing at 2 kg/s is adiabatically mixed with air flowing at 4 kg/s and having conditions of 20°C wet bulb temperature and 30°C dry bulb temperature. Determine the following properties of the final mixture: **(20)**

   (i) Enthalpy
   (ii) Absolute humidity
   (iii) Relative humidity
   (iv) Dry and wet bulb temperature
   (v) Dew point

   [Mark the required points in the psychrometric chart provided with the question paper and attach it with your answer script]

   (b) What do you understand by one ton of refrigeration? Convert it to SI unit. **(6)**

   (c) What does an air handling unit (AHU) do in a central air conditioning system? **(9)**

3. (a) What happens during the intake stroke of an IC engine? Is there any difference in this stroke between SI and CI engines? If yes, what is/are the difference(s)? **(8)**

   (b) Draw the typical valve timing diagram for a four-stroke SI engine. **(7)**

   (c) A 450-cc single-cylinder square four-stroke SI engine runs at 2400 rpm. The engine has a compression ratio of 10. Calculate the following parameters: **(20)**

   (i) Clearance volume of the engine,
   (ii) The bore and the stroke,
   (iii) Average piston speed,
   (iv) Air standard efficiency and
   (v) Air standard MEP if heat is generated at a rate of 7.5 kW by fuel burning.

Contd ..... P/2

**ME 165/CSE**

4. (a) Define joint in context of robotics. Mention the names of any four types of joints and their allowed motions. **(10)**

(b) Write short notes on the following: **(10)**

(i) Robot software

(ii) Open and closed loop control system

(c) Suppose that a cylindrical robot has the following three degrees of freedom sequentially: It can move along $x$ axis, can rotate about $z$ axis and can move along $z$ axis. Determine a 4×4 transformation matrix for the cylindrical robot and hence find the joint variables of the robot to place the origin of its hand frame at $[6\ \ -3\ \ -4]^T$. **(15)**

## SECTION – B

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

5. (a) The triangular plate ABC is supported by ball-and-socket joints at B and D and is held in the position shown in Fig. for Q. 5(a) by cables AE and CF. The summation of moments of force AE and CF about the line connecting points D and B is zero. If both cables are in tension and the force exerted by cable AE at A is 55 N, determine the magnitude of force exerted by cable CF at C. **(18)**

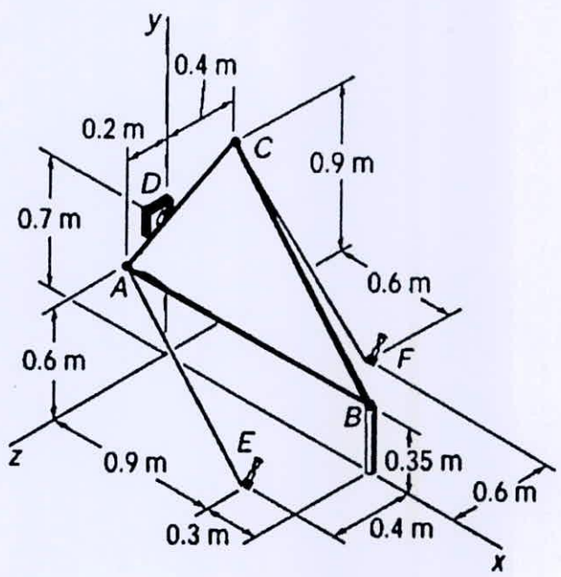


**Fig. for Q. 5(a)**

**ME 165/CSE**

**Contd.... for Q. No. 5**

(b) In trying to move across a slippery icy surface, a 180-lb man uses two ropes AB and AC as shown in Fig. for Q. 5(b). Assuming that a friend is helping the man at A by pulling on him with a force **P** = –**(48lb)** ***k***. determine the tension in each rope. **(17)**

