Examination: VII Sem. B.Tech (Mining Engineering) **Session: 2025-26**

Semester: Monsoon Semester **Max. Marks: 30**

Subject: Mine Systems Engineering MND 404 **Time: 1 Hrs.**

Q1. LINEAR PROGRAMMING GRAPHICAL **(10 points)**

A contractor needs to hire earth-moving equipment and has the option of choosing from two types of machines.

- **Type A machine** costs **£25 per day** to hire, requires **1 man** to operate, and can move **30 tonnes of earth per day**.
- **Type B machine** costs **£10 per day** to hire, requires **4 men** to operate, and can move **70 tonnes of earth per day**.

The contractor faces the following limits:

1. The total daily hiring cost cannot exceed **£500**.
2. The contractor has only **64 workers** available to operate the machines.
3. A maximum of **25 machines** can be used on the site.

The task is to determine: **What is the maximum weight of earth that the contractor can move in one day, and how many machines of each type should be hired?**

Q2. LINEAR PROGRAMMING DUALITY **(10 points)**

Maximize $2X_1 - 13X_2 - 3X_3 - 2X_4 - 5X_5$

subject to

$$X_1 - X_2 - 4X_4 - X_5 = 5$$

$$X_1 - 7X_4 - 2X_5 \geq -1$$

$$5X_2 + X_3 + X_4 + 2X_5 \leq 5$$

$$3X_2 + X_3 - X_4 + X_5 \geq 2$$

$X_j \geq 0$ for all j=1, 2, 3; $X_4 \leq 0$; X_5 unrestricted in sign

a. Is this solution feasible at the primal point X (6,0,1,0,1) ? Why

b. A basic feasible solution (BFS) is a solution to a linear programming problem that satisfies all constraints and has at most as many non-zero variables as there are constraints (often denoted as 'm'). Is this solution basic? Yes or No , Explain why

c. Write out in full a dual problem of the LP above, denoting your dual variables by Y1, Y2, etc.

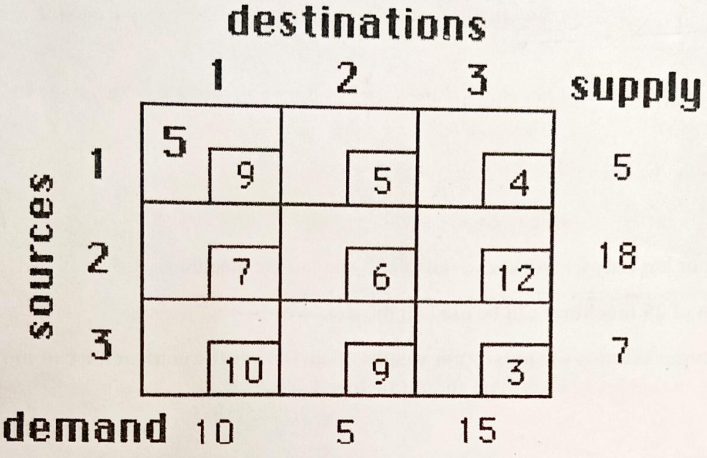
d. IF X=(6,0,1,0,1) is optimal in the primal problem, then which dual variables (including slack or surplus variables) must be zero in the dual optimal solution, according to the complementary slackness conditions for this primal-dual pair of problems?

Examination: VII Sem. B.Tech (Mining Engineering) | **Session: 2025-26**

Semester: Monsoon Semester | **Max. Marks: 30**

Subject: Mine Systems Engineering MND 404 | **Time: 1 Hrs.**

Q3. Transportation Problem: **(10 points)**



a. If the ordinary simplex tableau were to be written for this problem, how many rows (including the objective) will it have? __

b. How many variables (excluding the objective value -z) will it have? _

c. Is this transportation problem "balanced?" __

d. How many basic variables will this problem have?

e. An initial basic feasible solution is found using the "Northwest Corner Method"; complete the computation of this solution and write the values of the variables in the tableau.

Examination: VIII Sem. B.Tech (Mining Engineering) **Session: 2025-26**

Semester: Monsoon Semester **Max. Marks: 50**

Subject: Mine Systems Engineering -- MND 404 **Time: 2 Hrs.**

Q1 **(10 points)**

The purchasing department of a company has suggested two inventory policies:

- *Policy 1.* Order 150 units. The reorder point is 50 units, and the time between placing and receiving an order is 10 days.
- *Policy 2.* Order 200 units. The reorder point is 75 units, and the time between placing and receiving an order is 15 days.

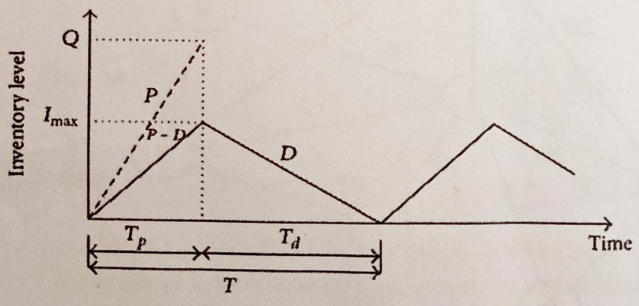
The setup cost per order is $20, and the holding cost per unit inventory per day is $.02.

(a) Which of the two policies should the company adopt?

