L-4/T-1/ME **Date : 18/04/2024**

BANGLADESH UNIVERSITY OF ENGINEERING AND TECHNOLOGY, DHAKA

L-4/T-1 B. Sc. Engineering Examinations 2022-2023

Sub : **ME 415** (Refrigeration and Building Mechanical Systems)

Full Marks : 210 Time : 3 Hours

The figures in the margin indicate full marks.

Assume reasonable values for missing data.

All symbols have their usual meaning and interpretation.

Refrigeration and A/C Data Book will be provided.

USE SEPARATE SCRIPTS FOR EACH SECTION

SECTION – A

There are **FOUR** questions in this section. Answer **Q. No. 3** and any **TWO** from the rest.

Question No. 3 is compulsory.

1. (a) What are the major applications of refrigeration system? Briefly describe the Immersion Freezing process with schematic diagram. **(10)**

   (b) A fish freezing plant uses multi stage compression refrigeration system with inter-cooling and removal of flash gas. Calculate the power required by the three compressors in a R134a system which serves a 60 TR evaporator at –30°C, 50 TR evaporator at –20°C and 40 TR evaporator at –10°C. The system uses three stage compressions with inter-cooling and removal of flash gas. The condensing temperature is 30°C and the intercooler temperature is –20°C and –10°C. Draw the schematic diagram and P-h diagram of the system. Also, calculate the COP of the system. **(20)**

2. (a) Why the outdoor air is required in air conditioning system? Compare all air and all water system with schematic diagram? Make comparison between ducted split type, multiple split type and VRF system with schematic diagram. **(15)**

   (b) A packaged air conditioner serves four rooms in an apartment. The schematic layout of the duct system, together with the volume flow rate of each room, is shown in Fig. for Q. No. 2(b). (i) Size the duct system using the equal-friction method. The duct shall be of standard round sections with diameters in increments of 25 mm. The air velocity in the first section is not to exceed 8 m/s. (ii) Estimate the static pressure in the index run of the duct network. There is a pressure drop of 25 Pa at each of the outlet grilles at E, F, G and H. In the calculation, consider the resistance due to the elbow and Tee as 10 Pa and 15 Pa respectively. **(15)**

3. (a) What are the main sources of fire? Why is fire such a devastating hazard in Bangladesh? Classify fire according to BNBC with examples. Make comparison between different types of fire extinguisher and specify which type of extinguisher will be used for different class of fire. **(25)**

Contd P/2

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Contd ... Q. No. 3

(b) Describe standpipe and hose fire protection systems in details with schematic diagram. Draw the typical diagram for fire protection with automatic fire pump in different water supply zones of a tall building (according to BNBC). **(20)**

4. (a) Classify elevator in different way. Draw the schematic diagram of an electric traction lift and show its different components. For an office building, downtown, diversified use, 12 rentable floors above the lobby, each 1500 m^2 net. Floor-to-floor height = 3.7 m, determine a workable elevator system arrangement. **(25)**

   (b) Draw the schematic diagram of different arrangements of escalator. For an escalator of 35° incline, two passengers per step, speed of 0.6 m/s and 600 mm step length, determine the number of persons moved per hour. **(5)**

SECTION – B

There are **FOUR** questions in this section. Answer **Q. No. 8** and any **TWO** from the rest.

Question No. 8 is compulsory.

5. (a) Why does volumetric efficiency decrease with pressure ratio for compressor? Find out the reasons due to which scroll compressor attains maximum volumetric efficiency. Hence, describe the working principle of a scroll compressor with necessary schematic diagram. **(15)**

   (b) How is cooling produced in a steam jet refrigeration system? Describe a steam jet refrigeration system with neat sketches. Hence, explain the mathematical formula to show the amount of cooling produced. **(15)**

6. (a) Why is an electromotive force produced when the junctions of two dissimilar conductors are maintained at two different temperatures? Hence, describe the thermoelectric refrigeration system with relevant mathematical expression. **(15)**

   (b) Describe an air-cooled condenser used in air conditioning system with proper schematic diagram. Justify the statement "On days when maximum cooling is needed, the least is available" with the context of climate of Bangladesh. **(15)**

7. (a) The operating temperatures of a lithium bromide-water absorption system are as: Generator 100°C, condenser 36°C, evaporator 6°C, absorber 28°C. Draw the schematic/block diagram of the system and calculate the followings: **(15)**

   (i) The heat supplied to the generator

   (ii) The heat rejected at the condenser

   (iii) The coefficient of performance of the cycle

   The mass flow rate delivered by the aqua pump is 0.42 kg/s.

Contd P/3

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Contd ... Q. No. 7

(b) Why is intercooling necessary for the compressor in a Linde liquefaction process? How is Joule-Thomson effect applicable for Linde liquefaction process? Hence, describe the Linde liquefaction process with neat sketches. **(15)**

8. Estimate the cooling load of a class-room for 50 students at 4 pm for the following conditions: **(45)**

Location : Chattogram

Date : July 15

Floor : 12 m × 8 m, 3.5 m height

Roof : Type 5, without suspended, 25 mm wood, 25 mm insulation

Walls : 254 mm brick with 12.5 mm plaster on both sides

Windings : 20% of wall area on north and west walls. 10 mm clear glass, U = 2.5 W/m^2.°C

Light : 30 W/m^2 fluorescent bubls

(i) Assume standard indoor conditions as recommended in ASHRAE.

(ii) Assume no heat transfer through floor, south and east walls.

(iii) Assume reasonable electric appliances.

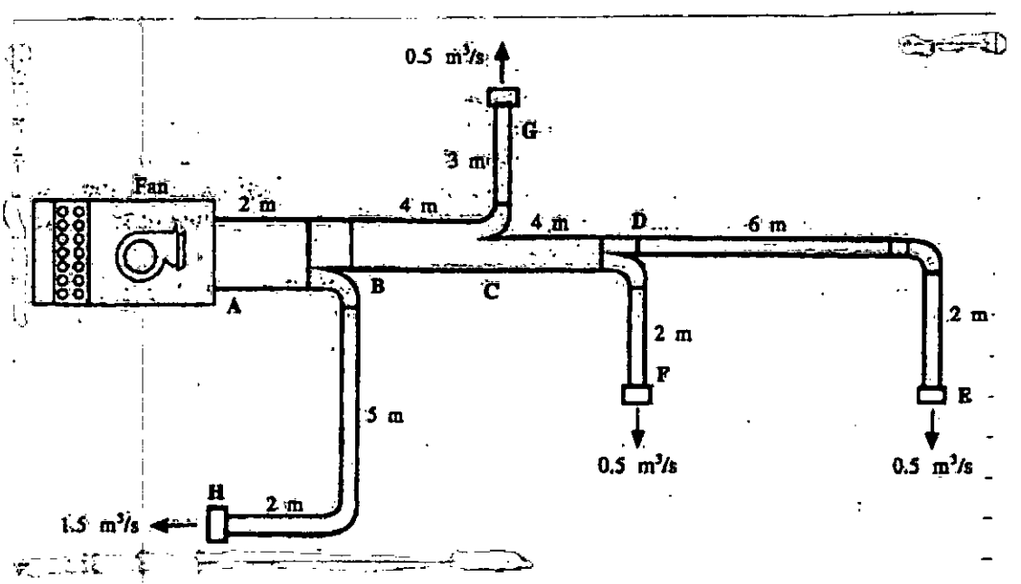

Figure for the Q. No. 2(b)