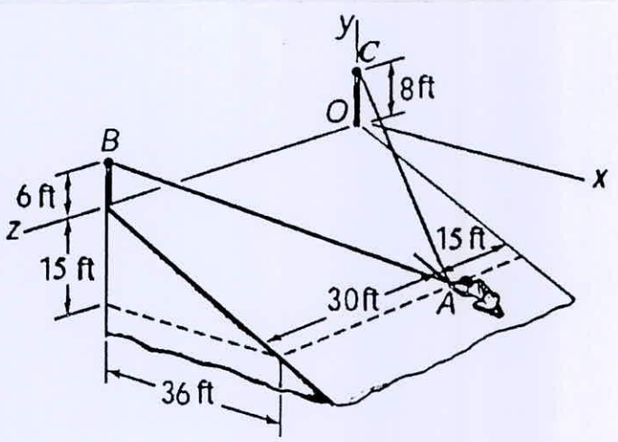


**Fig. for Q. 5(b)**

6. (a) Determine the force in members CE, EF and FH for the truss shown in Fig. for Q. 6(a). Also determine the reactions at A and B. **(17)**

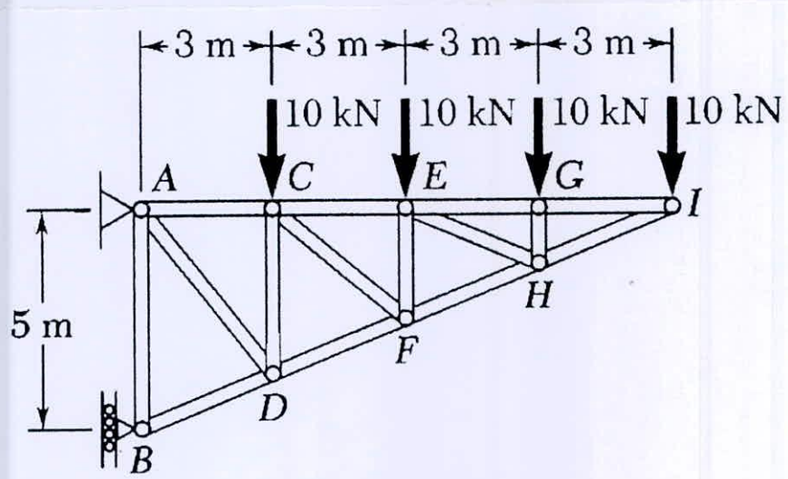


**Fig. for Q. 6(a)**

(b) For the frame and loading shown in Fig. for Q. 6(b), determine the components of all forces acting on member BC and CDE. **(18)**

Contd ..... P/4

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**Contd.... for Q. No. 6(b)**

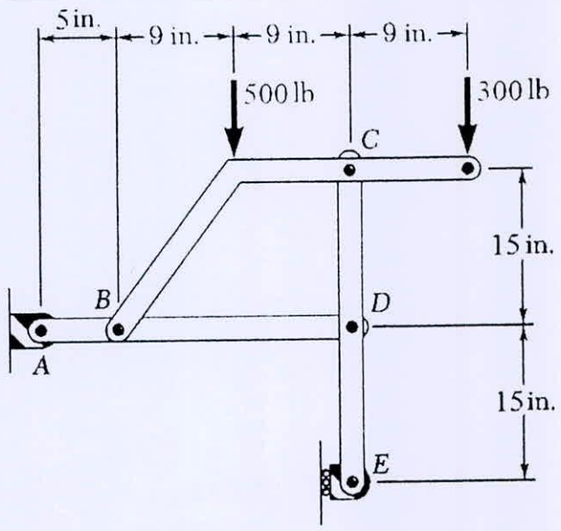


**Fig. for Q. 6(b)**

7. (a) A uniform rod AB of length 2R and weight W rest inside a hemispherical bowl of radius R as shown in Fig. for Q. 7(a). Neglecting friction, determine the angle θ corresponding to equilibrium. **(15)**