(b) If you were in charge of devising an inventory policy for the company, what would you recommend assuming that the supplier requires a lead time of 22 days?

Q2. A power plant near a coal mine demands 81,000 tons of coal annually. The mine produces 202,500 tons of coal per year. The mine is operational for 250 days a year, and the lead time is 3 days. The cost per ton of coal produced is $0.40, the cost per setup is $5.40, and the holding cost per ton of coal in the stockyard annually is $0.072. Use the appropriate inventory management model to cater to the demands of the coal power plant in the most economically efficient way. Hence, calculate, draw, and mark on the figure below the following **(10 points)**

i. the optimal size of a production run (Q*)
ii. total cost of production
iii. reorder point
iv. time of depletion run (Td)
v. total cycle time (T*) , and practical cycle time



Q3. A mining company is evaluating the potential profit from a new mineral extraction project. The project's profitability is subject to uncertainties in mineral quality, extraction costs, and market prices, all of which vary with market conditions. A Monte Carlo simulation has been performed to model these uncertainties and provide an estimate of the project's profit. The simulation ran 10,000 iterations and generated the following summary statistics of projected profit: **(15 points)**

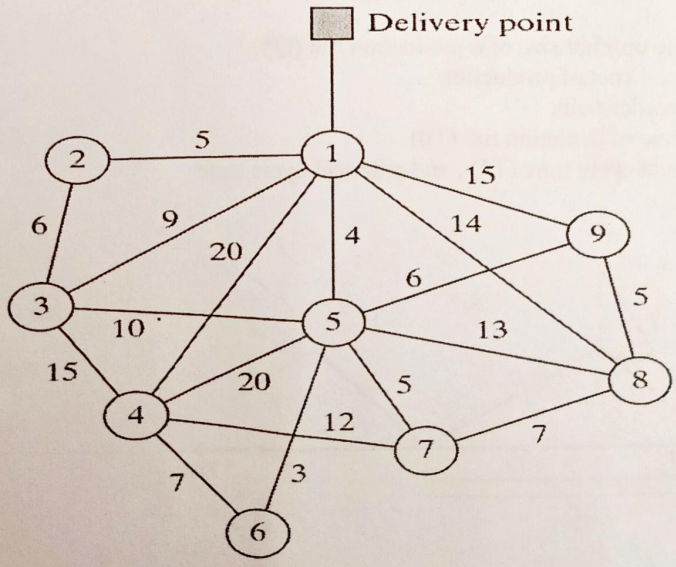
- Mean projected profit: $1,500,000
- Standard deviation of projected profit: $400,000
- Probability of a loss (profit < $0): 12%
- 90th percentile of projected profit: $2,000,000

(a) Interpret the 90th percentile of the projected profit. What does this value indicate about the simulation results?

(b) Assuming a normal distribution of profits based on the mean and standard deviation provided, calculate the probability that the profit will exceed $2,300,000.

(c) Suppose the company requires at least an 80% chance of making a profit of $1,200,000 or more to proceed with the project. Based on the simulation results, would you recommend proceeding with the project? Justify your answer.

Q4. The figure below gives the mileage of the feasible links connecting nine offshore natural gas wellheads with an inshore delivery point. Because wellhead 1 is the closest to shore, it is equipped with sufficient pumping and storage capacity to pump the output of the remaining eight wells to the delivery point. Determine the minimum pipeline network that links the wellheads to the delivery point. Use the appropriate algorithm. Please draw the complete network **(15 points)**



List of formulae:

Without shortage EOQ

EOQ = Q^* = Square root of two times of ordering cost multiplied by annual demand divided by carrying cost/per unit

$$= \sqrt{\frac{2C_o D}{C_h}}$$

The cycle period t is given by $\frac{\text{Optimal Order Quantity}}{\text{Annual demand}}$

or $$t^* = \frac{Q^*}{D} = \sqrt{\frac{2C_o}{C_h D}}$$

The total number of orders per year (= N) is the reciprocal of the cycle period i.e.,

$$N = \frac{D}{Q^*} = \sqrt{\frac{C_h D}{2C_o}}$$

To find a practical T:

1. Calculate T*
2. Pick a base time period (day, week, etc.)
3. Find the lowest value of k that satisfies:

$$\frac{T^*}{\sqrt{2}} \le 2^k \le \sqrt{2}\,T^*$$

- **Total cost:**

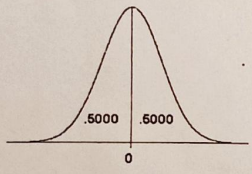
$$TC_{EPQ} = \left(\frac{D}{Q}S\right) + \left(\frac{I_{MAX}}{2}H\right)$$

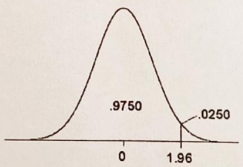
- **Maximum inventory:**
  - d=avg. daily demand rate
  - p=daily production rate

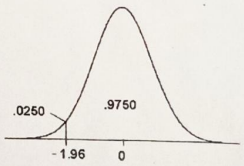
$$I_{MAX} = Q\left(1 - \frac{d}{p}\right)$$

- **Calculating EPQ**

$$EPQ = \sqrt{\frac{2DS}{H\left(1 - \frac{d}{p}\right)}}$$







$z_{.5000} = 0.00$; $z_{.9750} = +1.96$; $z_{.0250} = -1.96$

- z-table, a z-score of -0.75 corresponds to a cumulative probability of 0.2266.
- a z-score of 2 corresponds to a cumulative probability of about 0.9772.