T1: Recommended Elevator Intervals & Waiting Times

Facility Type	Interval (sec)	Waiting Time[a] (sec)
OFFICE BUILDINGS		
Excellent service	15–24	9–14
Good service	25–29	15–17
Fair service	30–39	18–23
Poor service	40–49	24–29
Unacceptable service	50+	30+
RESIDENTIAL		
Prestige apartments	50–70	30–42
Middle-income apartments	60–80	36–48
Low-income apartments	80–120	48–72
Dormitories	60–80	36–48
Hotels—first quality	30–50	18–30
Hotels—second quality	50–70	30–42

T2: Minimum PHC

Facility	Percent of Population to Be Carried in 5 Minutes
OFFICE BUILDINGS	
Center city	12–14
Investment	11.5–13
Single-purpose	14–16
RESIDENTIAL	
Prestige	5–7
Other	6–8[a]
Dormitories	10–11
Hotels—first quality	12–15
Hotels—second quality	10–12

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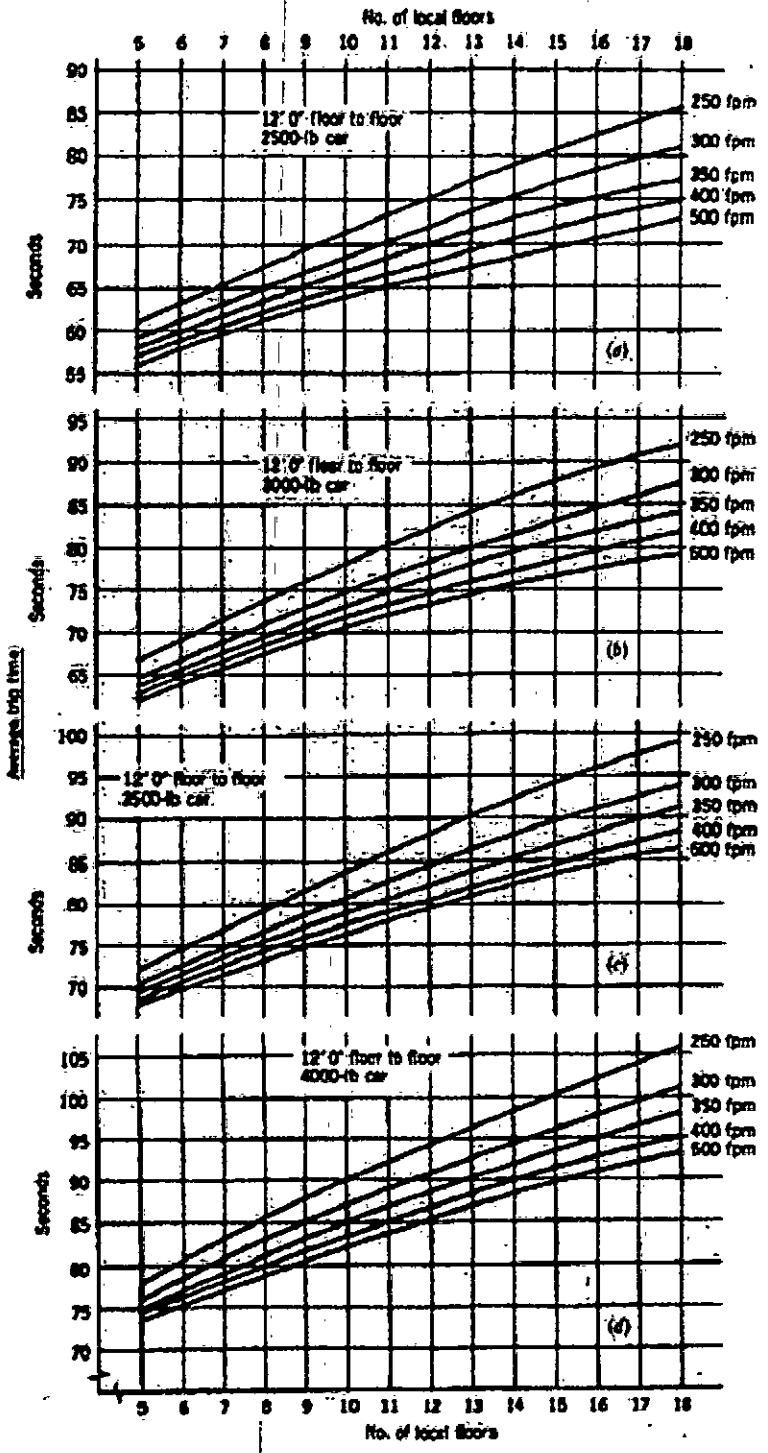
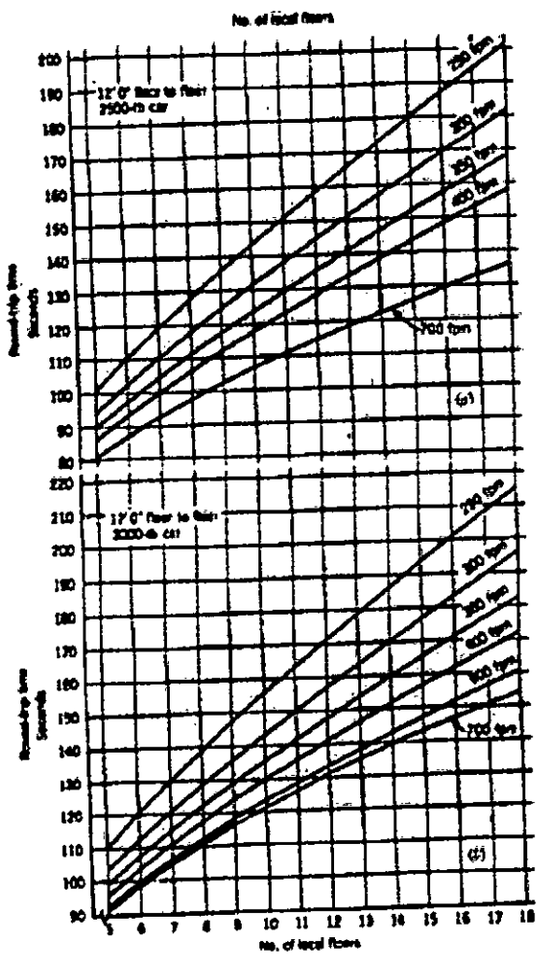
T3: Car Passenger Capacity (p)

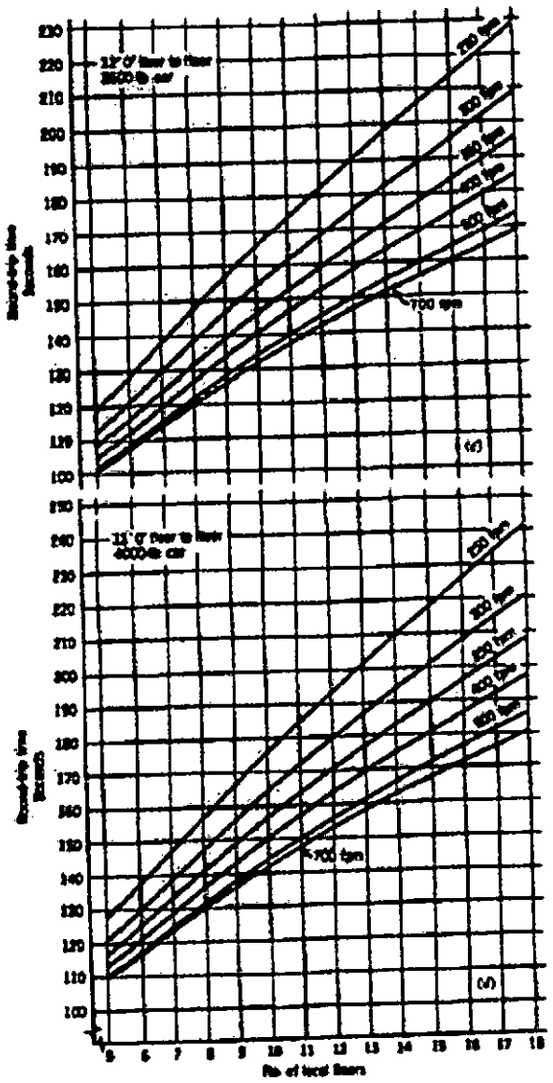
Elevator Capacity lb (kg)	Maximum Passenger Capacity	Normal Passenger[a] Load per Trip
2000 (907)	12	10
2500 (1134)	17	13
3000 (1361)	20	16
3500 (1588)	23	19
4000 (1814)	28	22