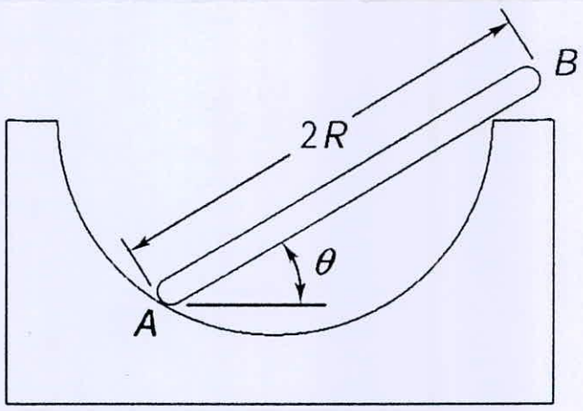


**Fig. for Q. 7(a)**

(b) For the system shown in Fig. for Q. 7(b) collar A starts from rest at t = 0 s and moves downward with a constant acceleration of 7 in/s$^2$. Collar B moves upward with a constant acceleration, and its initial velocity is 8 in./s. Knowing that collar B moves through 20 in. between t = 0 s and t = 2 s, determine (i) the accelerations of collar B and block C, (ii) the time at which the velocity of block C is zero, (iii) the distance through which block C will have moved at that time . **(20)**

Contd ..... P/5

**ME 165/CSE**

**Contd.... for Q. No. 7(b)**

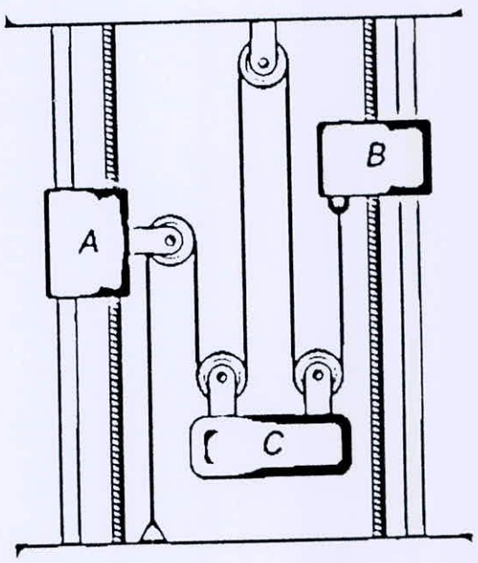


**Fig. for Q. 7(b)**

8. (a) The roller-coaster track shown in Fig. for Q. 8(a) is contained in a vertical plane. The portion of track between A and B is straight and horizontal, while the portions to the left of A and to the right of B have radii of curvature as indicated. A car is travelling at a speed of 72 km/h when the brakes are suddenly applied, causing the wheels of the car to slide on the track ($\mu_k = 0.20$). **(18)**

Determine the initial deceleration of the car if the brakes are applied as the car (i) has almost reached A, (ii) is traveling between A and B, (iii) has just passed B.

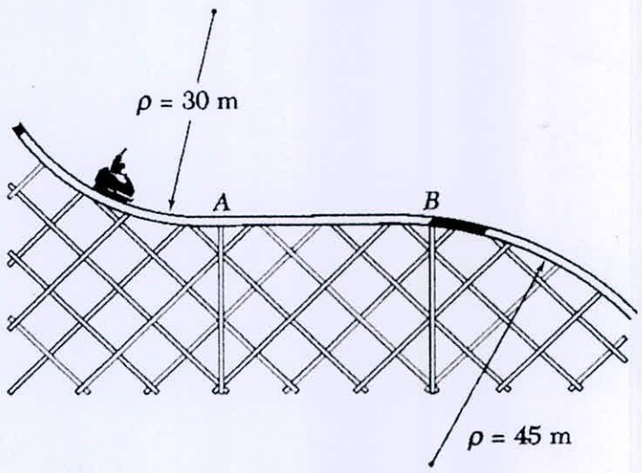


**Fig. for Q. 8(a)**

Contd ..... P/6

**ME 165/CSE**

**Contd.... for Q. No. 8**

(b) A 15-kg block B is suspended from a 2.5 m cord attached to a 20-kg cart A. The coefficients of frictions between block A and the inclined surface are $\mu_s = 0.24$ and $\mu_k = 0.20$. Check whether the system is in static equilibrium or not. If the system is not in static equilibrium determine (i) the acceleration of the cart, (ii) the tension in the cord, (iii) the acceleration of the block relative to the cart, immediately after the system is released from rest in the position shown in Fig. for Q. 8(b). **(17)**