INDIAN INSTITUTE OF TECHNOLOGY (INDIAN SCHOOL OF MINES), DHANBAD

MID-SEMESTER EXAMINATION

Course: 7th Sem B.Tech (CHE, CSE, ECE, EE, ESE, MNE, ME, MME, M&C, MLMTE, PE & PHY)

Session: ~~2024-2025~~ 25-2026 **Semester:** Monsoon

Subject: Mine Environmental Engineering (MND – 406)

Time: 1 hr **Max. Mark:** 30

Instructions: ***Answer ALL questions.***

Q.No.	*Question*	*Marks*
1	What are the causes of fire in coal pillars? Suggest the precautions that should be taken to prevent them.	2 + 4
2	A panel developed on bord and pillar in mine has been sealed off due to a fire. What are the regular checks to be made to determine the conditions inside the sealed off area? When can the conditions be considered safe to re-open the panel?	4 + 2
3	A coal mine has been sealed off after an ignition of firedamp. The results of analysis of mine air taken at six hours' intervals after sealing are given below. What does it indicate regarding (a) the condition of fire and (b) airtightness of the stoppings?	4+2
4	An analysis of mine air gave the following results: • CO_2 = 0.55% • CH_4 = 1.15% • O_2 = 19.76% • CO = 0.008% • N_2 = 78.532% a) Calculate the Graham's ratio and give your interpretation of this ratio. b) Is this ratio affected by nitrogen flushing? c) Calculate the percentage of blackdamp by volume.	2+2+2
5	a) Describe the symptoms indicating outbreak of the fire due to spontaneous heating. b) What precautions shall be taken for an early detection of fire in a mine working a coal seam liable to spontaneous heating? c) What measures would you be taking to control the fire after it has been detected?	2+2+2

Sample	First	Second	Third	Fourth
CO_2	1.05	0.80	1.00	0.76
O_2	18.98	19.25	18.73	19.28
CO	0.10	0.08	0.09	0.08
H_2	0.30	0.08	0.09	0.06
CH_4	0.23	0.14	0.22	0.08
N_2	79.34	79.65	79.87	79.84

End of the Question Paper

END-SEMESTER EXAMINATION
Department of Mining Engineering
Indian Institute of Technology (Indian School of Mines), Dhanbad

Course: 7th Sem B.Tech

Session: 2025-2026 **Semester**: Monsoon

Subject: Mine Environmental Engineering (MND – 406)

Time: 2 hrs **Max. Mark**: 50

Instructions: ***Answer any FIVE questions.***

Q.No.	*Question*	*Marks*
1	With a neat and labelled sketch, describe the details of a stone-dust barrier suitable for a bord-and-pillar development panel having six level headings. The gap on either side of the shelf in the gallery is 10 cm. Stone dust is loaded on each shelf at the rate of 30 kg per meter of shelf length for light-type barriers and 160 kg per meter of shelf length for heavy-type barriers. Light-type barriers are loaded with 110 kg of stone dust per square metre cross-sectional area of the gallery, whereas heavy-type barriers are loaded with 390 kg of stone dust per square metre cross-sectional area of the gallery. The galleries are 4.5 m wide and 2 m high, and the pillars are spaced 18 m centre-to-centre. Calculate (a) total dust loading of the barrier, (b) number of shelves heavily loaded, (c) number of shelves lightly loaded, and (d) length of each shelf.	2+1+3+3+1
2	a) Spontaneous heating is suspected in one section of the workings. Explain the methodical approach you would adopt to investigate the condition and to mitigate any related risks. b) Given below the analysis result of a sample taken from inside a sealed off fire area: N_2 = 79.79%, CO_2 = 8.44%, CH_4 = 3.86%, O_2 = 4.97%, CO = 2.00%, H_2 = 0.94%. Calculate CO/O_2 and CO_2/O_2 ratios. Also indicate the conclusions you would draw.	2+2 2+2+2
3	a) In an underground mine, water is flowing in a gallery of 4 m width and 3 m height at a rate of 2000 GPM with 120 m head. Describe how you will construct the brick dam and what precautions you will take. Also outline the procedure mandated by the Coal Mines Regulations prior to commencing such construction. Assume that the safe crushing strength of the brick is 17.5 kg/cm^2. b) Discuss the precautions you will take while approaching old workings?	3+2+2 water-logged 3

P.T.O.