C1: Average Trip Time (AVRTP)



C2: Round Trip (RT) Time





T4: Population of Typical Buildings

Building Type	Net Area
OFFICE BUILDINGS	FT2 PER PERSON (M2/PERSON)
Diversified (multiple tenancy)	
Normal	110–130 (10–12)[a]
Prestige	150–250 (14–23)
Single tenancy	
Normal	90–110 (8–10)
Prestige	130–200 (12–19)
HOTELS	PERSONS PER SLEEPING ROOM
Normal use	1.3
Conventions	1.9
HOSPITALS	VISITORS AND STAFF PER BED[b]
General private	3
General public (large wards)	3–4
APARTMENT HOUSES	PERSONS PER BEDROOM
High-rental housing	1.5
Moderate-rental housing	2.0
Low-cost housing	2.5–3.0

T5: Office Building Occupancy

Building Height	Net Usable Area as Percentage of Gross Area
0–10 floors	Approximately 80%
0–20 floors	Floors 1–10 approximately 75%
	11–20 approximately 80%
0–30 floors	Floors 1–10 approximately 70%
	11–20 approximately 75%
	21–30 approximately 80%
0–40 floors	Floors 1–10 approximately 70%
	11–20 approximately 75%
	21–30 approximately 80%
	31–40 approximately 85%

T6: Elevator Equipment Recommendations

Building Type	Car Capacity lb	Car Capacity kg	Rise ft	Rise m	Minimum Car Speed fpm	Minimum Car Speed m/s
Office building	2500	1250	0–125	0–40	350–400	2.0
	3000	1360	126–225	41–70	500–600	2.5
	3500	1600	226–275	71–85	700	3.6
			276–375	86–115	800	4.0
			Above 375	>115	1000	5.0
Hotel	2500	1250	As above		As above	
	3000	1360				
Hospital	3500	1600	0–60	0–20	150	0.63
	4000	2000	61–100	21–30	200–250	1.0
			101–125	31–40	250–300	1.6
			126–175	41–55	350–400	2.0
			176–250	56–75	500–600	2.5
			>250	>75	700	3.6
Apartments	2000	1000	0–75	0–25	100	0.63
	2500	1250	76–125	26–40	200	1.0
			126–200	41–60	250–300	1.6
			>200	>60	350–400	2.0
Stores	3500	1600	0–100	0–30	200	1.0
	4000	2000	101–150	31–45	250–300	1.6
	5000	2500	151–200	46–60	350–400	2.0
			>200	>60	500	2.5

Water Supply System

Table 4.4.1: Fire Protection Flow Requirements*

Building Type**	Sprinkler System (litre/min.)	Standpipe and Hose System (litre/min.)	Duration in Minutes for Building Heights		
			Up to 51 m	51 m to 102 m	Above 102 m
Light hazard- I	1000	1000	30	38	45
Light hazard- II	1900	1900	50	62	75
Ordinary hazard- I	2650	1900	75	95	112
Ordinary hazard - II	3200	1900	75	95	112
Ordinary hazard - III	4800	1900	75	95	112

Notes:

* Values will be for one riser serving floor area of 1000 m^2.

** These durations shall be for a building up to the height of 51 m. For greater height of 51-102 m and above 102 m, the duration will be 1.25 times and 1.5 times of the specified values respectively.

(Part 4, Chapter 4, BNBC 2020)

L-4/T-1/ME **Date: 25/03/2024**

BANGLADESH UNIVERSITY OF ENGINEERING AND TECHNOLOGY, DHAKA

L-4/T-1 B. Sc. Engineering Examinations 2022-2023

Sub: **ME 417 (Internal Combustion Engines)**

Full Marks: 210 Time: 3 Hours

The figures in the margin indicate full marks

USE SEPARATE SCRIPTS FOR EACH SECTION

SECTION – A

There are **FOUR** questions in this section. Answer all the Questions.

Symbols indicate their usual meaning.

Assume any missing data or missing information reasonably.

1. **(a)** Describe the sequential phases involved in the combustion process within spark-ignition (SI) engines. **(10)**

(b) A 3.2-liter SI engine is to be designed with bowl-in-piston combustion chambers. With a central spark plug and combustion at TDC, this gives a flame travel distance of B/4. The engine is to operate with an average piston speed of 8 m/sec and a burn angle of 25° of engine rank rotation. Stroke and bore will be related by S = 0.95 B. Calculate:

(i) Average flame speed if the design is for an in-line four-cylinder engine. **(16.25)**

(ii) Average flame speed if the design is for a V8 engine.

OR

1. **(a)** Describe the sequential stages of the ignition process in spark-ignition (SI) engines, highlighting the distinctive characteristics of each phase of the spark plug discharge cycle. **(10)**

(b) An SI engine operating at 1200 RPM has a 10.2-cm bore with the spark plug offset by 6 mm from center. The spark plug is fired at 20° bTDC. It takes 6.5° of engine rotation for combustion to develop and get into flame propagation mode, where the average flame speed is 15.8 m/sec. Calculate: **(16.25)**

(i) Time of one combustion process

(ii) Crank angle position at the end of combustion.

2. **(a)** Illustrate a standard water cooling system utilized in a spark-ignition (SI) engine, including all primary components. **(10)**

(b) A large super charged aircraft engine generates 900 kW at 3600 rpm when operating with air and gasoline at a fuel equivalence ratio φ = 1.05. After supercharging and fuel addition, air enters the engine at 65°C. Gasoline can be approximated as isooctane. Calculate how much the air is cooled by evaporative cooling when the fuel vaporizes. **(16.25)**

Continued --- Page 2

OR

2. (a) Why is wear on the cylinder walls not the same along the length of the cylinder? Why is piston frictional force not equal to zero at TDC and BDC? **(10)**

(b) A five-cylinder, in-line engine has an 8.15-cm bore, a 7.82-cm stroke, and a connecting rod length of 15.4 cm. Each piston has a skirt length of 6.5 cm and a mass of 0.32 kg. At a certain engine speed and crank angle, the instantaneous piston speed is 8.25 m/sec, and clearance between the piston and cylinder wall is 0.004 mm. SAE 10W-30 motor oil is used in the engine, and at the temperature of the piston-cylinder **(16.25)** interface the dynamic viscosity of the oil is 0.006 N-sec/m^2. At this point pressure on the cylinder is 3200 kPa and the compressive force in the connecting rod is 8.1 kN. Calculate the thrust force on the cylinder at this condition.