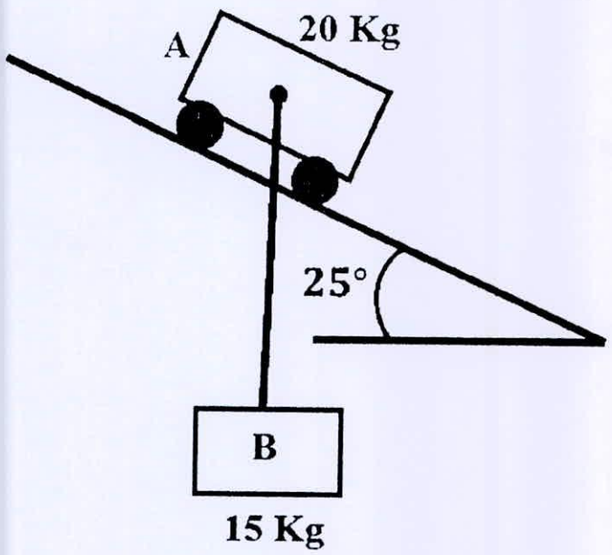


**Fig. for Q. 8(b)**

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ME 165/CSE



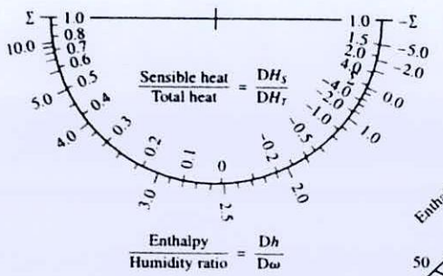
Saturated refrigerant-134a—Pressure table