4	a) A miner has accidentally moved into an irrespirable atmosphere and is found unconscious underground. Explain the appropriate rescue apparatus required for conducting the rescue in this situation.	5
	b) In an underground mine, a miner inhales the normal air and exhales the air containing 15.5% O_2 and 3.5% CO_2. What is the respiratory quotient of breathing for the worker?	2
	c) Air is flowing with a flow rate of 24 m^3/s in a roadway of 4 m width × 3 m height × 100 m length in an underground coal mine. Is there any danger of methane layering if the percentage of methane in the mine atmosphere is 3.5%?	3
5	a) Drilling in a gallery of 3 m × 4 m in an underground coal mine produces 1.5 gm of dust of < 5 µm size every minute. Calculate the airflow rate required to dilute the dust to the threshold limit value if the intake air has a respirable dust load of 0.8 mg/m^3 and the respirable dust has a free silica content of 8%. What actions would you recommend to prevent the production of dust in coal mines?	3+2
	b) A long heading 3 m wide and 2.5 m high is ventilated by a forcing tube circulating 2.8 m^3/s of air at the face. Calculate the distance from the face at which all the +10 µm dust particles would have settled down from the air stream. The dust particles have a density of 2650 kg/m^3.	5
6	a) Give briefly the statutory and other requirement in the respect of the "Standard of underground lighting".	3
	b) What is the difference between "intrinsically safe" and "flame proof electrical equipment"?	2
	c) A centrally placed roof lamp delivers an illumination of 40 lux directly beneath it on the floor of an underground workshop. If the workshop measures 20 m × 20 m with a height of 4 m, determine the illumination at any corner point on the floor, assuming uniform spherical light dispersion.	5

End of the Question Paper

DEPARTMENT OF MINING ENGINEERING

INDIAN INSTITUTE OF TECHNOLOGY (INDIAN SCHOOL OF MINES), DHANBAD

Mid-Semester Examination

Examination: VII B. Tech.

Semester: Monsoon **Session: 2025-2026**

Subject: Advanced Mine Ventilation (MND 401)

Time: 1 Hour Total Marks: 30

Instruction: Answer ALL questions

Q. No.		Marks
1.	With neat sketches discuss the thermodynamic aspects of mine ventilation of an underground mine consisting of a downcast and an upcast shaft. **Or** Discuss the generation and utilization of geothermal energy. Also, discuss the geothermal gradient and its role in mine ventilation.	10
2.	The following data are given for an underground mine airway: Cross-sectional area of the airway: 4 m × 3 m Length of the airway: 100 m Friction factor of the airway (K): 0.014 Ns^2m^{-4} Airflow rate in the airway: 30 m^3/s Dry-bulb temperature of air: 30°C Relative humidity of air: 90% Strata temperature: 25°C Barometric pressure: 101.0 kPa Dynamic viscosity of air at 30°C: 18.61 × 10^{-6} Pa.s Thermal conductivity of air: 0.026 W/m°C Calculate the latent heat transfer in the airway. Assume any other data, if required.	20

Important formulae:

$e = e'_{wb} - 0.000644B(t_{db}-t_{wb})$, $e'_{wb} = 0.6105 \exp [17.27t_{wb}/(t_{wb}+237.3)]$

$q = 2\pi K.T.L\ (t_{vr} - t_s)$, $q_R = h_r.A_I\ (t_{db}-t_s).F_{ev}$

$q_C = h_c.A\ (t_s-t_{db})$, $q_L = hc.A.\lambda\ [0.7\ (\phi e'_{db}-e'_s)/B]$, $hc = Nu.Ka/D$

$Nu = 0.35.f.Re/[1+1.592(15.217.f.Re^{0.2}-1)/Re^{0.125}]$

$q_R = 5.67 \times 10^{-8}\ (T_I^4-T_2^4) \times A_I \times F_{ev}$

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DEPARTMENT OF MINING ENGINEERING

INDIAN INSTITUTE OF TECHNOLOGY (INDIAN SCHOOL OF MINES), DHANBAD

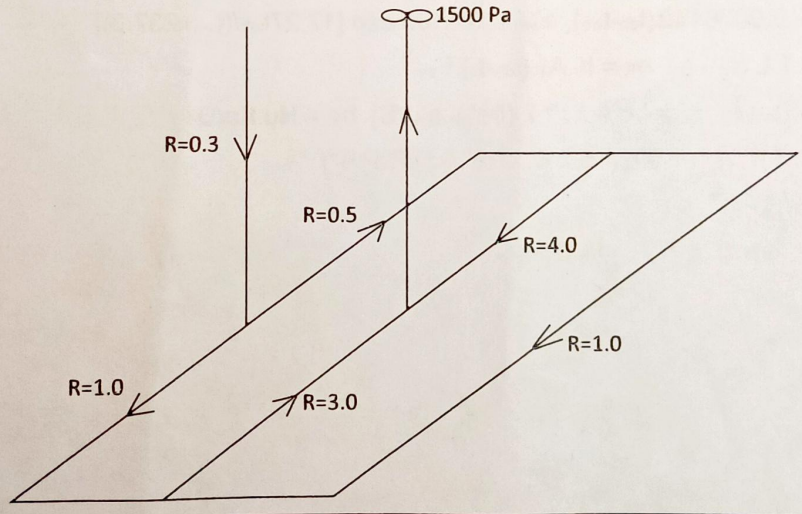
End-Semester Examination

Semester: Monsoon **Session: 2025-2026**

Subject: Advanced Mine Ventilation (MND 401)

Time: 2 Hours **Total Marks: 50**

Instruction: Answer ALL questions

Q. No.	Question	Marks
1.	With the help of a numerical example, discuss the application of Kirchhoff's laws in mine ventilation network analysis.	10
2.	Derive the formula for calculating the mesh correction factor in a mine ventilation network by Hardy Cross iteration technique. **Or** The ventilation network of a mine shown in figure consists of a downcast and an upcast shaft. The resistance values of the branches in Ns^2m^{-8} are shown in figure. If the main mine fan installed at the upcast shaft produces 1500 Pa pressure, and that there is no natural ventilation, determine the distribution of airflow in the network using the Hardy Cross iteration technique up to 3 iterations.  	15