3. (a) What is delay period in CI engine combustion and what are the factors that affect it? If octane is used in a CI engine, what will happen? **(10)**

(b) A 6.8-liter, in-line, eight-cylinder CI engine has a compression ratio $r_c = 18.5$ and a crevice volume equal to 3% of the clearance volume. During the engine cycle pressure in the crevice volume equals combustion chamber pressure while remaining at the cylinder wall temperature of 190^{0}C. Cylinder conditions at the start of compression are 75^{0}C and 120 kPa, and peak pressure is 11,000 kPa. Cutoff ratio is $r_k = 2.3$. Calculate:

(i) Crevice volume of one cylinder. **(16.25)**

(ii) Percent of air-fuel mixture in the crevice volume at the end of compression.

(iii) Percent of air-fuel mixture in the crevice volume at the end of combustion.

4. (a) Explain the importance of distillation curves in the context of analyzing fuel properties and behavior. **(6)**

(b) A fuel mixture consists of 20% isooctane, 20% triptane, 20% isodecane, and 40% toluene by moles. Write the chemical reaction formula for the stoichiometric combustion of one mole of this fuel. Calculate: **(20.25)**

(i) Air-fuel ratio.

(ii) Research octane number

(iii) Lower beating value of fuel mixture

Continued --- Page 3

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SECTION - B

There are **FOUR** questions in this section. Answer all the Questions.

Symbols indicate their usual meaning.

5. Answer either (a) or (b)

(a) i. Formation of NO_2 is insignificant in SI engine as compared to CI engine -Explain. **(6)**

ii. Why do some emission control techniques use an air pump to inject ambient air into the exhaust manifold? **(6)**

iii. If half of the cylinders in an 8-cylinder SI engine run lean and the other half run rich, characterize the engine's average CO emission in terms of average cylinder equivalence ratio. **(6)**

iv. Briefly discuss the trade-off between combustion process control of NO_x and particulate formation in diesel engines. **(8)**

OR

(b) i. What are the additional emission control measures implemented in lean combustion engines? Discuss. **(6)**

ii. Direct injection engines emit more hydrocarbons than indirect injection engines - Explain. **(6)**

iii. Explain why there are two distinct peaks in the measured hydrocarbon emission mass flow rate as a function of time during the exhaust stroke. **(6)**

iv. Discuss the effect of spark timing on the NO formation for both lean and rich running engine. **(8)**

6. Answer either (a) or (b)

(a) i. What are the drawbacks of the Miller cycle? How can one circumvent those? **(6)**

ii. Name the investors who were instrumental in developing the four-stroke cycle internal combustion engine. **(6)**

iii. What are the advantages of two-stroke operating cycles over the four-stroke cycles? **(6)**

iv. Briefly discuss the operation of a port fuel injection SI engine's fuel injection system. Why is it preferred to move the point of fuel injection closer to the cylinder? **(8)**

OR

(b) i. For a fixed compression ratio, the constant pressure cycle always has a higher imep/p_3 than the constant volume cycle. Is the same true for $\eta_{f,ig}$? Discuss. **(6)**

Continued --- Page 4

ii. An overexpanded four-stroke SI engine's imep significantly decreases as the expansion ratio increases - give brief reasoning for this statement. **(6)**

iii. What are the primary distinctions between a supercharged and turbocharged engine? Comment on their dynamic response. **(6)**

iv. Classify SI and CI engines in terms of fuel intake method. What is the typical direct injection CI engine fuel injection pressure? Justify your answer. **(8)**

7. Answer all the following questions.

(a) Explain the effect of the following factors on the performance of an SI engine: **(6)**

i. Compression ratio
ii. Air-fuel
iii. Spark timing
iv. Engine speed
v. Mass of inducted charge
vi. Heat losses

(b) Briefly explain the reason of poor part load thermal efficiency of the SI engine compared with CI engine. **(6)**

(c) By means of a Sankey diagram explain the energy flow through an engine. **(6)**

(d) What are the advantages of an over square engine? What are the advantages of an under square engine? **(8)**

8. Answer all the following questions.

(a) Assume you need to design a test rig to measure the gaseous emissions of a CI engine. What sensors will you be using? Discuss briefly. **(14)**

(b) What instruments are used during engine performance test? Name the instruments according to their intended usage. **(13)**

TABLE A-2 PROPERTIES OF FUELS

Fuel		Molecular Weight	Heating Value HHV (kJ/kg)	Heating Value LHV (kJ/kg)	Stoichiometric (AF)$_s$	Stoichiometric (FA)$_s$	Octane Number MON	Octane Number RON	Heat of Vaporization (kJ/kg)	Cetane Number
gasoline	C_8H_{15}	111	47300	43000	14.6	0.068	80–91	92–99	307	
light diesel	$C_{12.3}H_{22.2}$	170	44800	42500	14.5	0.069			270	40–55
heavy diesel	$C_{14.6}H_{24.8}$	200	43800	41400	14.5	0.069			230	35–50
isooctane	C_8H_{18}	114	47810	44300	15.1	0.066	100	100	290	
methanol	CH_3OH	32	22540	20050	6.5	0.155	92	106	1147	
ethanol	C_2H_5OH	46	29710	26950	9.0	0.111	89	107	873	
methane	CH_4	16	55260	49770	17.2	0.058	120	120	509	
propane	C_3H_8	44	50180	46190	15.7	0.064	97	112	426	
nitromethane	CH_3NO_2	61	12000	10920	1.7	0.588			623	
heptane	C_7H_{16}	100	48070	44560	15.2	0.066	0	0	316	
cetane	$C_{16}H_{34}$	226	47280	43980	15.0	0.066			292	100
heptamethylnonane	$C_{12}H_{34}$	178			15.9	0.063				15
α-methylnaphthalene	$C_{11}H_{10}$	142			13.1	0.076				0
carbon monoxide	CO	28	10100	10100	2.5	0.405				
coal (carbon)	C	12	33800	33800	11.5	0.087				
butene-1	C_4H_8	56	48210	45040	14.8	0.068	80	99	390	
triptane	C_7H_{16}	100	47950	44440	15.2	0.066	101	112	288	
isodecane	$C_{10}H_{22}$	142	47590	44220	15.1	0.066	92	113		
toluene	C_7H_8	92	42500	40600	13.5	0.074	109	120	412	
hydrogen	H_2	2	141800	120000	34.5	0.029		90		

L-4/T-1/ME Date: ~~28/04/2024~~ 19/05/2024

BANGLADESH UNIVERSITY OF ENGINEERING AND TECHNOLOGY, DHAKA

L-4/T-1 B. Sc. Engineering Examinations 2022-2023

Sub: **ME 421** (Fluid Machinery)

Full Marks: 210 Time: 3 Hours

The figures in the margin indicate full marks.

Symbols used have their usual meaning. Assume reasonable values for any missing data.

