L-4/T-2/ME **Date: 22/04/2024**

BANGLADESH UNIVERSITY OF ENGINEERING AND TECHNOLOGY, DHAKA

L-4/T-2 B.Sc. Engineering Examinations 2021-2022

Sub: **ME 409 (Renewable Energy)**

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 any **THREE** questions.

1. (a) Classify various sources of energy based on availability. **(15)**

(b) Why heat is a low grade energy? Explain briefly with simple diagrams. **(10)**

(c) Draw and label a hydro power plant to show its working principle. **(10)**

2. (a) What is biomass? Why is it "Carbon cycle neutral"? What are the major factors which affect the quality and quantity of biogas production? **(15)**

(b) Draw and label a "floating drum type" biogas plant. What is the purpose of partition wall provided in the digester of this type of biogas plant? **(10)**

(c) How much biogas would be produced from processing approximately 550 tonnes of MSW (Municipal Solid Waste) per day form a typical city? With this volume of biogas so produced per day, how much grid-quality power will be generated by 100% biogas engine? Show the block diagram of MSW-based power project. **(10)**

3. (a) What is geothermal energy? With a neat sketch describe briefly the working principle of a "binary cycle geothermal power plant". Why water cannot be used as working fluid in this type similar to "flashed steam geothermal power plant"? **(15)**

(b) Regarding electricity generation from tidal energy, show with necessary figures, the positions of the sun and the moon creating (i) spring tides and (ii) neap tides.. **(10)**

(c) Draw the (i) plant layout and (ii) height versus operating cycle curve for a "Double-basin Single-tide" working installation. **(10)**

4. (a) What are the 3 components of a fuel cell? What is the main function of electrolyte of a fuel cell? With a neat sketch briefly describe the working principle of a Proton Exchange Membrane Fuel Cell. **(15)**

(b) When was the "Renewable Energy Policy of Bangladesh" finalized and which ministry did this? How many objectives are there in the policy and what are the targets? **(10)**

(c) Based on "CASE-STUDY", if you are asked to present a topic on "Renewable Energy for Bangladesh", which 4 major items should you consider for your presentation? Make free hand sketches of sample slides of these 4 items. **(10)**

Contd............ Page/2

SECTION – A

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

Symbols have their usual meaning. Assume reasonable values for missing data. Necessary charts and Table are attached.

5. (a) What is Betz limit? Mentioning the assumptions, prove that the maximum power can be extracted up to this limit from a wind turbine. **(15)**

(b) The power coefficient of a HAWT of 3 m diameter operating at a wind speed of 5 m/s is given by the equation: $C_p = 0.35\,(2 - \lambda)\,\lambda$. For this wind turbine, determine - **(20)**

i) maximum power output

ii) maximum torque

iii) torque at maximum power

iv) maximum rotational speed

v) draw C_p vs. λ and C_T vs. λ curve.

6. (a) What do you understand by "tip speed ratio" of a wind turbine? Draw the necessary performance curves and explain the effects of tip speed ratio on the performance parameters of wind turbine for different rotor solidity. **(7)**

(b) A wind turbine is connected to a water pump to supply water for a typical village having the following data: **(8)**

- Present Population: 400 people, 300 cattle, 390 goats, 500 chickens, 400 sheeps, 500 pigs and 160 horses.
- Overall population growth 2.25% and working life 10 years.
- Average wind speed 4 m/s and starting wind speed 32.5% higher than the average wind speed.
- Total pumping head 40 m.
- Used attached Tables and Charts and use WHO recommended water demand/person/day = 40 liter

Determine the diameter of wind turbine rotor blade and diameter of the pump impeller.

(c) A pump has to be set up to supply water for a typical village. Carry out economic assessment in real terms to compare the system of (A) Wind Pump, and (B) Diesel pump with the data given below to calculate: **(20)**

(i) Capital cost.

(ii) Recurrent cost.

(iii) Life cycle cost.

(iv) Annualized life cycle cost.

(v) Unit water cost.

Contd............ Page/3

1.	Period of Financial Assessment	6 years
2.	Daily water demand	50 m^3
3.	Storage tank safety factor	1.5
4.	Discount rate	10%
5.	Inflation rate	0%
6.	Longest lull period	5 days
7.	Max, period required for Diesel engine R & M	3 days
8.	Life of delivery pipe	2 years
9.	Fuel consumption	3 liters/day
10	Cost of construction of storage tank	Tk. 150 per m^3
11.	Cost of borehole construction	Tk. 35,000
12.	Cost of delivery pipe	Tk. 4,000
13.	Cost of foundation	Tk. 5,000
14.	Price of Wind Pump	Tk. 70,000
15.	Cost of wind pump installation	Tk. 10,000
16.	Price of Diesel pump	Tk. 40,000
17.	Cost of Diesel pump installation	Tk. 6,000
18.	Cost of Fuel	Tk. 20 per litre
19.	Wind Pump Repair and Maintenance (R & M)	Tk. 1,000 per year
20.	Diesel Pump Repair and Maintenance (R & M)	Tk. 3,000 per year

(Use WHO recommended water demand/person/day = 40 liter)

Is wind pump the best option?