3.	A steel pipe of 160 mm inside diameter and 170 mm outside diameter carries cold water at 10°C at 0.5 m/s along a mine airway. The outer surface of the pipe is at a temperature of 11°C when the temperature of the water inside the pipe is 10°C. The wet-bulb and dry-bulb temperatures of air in the airway are 25°C and 28°C, respectively, and the barometric pressure of air is 100 kPa. Determine the rate of heat pickup by the water, given the convective heat transfer coefficient = 20.5 W/m^2°C, Emissivity and view factor = 0.95, saturated vapour pressure at 11°C is 1.312 kPa, and actual vapour pressure = 2.79 kPa. Assume your own data, if required.	**15**
4.	Using the pressure-enthalpy diagram superimposed by the state diagram of the refrigerant, thermodynamically explain the working of a vapour-compression refrigeration system. **Or** With neat sketches, discuss the Tube-bundle and Wireless System Network (WSN) systems of underground coal mine environmental monitoring.	**10**

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Important formulae:

$e = e'_{wb} - 0.000644B(t_{db}-t_{wb})$, $e'_{wb} = 0.6105 \exp [17.27t_{wb}/(t_{wb}+237.3)]$

$q = 2\pi K.T.L\ (t_{vr} - t_s)$, $q_R = h_r.A_1\ (t_{db}-t_s).F_{ev}$

$q_C = h_c.A\ (t_s-t_{db})$, $q_L = hc.A.\lambda\ [0.7\ (\phi e'_{db}-e'_s)/B]$, $hc = Nu.Ka/D$

$Nu = 0.35.f.Re/[1+1.592(15.217.f.Re^{0.2}-1)/Re^{0.125}]$

$T = 0.685/Fo^{0.146}$

$q_R = 5.67 \times 10^{-8}\ (T_1^4-T_2^4) \times A_1 \times F_{ev}$

Department of Computer Science & Engineering
Mid Semester Examination
Monsoon Semester, Session: 2025-2026
Subject: Machine Learning (NCSD519)

Time: 1 Hours
Max. Marks: 30

Instructions: Answer the questions as per the instruction within each section.

Sl. No.	Section-I (20 Marks: Attempt All Question)	Marks
1.	**(a)** A hospital wants to predict whether a patient has diabetes (1) or not (0) based on their fasting blood sugar level (in mg/dL). A logistic regression model was built using the following equation: $$P(\text{Diabetes} = 1) = \frac{1}{1 + e^{-(-7-0.08 \times X)}}$$ Where X is the fasting blood sugar level. (i)Calculate the probability that a patient with a fasting blood sugar level of 100 mg/dL has diabetes. (ii) Based on a threshold of 0.5, will this patient be classified as diabetic? (iii)What fasting blood sugar level corresponds to a predicted probability of diabetes of 0.5? (iv) Calculate the log-odds (logit) for X = 95 mg/dL **(b)** A startup wants to predict monthly sales (in $1000s) based on online advertising spend (in $1000s). The dataset contains 3 points: Advertising Spend (x) | Actual Sales 1 | 3 2 | 5 3 | 7 The model is: $\hat{y}=w \times x+b$ Initially, parameters are w=0, b=0, and learning rate $\alpha=0.1$. Perform one gradient descent update to find new *w* and b.	(1) (1) (2) (2) (2+2)
2.	**(a)** A robot needs to navigate inside a warehouse from its starting point to a destination while avoiding obstacles (like shelves, boxes, and walls). The developers collect a dataset of past navigation example where: Inputs: Robot's sensor readings (e.g. distance to obstacles, current position, orientation) Output: Correct action taken (e.g. move forward, turn left, turn right , stop) (i) Explain how this navigation task can be formulated as supervised learning problem. (ii) Mention the nature of problem (regression or binary/multiclass classification). (iii)Which supervised model is suitable for above given problem and why? **(b)** Consider the following use cases and mention what type of machine learning technique to be used. (i) A mall wants to divide its customers into groups based on their shopping behavior. They do not have predefined categories or labels for the customer. (ii) A self-driving car learns to navigate by interacting with environment, steering, braking and receiving rewards (safe driving) or penalties. (iii) A streaming platform suggests movies to users by analyzing what similar users have watched. **(c)** Define machine learning model Underfititng and Overfitting case from bias/variance perspective.	(2) (1) (2) (1) (1) (1) (2)

Section-II (10 Marks : Attempt Any ONE Questions)

3. We will use the dataset below to learn a decision tree which predicts if people pass Machine learning (Yes or No), based on their previous GPA (High, Medium, or Low) and whether or not they studied.