USE SEPARATE SCRIPTS FOR EACH SECTION

SECTION – A

There are **FOUR** questions in this section. Answer **All.**

1. **Answer either (a) or (b)**

(a) (i) Draw the indicator diagram of a single-acting reciprocating pump including acceleration head, frictional head and velocity heads. Also write he detail expressions for the calculation of power input required by the pump. **(15)**

(ii) A single acting reciprocating pump has a stroke length of 150 mm. The suction pipe is 7 m long. The water level in the sump is 2.5 m below the cylinder. The diameters of suction pipe and the plunger are 75 mm and 100 mm respectively. If the speed of the pump is 75 rpm, determine the pressure head on the piston at the beginning, middle and end of the suction stroke. Take Darcy-Weisbach friction factor, $f = 0.02$. **(12)**

OR

(b) (i) Illustrate what happens to the indicator diagram and the power input requirement when air vessels are fitted very near to both the suction and the delivery pipes. Also write the detail expressions for the calculation of power input requirement in such case. **(12)**

(ii) An air vessel is fitted on the delivery side to a single-acting reciprocating pump, with piston diameter of 300 mm and stroke of 500 mm. The length and the diameter of the delivery pipe are 40 m and 100 mm, respectively. If the pump runs at 50 rpm, find the power saved in overcoming friction by fitting the air vessel. Assume atmospheric pressure head as 10.3 m water abs and friction factor as 0.03. **(15)**

2. **Answer either (a) or (b)**

(a) (i) Derive an expression for the minimum starting speed of a centrifugal pump. **(8)**

(ii) A centrifugal water pump rotates at 500 rpm. The impeller has uniform blade widths at inlet as 50 mm and at outlet as 25 mm. The diameters of the impellers at inlet and outlet are 80 mm and 250 mm, respectively. The blade angles at inlet and outlet are 45° and 30°, respectively. Determine the ideal flow rate, pressure head rise across the impeller, the theoretical torque and power requirements. **(18)**

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Contd... Q. No. 2

OR

(b) (i) Sketch the guideline for the selection of a particular type of pump based on desired Head, Discharge and the required Power input. **(8)**

(ii) The external and internal diameters of an impeller of a centrifugal pump are 450 mm and 225 mm respectively. The pump delivers 200 liter/s water at 1250 rpm. The outside and inside widths of the impeller are 70 mm and 150 mm. The vanes are curved backward at an angle of 30° at exit. If the manometric efficiency is 82%, find the Euler head and manometric head. **(18)**

3. **Answer all the following questions.**

(a) What are $NPSH_A$ and $NPSH_R$ in a centrifugal pump? How are these parameters determined? **(10)**

(b) A centrifugal pump running at 1500 rpm was tested and the following data were obtained: **(16)**

$Q\ (m^3/h)$	0	27.24	54.3	81.6	108.6	136.2	163.2	228.0
$H\ (m)$	12.2	12.8	13.1	13.4	13.4	13.1	12.2	11.0
$\eta\ (\%)$	0	26	46	59	70	78	78	74

Plot the characteristics curves (Head and Efficiency vs. Discharge) of the pump and determine its duty point and shut-off head. Also calculate its specific speed keeping agreement with the US customary values for the specific speeds of pumps.

4. **Answer all the following questions.**

(a) Compare between 'submersible pumps' and 'deep-well turbine pumps' mentioning their relative merits and demerits. **(7)**

(b) What are hydraulic accumulators and hydraulic intensifiers? Where are they used? **(7)**

(c) Differentiate between a fluid coupling and a torque converter. Explain with sketches how a torque converter acts as a torque multiplier. **(12)**

SECTION – B

There are **FOUR** questions in this section. Answer **All**.

5. **Answer either (a) or (b)**

(a) (i) A jet of water issuing from a nozzle impinges on a series of moving curved vanes mounted on a wheel at the center of the vane. With neat sketch, establish an expression of the efficiency of power transmission of this system and also estimate the maximum efficiency. **(15)**

Contd P/3

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Contd... Q. No. 5(a)

(ii) A jet of water having a velocity of 30 m/s impinges on a series of vanes moving with a velocity of 15 m/s. The jet makes an angle of 30° to the direction of motion of vanes when entering and leaves at an angle of 120°. Sketch the velocity triangles at entrance and exit and determine: **(15)**

- The angles of vanes tips so that water enters and leaves without shock,
- The work done per N of water entering the vanes, and
- The efficiency.

OR

(b) (i) A jet of water issuing from a nozzle impinges on a symmetrical moving curved vane at the center of the vane. With neat sketch, establish an expression of the efficiency of power transmission of this system and also estimate the maximum efficiency. **(15)**

(ii) A jet of water moving at 18 m/s impinges on a symmetrical smooth concave shaped vane to deflect the jet through 120° when stationary. If the vane is moving at 6 m/s, sketch the velocity triangles at entrance and exit and determine:

- The angle of jet at inlet of the vane so that there is no shock,
- The absolute velocity of the jet at exit both in magnitude and direction, and
- The work done per N weight of water. **(15)**

6 **Answer either (a) or (b).**

(a) (i) Discuss about the recommended shape of the blade of a Pelton wheel and compare it to that of a Kaplan turbine. **(6)**

(ii) The water surface in a reservoir supplying water to a Pelton wheel is 400 m above the center of the nozzle. The pipe line supplying the water to the wheel is 60 cm in diameter and 4 km long with $f = 0.03$. The buckets deflect the jet of 8 cm diameter through an angle of 165°. The bucket friction reduces the relative velocity by 15% and 8% of the power developed by the wheel is lost in mechanical friction. Assuming the coefficient of velocity of the nozzle as 0.98, speed ratio as 0.45, jet ratio as 12, determine:

- the quantity of water striking the bucket
- power developed at the shaft
- hydroelectric power potential of the plant (generator efficiency = 80%) per year in KWH
- the speed of the wheel. **(20)**

OR

(b) (i) Make comparison between Francis and Kaplan turbine. **(6)**

Contd P/4

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

(ii) The following are the design particulars of a Pelton turbine: **(20)**

Jet diameter = 12 cm, Jet ratio = 12, Coefficient of velocity of the nozzle = 0.985, Speed ratio = 0.45, Bucket friction coefficient = 0.96, Bucket deflection angle = 170°, Mechanical efficiency = 96%, Net head = 150 m.

Calculate the overall efficiency, torque at the start, torque at normal speed, and number of buckets.

7. (a) Derive the expressions of "unit speed" and "unit power" from the concept of unit turbine. **(8)**

(b) What is the significance of specific speed of turbines? Classify turbines on the basis of specific speed. **(7)**

(c) A model turbine has a runner of diameter 0.61 m. It develops 50 kW under a head of 30 m at a speed of 4000 r.p.m. Identify the type of runner used in this turbine and its unit speed. It is required to build a similar turbine to develop 155 kW under a head of 36 m. Calculate the required dimension and performance parameters. **(10)**

8. (a) What is meant by 'cavitation'? Where does cavitation take place? Discuss about its effects and remedy process in turbines. **(14)**

(b) A Francis turbine having a design power of 2.50 MW under a head of 35 m and speed of 200 rpm is selected for installation at a site. The atmospheric pressure head at the site is 10.0 m and the vapour pressure head is 0.24 m. Identify the turbine. Assuming the critical cavitation parameter σ_c is related to the turbine specific speed by the following empirical formula: **(10)**

$$\sigma_c = 0.625\left(\frac{N_s}{380.78}\right)^2$$

where N_s is in (r.p.m, kW, m) units.

Verify whether the proposed turbine setting at a draft height of 7.0 m at the site is safe from cavitation consideration. A safety margin of 0.5 m is mandatory in the draft height.

L-4/T-1/ME **Date: 04/05/2024**

BANGLADESH UNIVERSITY OF ENGINEERING AND TECHNOLOGY, DHAKA

L-4/T-1 B.Sc. Engineering Examinations 2022-2023

Sub: **ME 441 (Theory of Structures)**

Full Marks: 210 Time: 3 Hours

The figures in the margin indicate full marks.

USE SEPARATE SCRIPTS FOR EACH SECTION

SECTION – A

There are FOUR questions in this section. **Question No. 1 is compulsory.** Answer any TWO questions from Questions 2-4. Symbols have their usual meaning.