7. (a) Determine the followings at 3:00 pm on December 25, 2024 for an observer at Dhaka city (23.5°N, 90.0°E). **(22)**

i) Declination angle

ii) Altitude angle

iii) Azimuth angle

iv) Noontime zenith angle

v) The time of sunrise and sunset

vi) The number of daylight hours

vii) The sunrise and sunset azimuth angle

(b) What do you understand by active and passive solar heating systems? With neat sketches of " Trombe wall" , explain solar heating/cooling systems at day and night time operation. **(13)**

Contd........... Page/4

8. (a) Consider the sun (as a black body) were to cool down to 5527°C, Find: **(14)**

i) total flux emitted by the sun at this temperature.

ii) the characteristic color

iii) the new solar constant for the earth.

Sketch the spectral distribution.

(b) Show that only 25 percent of the total radiant energy of a black-body spectrum at any temperature is contained by wavelengths shorter than the characteristics wavelength λ_{max}. **(6)**

(c) Classify active solar heating systems. With neat sketch explain evacuated tube solar collector. **(15)**

Table–1: Daily Water requirements of farms animals.	
	Daily Water needs in Litres
Horse	50
Cattle	40
Pig	20
Goat	5
Sheep	5
Chicken	0.1

Table–2: Population increase for various annual growth rates.		
Annual growth rate of population	% increase in population	
	in 5 years	in 10 years
1%	5	10
2%	10	22
3%	16	34
4%	22	48

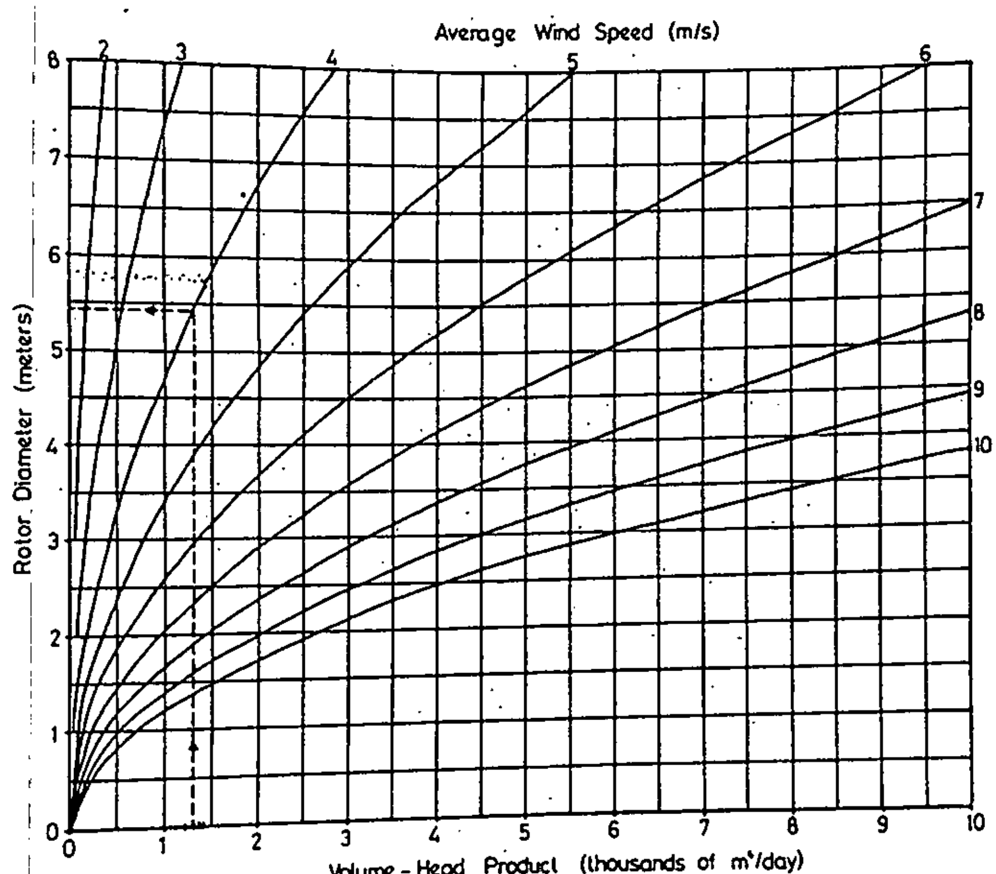


Fig.1: Windpump rotor-sizing nomogram.