GPA	Studied	Passed
L	F	No
L	T	Yes
M	F	No
M	T	Yes
H	F	Yes
H	T	Yes

(i) Which attribute will be selected as root? (4)
(ii) Draw the full decision tree that would be learned for this dataset. (6)

4. (i)Why is Support Vector Machine (SVM) often effective when dealing with datasets that have a large number of features (high-dimensional space)? (2)

(ii)What is the effect of a small C on the SVM decision boundary in case of soft margin? How does it affect Overfitting and Underfititng? (3)

(iii) Why do we need semi-supervised learning? Mention basic steps involved in self-training semi supervised learning algorithm. (2+3)

Department of Computer Science & Engineering
End Semester Examination
Monsoon Semester, Session: 2025-2026
Subject: Machine Learning (NCSD519 & CSO504)

Time: 2 Hours
Max. Marks: 50

Instructions: Answer the questions as per the instruction within each section.

Sl. No.	Section-I (20 Marks: Attempt All Question)	Marks
1.	**(a)** A hospital uses a machine learning system to classify whether a patient has pneumonia using lung X-ray features. A single decision tree performs well on training data but poorly on new patients. The data also contains missing values, noisy pixels, and correlated features. The hospital considers using a random forest to improve performance. (i)Which components of a random forest help to improve the model generalization on unseen patients. (ii) How do these components handle missing values and correlated features effectively?	(2) (3)
	(b) Consider the following 5 training examples: **Customer** | **Feature x** | **True Label y** 1 | 2 | +1 2 | 3 | +1 3 | 5 | -1 4 | 7 | -1 5 | 8 | -1 Suppose that you are using AdaBoost with a decision stump (one-level decision tree) as a weak learner and the decision stump predicts based on the following $h(x) = +1$ if $x < 6$ else -1 (i)What is initial weight of each sample? (ii)Find the weighted classification error. (iii)Compute the weight (alpha) of weak model.	(1) (2) (2)
2.	**(a)**How many binary classifiers are needed in an SVM with N classes when using the One-vs-All (OvA) strategy and the One-vs-One (OvO) strategy? How do the One-vs-All (OvA) and One-vs-One (OvO) strategies in SVM make the final classification decision for a given test sample?	(2+3)
	(b) A company wants to build a machine learning model for three different problems: 1. **Problem A:** Predict whether a transaction is fraud or not fraud based on numerical and categorical features. 2. **Problem B:** Classify handwritten digits (0–9) from images. 3. **Problem C:** Predict whether customers will buy a product, with the goal of explaining how each feature influences the probability of purchase. Which classifier would be most suitable for Problem A, Problem B, and Problem C? Justify your answer.	(2+2+1)

Section-II (30 Marks: Attempt Any TWO Questions)

3. **(a)** A hospital is developing a machine learning model to predict whether patients have heart disease. After testing the model on 100 patients, the confusion matrix is as follows:

	Predicted Positive	Predicted Negative
Actual Positive	50	10
Actual Negative	30	10

(i) Calculate the F1-score for this model. (2)

(ii) When the primary concern is minimizing missed cases of heart disease rather than avoiding false alarms, how should the F1-score be interpreted in evaluating the model's performance? (2)

(iii) If another model has Precision = 0.9 and Recall = 0.6, which model would you recommend based on F1-score, and why? (3)

(b) A dataset contains 100 samples for predicting whether a patient has a certain disease (binary classification). A data scientist wants to evaluate the performance of a logistic regression model using cross-validation. He decides to use Leave-One-Out Cross-Validation (LOOCV).

(i) Explain what LOOCV is and how it works in this scenario. (2)

(ii) How many models will be trained during LOOCV for this dataset? (1)

(iii) What are the advantages and disadvantages of using LOOCV compared to, say, 5-Fold Cross-Validation? (2)

(c) A language processing company is building models for the following tasks:

1. Named Entity Recognition (NER): Identifying entities in a sentence (e.g., names, locations). (3)
2. Weather forecasting: Predicting temperature over the next week based on historical daily data.
3. Chatbot response generation: Predicting next dialogue response in real-time.

Suggest a suitable RNN variant (Vanilla RNN, Bidirectional RNN, LSTM, GRU) for each task. Justify your choice.

4. **(a)** A delivery robot uses epsilon (ε)-greedy Q-learning with $\varepsilon = 0.2$ to choose actions in a warehouse. In state **S**, it has the following Q-values:

$Q(S, \text{Forward}) = 5$, $Q(S, \text{Right}) = 8$

During one step, the robot unexpectedly chooses the action Forward, even though it has a lower Q-value. After taking this action, it receives a reward $r = -1$, and the next state S′ has a maximum Q-value of 10. The learning rate $\alpha = 0.4$ and discount factor $\gamma = 0.9$.

(i) Explain why the robot might have selected Forward instead of the higher-valued action Right and identify whether this selection is exploration or exploitation. (2)

(ii) Using the Q-learning update rule, compute the updated Q-value for following: Q(S, Forward). (3)

(b) (i) Differentiate between model interpretability and model explainability and discuss how each relates to understanding machine learning predictions. Additionally, explain the trade-off between interpretability, explainability, and model accuracy. (3)

(ii)A company is designing a convolutional neural network (CNN) for colour images of size 32 × 32 × 3 (Height × Width × Channels). The first convolutional layer has the following parameters: (2)

Number of filters: 8, Filter size: 3 × 3, Stride: 1, Padding: 0 (no padding)

What is output feature map size?