| Press., $P$ kPa | Sat. temp., $T_{sat}$ °C | *Specific volume,* $m^3/kg$ Sat. liquid, $v_f$ | Sat. vapor, $v_g$ | *Enthalpy,* kJ/kg Sat. liquid, $u_f$ | Evap., $u_{fg}$ | Sat. vapor, $u_g$ | *Entropy,* kJ/kg·K Sat. liquid, $u_f$ | Evap., $u_{fg}$ | Sat. vapor, $u_g$ |
|---|---|---|---|---|---|---|---|---|---|
| 60 | -36.95 | 0.0007097 | 0.31108 | 3.837 | 223.96 | 227.80 | 0.01633 | 0.94812 | 0.96445 |
| 70 | -33.87 | 0.0007143 | 0.26921 | 7.722 | 222.02 | 229.74 | 0.03264 | 0.92783 | 0.96047 |
| 80 | -31.13 | 0.0007184 | 0.23749 | 11.20 | 220.27 | 231.47 | 0.04707 | 0.91009 | 0.95716 |
| 90 | -28.65 | 0.0007222 | 0.21261 | 14.36 | 218.67 | 233.04 | 0.06003 | 0.89431 | 0.95434 |
| 100 | -26.37 | 0.0007258 | 0.19255 | 17.27 | 217.19 | 234.46 | 0.07182 | 0.88008 | 0.95191 |
| 120 | -22.32 | 0.0007323 | 0.16216 | 22.47 | 214.52 | 236.99 | 0.09269 | 0.85520 | 0.94789 |
| 140 | -18.77 | 0.0007381 | 0.14020 | 27.06 | 212.13 | 239.19 | 0.11080 | 0.83387 | 0.94467 |
| 160 | -15.60 | 0.0007435 | 0.12355 | 31.18 | 209.96 | 241.14 | 0.12686 | 0.81517 | 0.94202 |
| 180 | -12.73 | 0.0007485 | 0.11049 | 34.94 | 207.95 | 242.90 | 0.14131 | 0.79848 | 0.93979 |
| 200 | -10.09 | 0.0007532 | 0.099951 | 38.41 | 206.09 | 244.50 | 0.15449 | 0.78339 | 0.93788 |
| 240 | -5.38 | 0.0007618 | 0.083983 | 44.64 | 202.68 | 247.32 | 0.17786 | 0.75689 | 0.93475 |
| 280 | -1.25 | 0.0007697 | 0.072434 | 50.16 | 199.61 | 249.77 | 0.19822 | 0.73406 | 0.93228 |
| 320 | 2.46 | 0.0007771 | 0.063681 | 55.14 | 196.78 | 251.93 | 0.21631 | 0.71395 | 0.93026 |
| 360 | 5.82 | 0.0007840 | 0.056809 | 59.70 | 194.15 | 253.86 | 0.23265 | 0.69591 | 0.92856 |
| 400 | 8.91 | 0.0007905 | 0.051266 | 63.92 | 191.68 | 255.61 | 0.24757 | 0.67954 | 0.92711 |
| 450 | 12.46 | 0.0007983 | 0.045677 | 68.80 | 188.78 | 257.58 | 0.26462 | 0.66093 | 0.92555 |
| 500 | 15.71 | 0.0008058 | 0.041168 | 73.32 | 186.04 | 259.36 | 0.28021 | 0.64399 | 0.92420 |
| 550 | 18.73 | 0.0008129 | 0.037452 | 77.54 | 183.44 | 260.98 | 0.29460 | 0.62842 | 0.92302 |
| 600 | 21.55 | 0.0008198 | 0.034335 | 81.50 | 180.95 | 262.46 | 0.30799 | 0.61398 | 0.92196 |
| 650 | 24.20 | 0.0008265 | 0.031680 | 85.26 | 178.56 | 263.82 | 0.32052 | 0.60048 | 0.92100 |
| 700 | 26.69 | 0.0008331 | 0.029392 | 88.82 | 176.26 | 265.08 | 0.33232 | 0.58780 | 0.92012 |
| 750 | 29.06 | 0.0008395 | 0.027398 | 92.22 | 174.03 | 266.25 | 0.34348 | 0.57582 | 0.91930 |
| 800 | 31.31 | 0.0008457 | 0.025645 | 95.48 | 171.86 | 267.34 | 0.35408 | 0.56445 | 0.91853 |
| 850 | 33.45 | 0.0008519 | 0.024091 | 98.61 | 169.75 | 268.36 | 0.36417 | 0.55362 | 0.91779 |
| 900 | 35.51 | 0.0008580 | 0.022703 | 101.62 | 167.69 | 269.31 | 0.37383 | 0.54326 | 0.91709 |
| 950 | 37.48 | 0.0008640 | 0.021456 | 104.52 | 165.68 | 270.20 | 0.38307 | 0.53333 | 0.91641 |
| 1000 | 39.37 | 0.0008700 | 0.020329 | 107.34 | 163.70 | 271.04 | 0.39196 | 0.52378 | 0.91574 |
| 1200 | 46.29 | 0.0008935 | 0.016728 | 117.79 | 156.12 | 273.92 | 0.42449 | 0.48870 | 0.91320 |
| 1400 | 52.40 | 0.0009167 | 0.014119 | 127.25 | 148.92 | 276.17 | 0.45325 | 0.45742 | 0.91067 |
| 1600 | 57.88 | 0.0009400 | 0.012134 | 135.96 | 141.96 | 277.92 | 0.47921 | 0.42881 | 0.90802 |
| 1800 | 62.87 | 0.0009639 | 0.010568 | 144.09 | 135.14 | 279.23 | 0.50304 | 0.40213 | 0.90517 |
| 2000 | 67.45 | 0.0009887 | 0.009297 | 151.78 | 128.36 | 280.15 | 0.52519 | 0.37684 | 0.90204 |
| 2500 | 77.54 | 0.0010567 | 0.006941 | 169.66 | 111.18 | 280.84 | 0.57542 | 0.31701 | 0.89243 |
| 3000 | 86.16 | 0.0011410 | 0.005272 | 186.51 | 92.57 | 279.08 | 0.62133 | 0.25759 | 0.87893 |

**ASHRAE Psychrometric Chart No. 1**
Normal Temperature
Barometric Pressure: 101.325 kPa



Sea Level







Prepared by Center for Applied Thermodynamic Studies, University of Idaho.

ME 165/CSE

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