1. (a) State and explain the Minimum Potential Energy method for analyzing the structural problems. Demonstrate the application of the method to determine the deformation of an axially loaded member and a tension spring under axial tensile forces. **(18)**

   (b) Derive the global (overall) coefficient matrix equation for determining the nodal (junction) displacements of the spring assemblage shown in Fig. Q1(b), using minimum potential energy approach. **(17)**

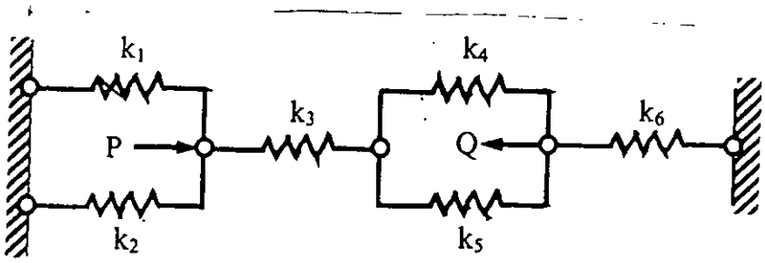

Fig. Q1(b)

2. (a) With neat sketches compare and contrast the following structural components: **(18)**

   (i) Beam, (ii) Column, and (iii) Beam-column

   Derive the differential equation that governs the lateral deflection of a beam-column. Assume that the beam column is subjected to an axial compressive force **P** at its ends, a lateral compressive force **Q** at its mid-span, and a uniformly distributed load of intensity q over its full span.

   (b) Give a classification of columns depending upon the end conditions. Mathematically show that the buckling load of a both-ends-fixed slender column is four times the buckling load of a hinged column. **(17)**

3. (a) With neat sketches, give the physical and mathematical interpretations of the conditions used at the boundaries of the following thin plates: **(18)**

   (i) Simply-supported plate,

   (ii) Clamped plate, and

   (iii) Cantilever plate.

Contd..... P/2

ME 441

(Contd....Q. No. 3)

(b) A thin elastic square plate of sides a is simply-supported on all four edges and supports a uniformly distributed load q. If the origin of the coordinate system coincides with the center of the plate, show that the deflection of the plate can be represented by the following function: **(17)**

$$W = \frac{q}{96D(1-\mu)}\left[B + 2\left(x^4 + y^4\right) - 3a^2(1-\mu)\left(x^2 + y^2\right) - 12\,\mu\, x^2 y^2\right]$$

Where B is an arbitary constant. For the plate, determine,

i) the maximum deflection

ii) the maximum bending moments

4. (a) How do the elastic supports differ from the conventional end supports of a beam? Suggest a general model of the beam with elastic end supports, and show that all conventional end supports can be derived as limiting cases of the elastic support. **(17)**

(b) Assuming an approximate trial solution, find the maximum deflection of a simply-supported beam subjected to a uniformly distributed load over its full span and a point load at its mid-span. Use a suitable energy method. **(18)**

Comment on the accuracy of the approximate solution of maximum deflection.

SECTION – B

There are FOUR questions in this section. Answer **Question No. 5** and any **TWO** questions from the rest. **Question No. 5 is compulsory.**

5. (a) Explain the concept of stress at a point. Show that stress at a point in a body is different for different planes passing through the same point. **(15)**

(b) How many engineering constants are required to define the constitutive relations of an isometric material? **(5)**

(c) Consider the following state of stress and strain: **(15)**

$$\sigma_{xx} = x^2, \qquad \sigma_{yy} = y^2, \qquad \sigma_{zz} = 0,$$
$$\gamma_{xy} = -2xy, \qquad \gamma_{yz} = 0, \qquad \gamma_{zx} = 0.$$

Determine the condition for which the above state is physically possible.

6. (a) With the plot of stress-strain curve, discuss the different material models available to describe the stress-strain relationship of different materials. **(10)**

(b) What is volumetric strain? Show that volumetric strain is the summation of normal strains on three mutually perpendicular planes. **(12)**

Contd..... P/3

ME 441

(Contd....Q. No. 6)

(c) A cylindrical steel rod having a diameter of 50 mm and length of 1.5 m is subjected to a load of 20 kN in the direction of its length. Determine the change in volume of the rod. The value of Young's Modulus and Poisson's ratio for steel are 200 GPa and 0.28, respectively. **(13)**

7. (a) Derive the 3D stress-strain relation in terms of Lame's constant, λ and shear modulus, G. **(15)**

(b) Justify the suitability of the following stress function for the problem shown in Fig. for Q. 7(b). **(20)**

$$\phi = \frac{P}{4La^3}\left[\frac{x^3y^3}{6} - \frac{xy^5}{10} - \frac{a^2x^3y}{2} + \left(\frac{a^2}{5} - \frac{L^2}{6}\right)y^3x + \left(\frac{a^2L^2}{2} - \frac{a^4}{10}\right)xy - \frac{a^3x^3}{3}\right]$$

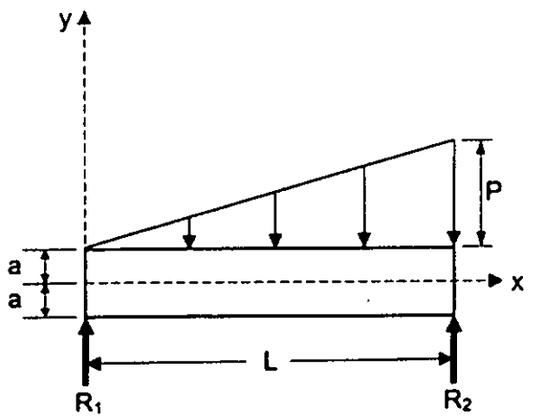

Fig. for Q. 7(b)

8. (a) Determine the stress distribution in a cylindrical bar of elliptic cross-section, subjected to uniform torque T. **(17)**

(b) Show that the stress function $\phi = k\left(r^2 - a^2\right)$ is applicable to a solid circular cylindrical bar of radius, a, under uniform torque, T. Also, determine (i) maximum stress in terms of applied torque, (ii) rate of twist in terms of applied torque. **(18)**

L-4/T-1/ME **Date: 04/05/2024**

BANGLADESH UNIVERSITY OF ENGINEERING AND TECHNOLOGY, DHAKA

L-4/T-1 B.Sc. Engineering Examinations 2022-2023

Sub: **ME 445 (Noise & Vibration)**

Full Marks: 210 Time: 3 Hours

The figures in the margin indicate full marks.

USE SEPARATE SCRIPTS FOR EACH SECTION

SECTION – A

There are **FOUR** questions in this section. **Answer Question No. 1** and **ANY TWO** from the rest. **Question No. 1 is compulsory.**

Symbols used have their usual meanings and interpretation. Assume reasonably any missing data.

Short list of formulae is attached.