(c) A smart city uses an IoT-based environmental monitoring system to record temperature, humidity, and air-quality levels from sensors placed throughout the city. The data is collected every minute and stored in the central system. Below is a description of several unusual observations recorded during one week: (5)

Observation A: One sensor reported a temperature of 85°C at 3:15 PM. All other sensors nearby recorded temperatures between 25°C and 30°C at the same time.

Observation B: A sensor located in a coastal area reports a humidity level of 15% during the early morning hours. However, the same humidity level is commonly observed in that location during noon hours.

Observation C: Over a period of 20 minutes, a cluster of air-quality sensors in the industrial zone recorded a sudden, sharp drop in air-quality index (AQI), indicating heavy pollution. However, each individual reading seems within the normal range when viewed alone.

For each observation (A, B, and C), identify whether it represents a point anomaly, contextual anomaly, or collective anomaly. Justify the reasoning behind your classification.

5. **(a)** (i) Describe how hierarchical clustering allows selecting a specific number of clusters from a dataset, and illustrate your answer with a dendrogram. (3)

(ii)Given Proximity (Distance) Matrix (4)

	A	B	C	D
A	0	4	8	7
B	4	0	6	9
C	8	6	0	5
D	7	9	5	0

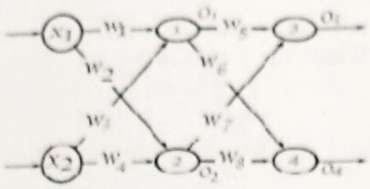
Determine the second merge clusters based on the updated distances after first merge clusters.

(b) A company records the monthly spending (in $100) of 5 customers: (3)

Customer	Spending
A	12
B	15
C	14
D	30
E	28

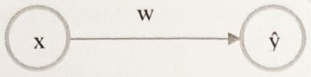
Use absolute distance to find the medoid of this dataset.

(c) Consider the following Multilayer Neural Network. (5)



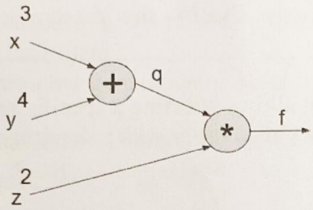
Assume that all internal nodes and output nodes use the sigmoid function as activation function. Show, how back propagation algorithm update the values of w_1, w_2, and w_8 for one epoch. Derive an explicit expression for same. Algorithm is given the example (x_1, x_2, y_1, y_2) with y_1 and y_2 being outputs at 3 and 4 respectively (there are no bias terms). Assume that the learning rate of your choice. Let o_1 and o_2 be the output of the hidden units 1 and 2 respectively. Let o_3 and o_4 be the output of the output units 3 and 4 respectively.

6. **(a)** Consider the simple neural network: (5)



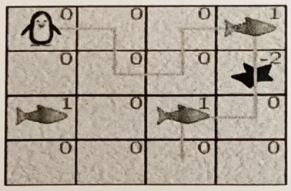
x is the input, $\hat{y}$ is the predicted output and w is the weight. Suppose you need to update the weight w based on the L2 loss L calculated based on the predicted output $\hat{y}$ and the actual output y. Write the gradient descent algorithm to update the weights of a neural network.

(b) Consider the computational graph associated with a neural network: (5)



The values associated with x, y and z are 3, 4 and 2 respectively. Let q = x + y and f = qz. Compute $\frac{\partial f}{\partial x}$, $\frac{\partial f}{\partial y}$ and $\frac{\partial f}{\partial z}$.

(c)Consider the following diagram: (5)



It shows a single trajectory through the example MDP. The penguin receives a reward of +1 when it reaches the first fish tile, −2 when it falls in the hole, and +1 for reaching the second fish tile. The discount factor γ is 0.9. Calculate the return G_t at t = 1 and t = 2.

7. **(a)** Define the basic terms used in Density-based Clustering. Explain with diagram how Density-based Clustering algorithm works. (2+2)

(b) Briefly discuss the merits and demerits of the following clustering algorithms i) hierarchical clustering, ii) Partitional clustering (2+2)

(c) Explain how the feature selection problem can be converted into an Optimization Problem? Discuss any one method in detail. (7)

Quiz 1

Session: 2025-2026 Semester: Monsoon

Time: 20 minutes **NECD509/ECO506: Machine Learning** Maximum Marks: 10

1. Let us consider n training examples $\{x^{(i)}, y^{(i)}\}, i = 1, 2, \ldots, n$ depicting the price $y^{(i)}$ for the i^{th} house against the size $x^{(i)}$. Further, we decide to fit the training data with the polynomial function of the form $h_{\bar{\theta}}(x) = \sum_{j=0}^{N} \theta_j x^j$ where N is the polynomial order, and θ_j is the weight associated with the j^{th} order polynomial. In general, we set $N = 10$. Furthermore, we consider the two scenarios, i.e., scenario A and B. In scenario A, we have a sufficiently large amount of training data samples, i.e., $n >> N$ whereas in scenario B, we have a limited number of training data samples, i.e., $n \approx N$. Considering both the scenarios, we further move on to run the gradient descent algorithm so as to minimize the mean squared error cost function $J(\bar{\theta})$. Based on this, answer the following questions.

   - What trend can we expect for the training error as well as testing error in both the scenarios? 3 marks
   - Suggest the appropriate modifications in the cost function $J(\bar{\theta})$ if the algorithm works very poorly on the testing data in any of these scenarios? 3 marks
   - Based on the modified cost function, derive the update rule for θ's considering both the batch gradient descent as well as stochastic gradient descent algorithm. 4 marks

Mid Term Examination

Session: 2025-2026 Semester: Monsoon

Time: 60 minutes **NECD509/ECO506: Machine Learning** Maximum Marks: 30

1. Suppose that you have n training examples associated with the housing data : $\{(\bar{x}^{(1)}, z^{(1)}), (\bar{x}^{(2)}, z^{(2)}), \ldots, (\bar{x}^{(n)}, z^{(n)})\}$. Further, $\bar{x}^{(i)} \in \mathbb{R}^d$ and $z^{(i)} \in \mathbb{R}$ for $i \in \{1, 2, \ldots, n\}$, respectively, is the input feature vector and the price associated with the i^{th} house. Furthermore, we try to approximate the price (z) of the house as $h_{\bar{\theta}}(\bar{x}) = \sum_{j=0}^{d} \theta_j x_j$.

   - Mention the appropriate cost function for the aforementioned data set. 3 marks
   - Determine the update rule for $\bar{\theta}$ considering the batch gradient descent algorithm. 3 marks
   - Considering normal equation, determine the optimum vector $\bar{\theta}_{optimum}$ that minimizes the cost function. 4 marks

2. Suppose we have n samples of the data set expressed as $\{x^{(1)}, x^{(2)}, \ldots, x^{(n)}\}$. Further, each $x^{(i)}, i = \{1, 2, \ldots, n\}$ is independent and belong to the samples drawn from the Gaussian distribution with unknown parameters μ and σ^2. Determine the maximum likelihood (ML) estimate of μ and σ^2. (10 marks)

3. Suppose that you have n training examples associated with the email classification (spam or not spam): $\{(\bar{x}^{(1)}, z^{(1)}), (\bar{x}^{(2)}, z^{(2)}), \ldots, (\bar{x}^{(n)}, z^{(n)})\}$. Further, $\bar{x}^{(i)} \in \mathbb{R}^d$ and $z^{(i)} \in \{0, 1\}$ for $i \in \{1, 2, \ldots, n\}$, respectively, is the input feature vector and the output label associated with the i^{th} training example. Based on this, answer the following questions

   - Mention the hypothesis function considered for this data set. (3 marks)
   - Write the cost function expression for this data set. (3 marks)
   - Determine the update rule for the weights considering stochastic gradient descent algorithm. (4 marks)

End Semester

Session: 2025-2026 Semester: Monsoon

Time: 2 Hours **NECD509/ECO506: Machine Learning** Maximum Marks: 50

1. Suppose we have a training data set consisting of n training examples : $\{(\bar{x}^{(i)}, y^{(i)}), i = \{1, 2, \ldots, n\}\}$ where $\bar{x}^{(i)} \in \mathbb{R}^d$ and $y^{(i)} \in \mathbb{R}$, respectively, is the input feature vector and output label. Further, we want to approximate $y^{(i)}$ as $h_{\bar{\theta}}(\bar{x}^{(i)}) = \sum_{j=0}^{d} \theta_j x_j^{(i)}$. Here, $\theta_j \in \mathbb{R}$ is the weight associated with the j^{th} feature of the training example.

   - Derive the appropriate cost function for the available training data set. (10 marks)
   - Mention the regularized cost function for the available training data set and derive the closed-form expression for the optimum value of $\bar{\theta}$ that minimizes the regularized cost function. (10 marks)

2. - Suppose we have a data set consisting of n samples : $\{x_i, i = \{1, 2, \ldots, n\}\}$. Further, each x_i is independent and belong to the samples drawn from the Poisson distribution with parameter λ. The probability mass function (PMF) for the draw x_i is expressed as

$$f(x_i; \lambda) = \frac{\lambda^{x_i} e^{-\lambda}}{x_i!}.$$

     Find the maximum likelihood estimate of the parameter λ. (5 marks)

   - Show that the Poisson distribution belongs to the exponential family and compute the appropriate related parameters. (5 marks)

3. Suppose we have a training data set consisting of n training examples : $\{(\bar{x}^{(i)}, y^{(i)}), i = \{1, 2, \ldots, n\}\}$ where $\bar{x}^{(i)} \in \mathbb{R}^d$ and $y^{(i)} \in \{0, 1\}$, respectively, is the input feature vector and output label.

   - Mention the cost function for the available training data and prove the convexity of the cost function. (10 marks)

4. Consider the cost function $J(\bar{\theta}) = (X\bar{\theta} - \bar{z})^T A(X\bar{\theta} - \bar{z})$. Here, $X \in \mathbb{R}^{n \times d}$ is the input feature matrix, $\bar{\theta} \in \mathbb{R}^{d \times 1}$ is the weight vector, $\bar{z} \in \mathbb{R}^{n \times 1}$ is the output vector, and $A \in \mathbb{R}^{n \times n}$ is a diagonal matrix consisting of the scaling coefficients $a_i \in \mathbb{R}, i \in \{1, 2, \ldots, n\}$ on the diagonal. Find the closed-form expression for the optimum value of $\bar{\theta}$ that minimizes the cost function $J(\bar{\theta})$. (10 marks)

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