1. (a) With necessary equations and sketches, describe: Diffuse sound field, sound diffraction and Dynamic microphone. **(11)**

   (b) Point A and B are at a distance of 1 m and 21 m, respectively from a plane wave source. SIL is 90 dB at point A. Calculate (i) spread out and absorption losses. Hence, find at point B: (ii) sound pressure (iii) particle displacement (iv) energy density. Given, α = 0.2 dB/m, acoustic impedance = 406 rayls. **(12)**

   (c) With necessary equations and sketches, describe how the machine room vibration can create noise in the higher floors of multistoried building. **(11)**

   (d) A machine (m/c) is to be installed on isolators. The m/c weighs 1 ton and it has to be operated a 200 rpm. For vibration isolation find the required minimum stiffness of the isolators if the inertia base is 3.5 ton. **(11)**

2. (a) Starting from the governing differential equation find the natural frequencies of a free-free slender rod vibrating in axial mode. **(10)**

   (b) A factory room has a dimension of 15m × 10m × 8m. Optimum RT for this room is 2 s at 1 kHz. Calculate: average absorption coefficient to achieve the optimum RT. **(10)**

   (c) An audio signal has 1/3rd octave band at a central frequency of 1.2 kHz and PBL of 115dB. **(10)**

   Find PSL (f_c) and Sp(f_c). Take $S_{ref} = 4 \times 10^{-10}$ Pa^2/Hz.

3. The base of a machine is subjected to random vibration (in terms of acceleration) input. It is desired to compute the response of any point P on the machine and establish the probability of exceeding any specified acceleration. Some experimental data are as follows: **(30)**

f (Hz)	Δf (Hz)	S (fi) (g^2/Hz)	G (fi) (g^2)	$\lvert H(fi)\rvert = a_p/a_0$	S (fi) $\Delta f \lvert H(fi)\rvert^2$ (g^2)
0	100	0		1	
100		0		1	
200		1		1.5	
300		0.8		0.9	
400		2		0.5	

Contd..... P/2

ME 445

(Contd .....Q. No. 3)

(a) with a freehand sketch plot the power spectrum and the power density spectrum. **(10)**

Using the above experimental data and given probability distributions, find the followings:

(b) the mean square output acceleration of the point *P*. **(10)**

(c) p [$a_{peak} > 3\hat{\sigma}$] = ? and p [$|a| > 3\hat{\sigma}$] = ? **(10)**

Gaussian probability

λ	Prob $[-\lambda\sigma \leq x(t) \leq \lambda\sigma]$	Prob $[\lvert x\rvert \geq \lambda\sigma]$
1	68.3%	31.7%
2	95.4%	4.6%
3	99.7%	0.3%

Rayleigh probability

λ	$P[A > \lambda\sigma]$
0	100%
1	60.7%
2	13.5%
3	1.2%

4. (a) A heavy-duty machine is to be installed in the machine room of an industry. Describe with necessary sketches and equations, the step-by-step procedure for such an installation as far as noise and vibration control is concerned.. **(15)**

(b) Describe the working principle of a reactive silencer with baffles. **(8)**

(c) Where is a sound barrier used? With sketches describe a standard sound barrier. **(7)**

SECTION – B

There are **FOUR** questions in this section. **Answer Question No. 5** and **ANY TWO** from the rest. **Question No. 5 is compulsory.**

5. (a) Find the natural frequency of vibration of a spring-mass system arranged on an inclined plane, as shown in Fig. for Q. 5(a). **(10)**

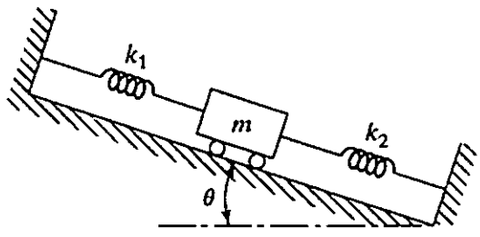

Fig. for Q. 5(a)

Contd..... P/3

ME 445

(Contd .....Q. No. 5)

(b) For the system shown in Fig. for Q. 5(b), determine the equation of motion and find the natural frequency of the system. **(15)**

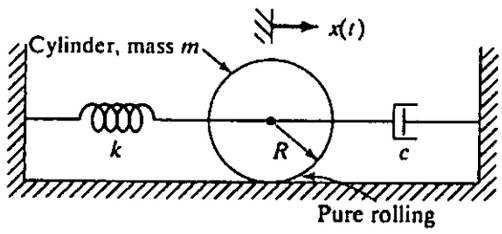

Fig. for Q. 5(b)

(c) An air compressor of mass 50 kg is mounted on an elastic support and operates at a speed of 1000 rpm. It has an unbalanced mass of 2 kg at a radial distance of 0.1 m from the axis of rotation. If damping factor of the elastic support is $\zeta = 0.1$, determine (i) the spring constant of the elastic support which transmits no more than 25% of the unbalanced force to the foundation, and (ii) the magnitude of the force transmitted to the foundation. **(20)**

6. (a) (i) Why are all machine elements capable of vibrations? **(15)**

(ii) Outline the bounds for the following vibration specifications in a plot: Max. acceleration = 5g, max displacement = 0.2 in., min and max. frequencies: 1 Hz and 100 Hz.

(b) A spring-mass-damper system is subjected to a harmonic force. The amplitude is found to be 20 mm at resonance and 10 mm at a frequency 0.75 times the resonant frequency. Find the damping ratio of the system. **(15)**

7. (a) Specify the DOF and nature of the vibration for the system shown in Fig. for Q. 7(a). Given that, $m_1 = 1$ kg, $m_2 = 2$ kg, $k_1 = 100$ N/m, $k_2 = 90$ N/m. Find: **(25)**
(i) equation of motion by Lagrange's method, and (ii) resonant frequencies for the system.

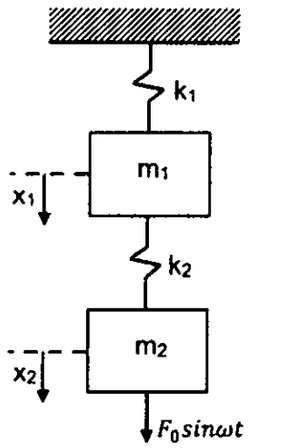

Fig. for Q. 7(a)

(b) List the names of different methods for finding the natural frequency of a vibrating system. **(5)**

Contd..... P/4

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8. (a) It is found that an exhaust fan of mass 80 kg and operating speed 1000 rpm, produces a repeating force of 10,000 N on its rigid base. If the maximum force transmitted to the base is to be limited to 2000 N using an undamped isolator, determine (i) the maximum permissible stiffness of the isolator that serves the purpose, (ii) the steady-state amplitude of the exhaust fan with the isolator that has the maximum permissible stiffness; and (iii) the maximum amplitude of the exhaust fan with isolation during start -up. **(18)**

(b) What are the various methods available for vibration control? With necessary equations and sketches, define a tuned dynamic vibration absorber. What is its limitation? **(12)**

ME445 Short list of formulae

$H(\omega) = \frac{\bar{X}}{F_0} = \frac{1/k}{1-(\omega/\omega_n)^2 + i2\zeta\omega/\omega_n}$	$\frac{M}{m}\frac{X}{e} = \frac{\left(\frac{\omega}{\omega_n}\right)^2}{\sqrt{\left[1-\left(\frac{\omega}{\omega_n}\right)^2\right]^2 + \left[2\zeta\frac{\omega}{\omega_n}\right]^2}}$
$\tan\phi = \frac{2\zeta\left(\frac{\omega}{\omega_n}\right)}{1-\left(\frac{\omega}{\omega_n}\right)^2}$	$TR = \left\lvert\frac{F_T}{F_0}\right\rvert = \sqrt{\frac{1+(2\zeta\omega/\omega_n)^2}{\left[1-(\omega/\omega_n)^2\right]^2 + [2\zeta\omega/\omega_n]^2}}$
$\frac{d}{dt}\left(\frac{\partial T}{\partial \dot{q}_i}\right) - \frac{\partial T}{\partial q_i} + \frac{\partial U}{\partial q_i} = Q_i$	$(m_1m_2)\omega^4 - \{(k_1+k_2)m_2 + (k_2+k_3)m_1\}\omega^2 + \{(k_1+k_2)(k_2+k_3) - k_2^2\} = 0$
$R = \frac{1}{2}\dot{\vec{x}}^T[c]\dot{\vec{x}}$	$\lambda^2 - \left(\frac{k_1+k_2}{m_1} + \frac{k_2+k_3}{m_2}\right)\lambda + \frac{k_1k_2+k_2k_3+k_3k_1}{m_1m_2} = 0$
$\frac{\partial R}{\partial \dot{x}_i}$	$\omega_n = n\sqrt{\frac{R}{r}}$
$\left\lvert\frac{K\theta_0}{M_0}\right\rvert = \sqrt{\frac{\mu^2(\omega/\omega_n)^2 + 4\zeta^2}{\mu^2(\omega/\omega_n)^2(1-\omega^2/\omega_n^2)^2 + 4\zeta^2\left[\mu(\omega/\omega_n)^2 - (1-\omega^2/\omega_n^2)\right]^2}}$	$T = -m(R+r)n^2R\phi$
$f_u = 2^n f_l$ and central frequency, $f_c = \sqrt{f_l f_u}$	$J_{eff} = \frac{m(R+r)^2}{1 - r\omega^2/Rn^2}$
Acoustic impedance = ρc = 406 rayls	Pressure amplitude, P = ω X ρ c = 2π f X ρ c
$\bar{\varepsilon}$ = l/c	*Pressure band level = 20 log $_{10}$ p_{band}/p_{ref}*
RT = 0.161 V/A A = $\bar{\alpha}$ S = $\sum \alpha i Si$	Pressure spectral level, PSL (f) = 10 $\log_{10}$ [S_p (f) /S_{ref}]
$L_p = L_w + 10\log_{10}(Q_\theta/4\pi r^2 + 4/\bar{\alpha}S)$	$N_F = (D_1 + D_2 - S)/(\lambda/2)$ IL = 16 + 10 log N_F

L-4/T-1/ME **Date: 04/05/2024**

BANGLADESH UNIVERSITY OF ENGINEERING AND TECHNOLOGY, DHAKA

L-4/T-1 B.Sc. Engineering Examinations 2022-2023

Sub: **ME 463 (Petroleum Engineering)**

Full Marks: 210 Time: 3 Hours

The figures in the margin indicate full marks.

USE SEPARATE SCRIPTS FOR EACH SECTION

SECTION – A

There are **FOUR** questions in this section. Answer **all**. For **Question 1 and 2** answer any one of the given options.

Assume reasonable value for any missing data. All symbols used have their usual meanings.

1. Answer either a and b, **OR** c and d.

(a) Define the terms "Folds" in context to earth structure. Briefly explain different types of earth folds in context to Petroleum Engineering. **(20)**

(b) Explain the "Plate Tectonics Theory". **(6.25)**

OR

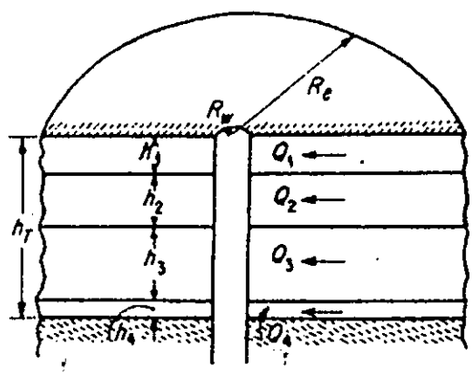
(c) What is "Kerogen"? Organize them based on H/C and O/C ratios. Also outline the "Maturation" of different types of Kerogens in terms of Oxygen index and Hydrogen Index. **(20)**

(d) Explain the term "Petroleum Migration". **(6.25)**

2. Answer either a and b, **OR** c and d.

(a) Define rock "Porosity" along with its classification. Mention important factors that affect rock "Porosity". **(10)**

(b) Obtain the expression for average reservoir permeability (k_{avg}) for linear parallel hydrocarbon flows to an extraction well through various radical layers $(h_1, h_2, h_3 ....)$ of various permeabilities $(k_1, k_2, k_3 ....)$ as shown below: **(16.25)**



OR

(c) Define "Wettability" and correlate it to "Contact Angle". Outline the case of "Wetting", "Neutral" and "Non-wetting" phenomena in reference to suitable solid-fluid combination. **(10)**

(d) Deduce the "Young-Laplace" Eqn. for Capillary rise (h) in tube immersion as follows: **(16.25)**

Contd..... P/2

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(Contd....Q. No. 2d)

$h = \frac{2\sigma Cos\theta}{(\rho_w - \rho_o)gR}$; Symbols have their usual meaning.

3. (a) Draw a typical "PT phase diagram" of a multi-component system and label it's key features. Classify hydrocarbon reservoirs with respect to reservoir pressure and temperature along with their key features in terms of composition, density and GOR (Gas Oil Ratio). **(16.25)**

(b) Define Oil Formation Volume Factor (B_o), Gas Formation Volume Factor (B_g), and Solution Gas-Oil Ratio (R_s) and Total Formation Volume Factor (B_T). Sketch their variation with reservoir pressure. Also prove that: **(10)**

$$B_T = B_o + B_g\left(R_{sb} - R_s\right)$$

4. (a) For an oil well that follows Exponential Decline (b = 0), prove that the flow rate (q) vs. Cumulative production (Q) curve has a linear profile with a slope of "-1/a", where: **(10)**

q: Production rate: Q: Cumulative Production; a: Nominal Decline rate

If q_{cc} represents the economic production rate, obtain the expression of economic lifetime of the well (t_e).

(b) Consider the following data of an oil reservoir: **(16.25)**

Area	= 30,000 acres
Net productive thickness	= 60 ft
Porosity	= 8%
Average S_w	= 45%
Initial reservoir pressure, p_i	= 3000 psia
Abandonment pressure, p_a	= 300 psia
B_o at p_i	= 1.68 bbl/STB
B_o at p_a	= 1.15 bbl/STB
S_g at p_a	= 32%
S_{or} after water invasion	= 20%

Calculate:

i) Original Oil In Place (OOIP)

ii) Oil in place after volumetric depletion to abandonment pressure

iii) Oil in place after water invasion at initial pressure

iv) Oil reserve by volumetric depletion to abandonment pressure

v) Oil reserve by full water drive

Contd..... P/3

ME 463

SECTION – B

There are **FOUR** questions in this section. Question no. **5 is compulsory** and carries **50** marks. Answer any **TWO** From the rest of the three.

5. (a) What is a drill collar? Write down the functions of a drill collar. **(10)**

   (b) Explain top drive and rotary table. Discuss the advantages of top drive over rotary table. **(15)**

   (c) Write a short note on drill bit. Mention the main advantages of PDC bits. **(10)**

   (d) List the most prevalent drilling problems. Explain the term 'formation damage'. **(15)**

6. (a) What is air drilling system? Discuss different types of air drilling system with their advantages and disadvantages. **(15)**

   (b) Categorize drilling holes depending on purpose. Explain each of them with examples. **(12.5)**

7. (a) How drilling is classified based on wellbore pressure during drilling? Discuss each of them with their advantages and disadvantages. **(20)**

   (b) Why does blow out occur? Discuss the major components of a BOP system. **(7.5)**

8. (a) Write down the full forms of these terms: BHA, WOB, DTH, UBD, ROP **(5)**

   (b) Explain cable tool drilling with proper illustration. What are the pros and cons of cable tool drilling? **(22.5)**