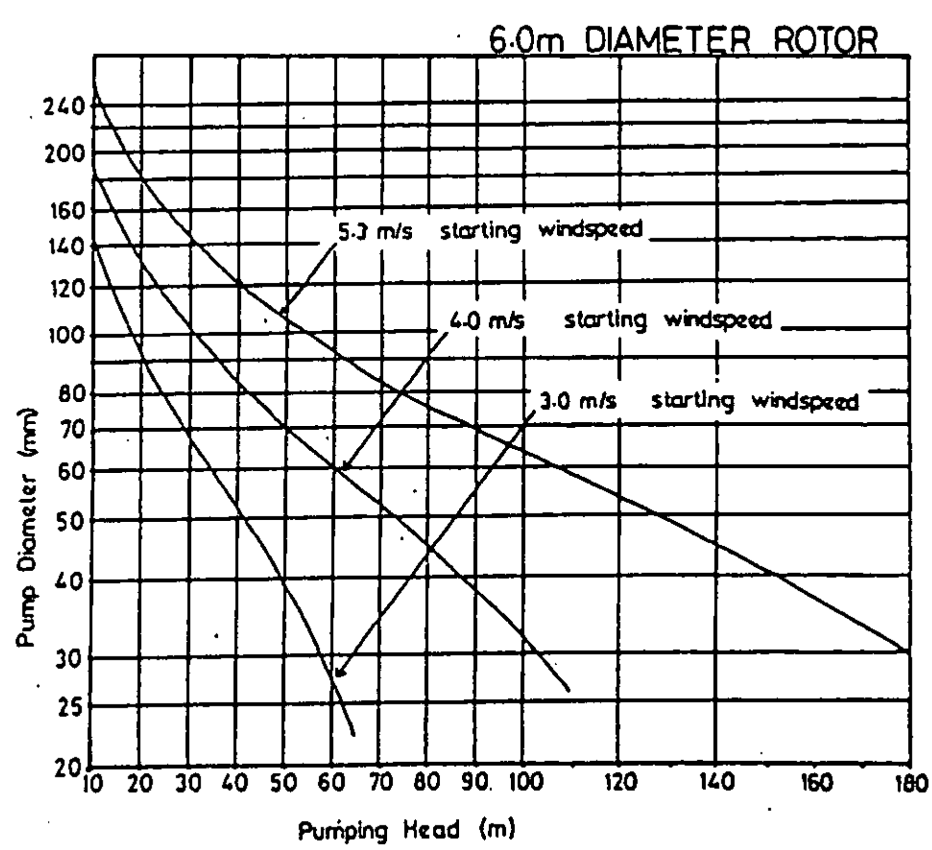


Fig.2: Typical charts for pump sizing by head and average wind speed (suppliers can generally provide sizing advice).

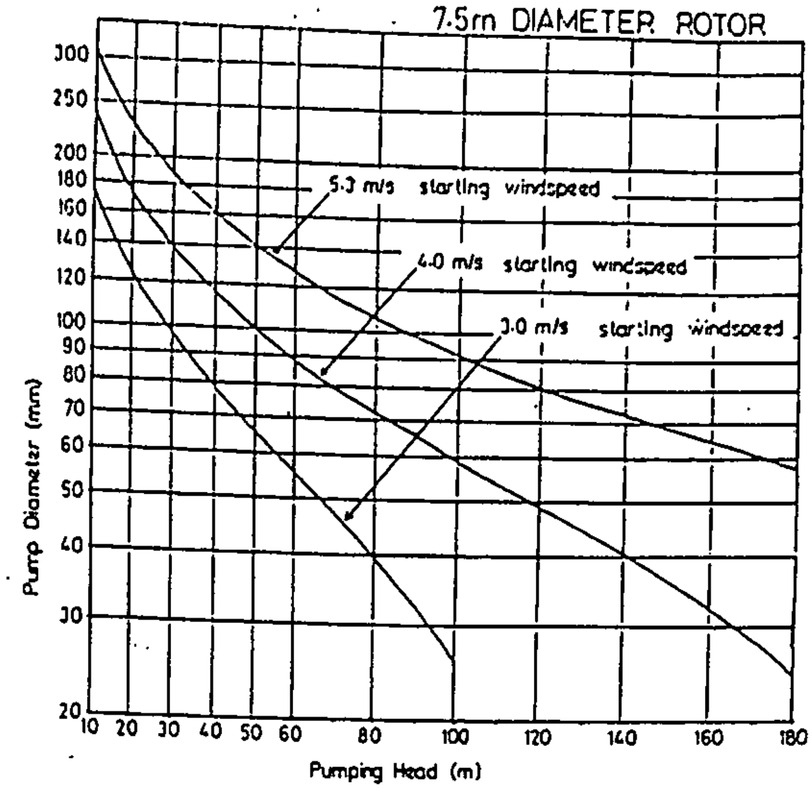


Fig.3: Typical charts for pump sizing by head and average wind speed (suppliers can generally provide sizing advice).

Table 3: Discount factors for various discount rates and number of years (zero inflation).

	DISCOUNT RATE %									
NUMBER OF YEARS	2	4	6	8	10	12	14	16	18	20
1	0.98	0.96	0.94	0.93	0.91	0.89	0.88	0.86	0.85	0.83
2	0.96	0.92	0.89	0.86	0.83	0.80	0.77	0.74	0.72	0.69
3	0.94	0.89	0.84	0.79	0.75	0.71	0.67	0.64	0.61	0.58
4	0.92	0.85	0.79	0.74	0.68	0.64	0.59	0.55	0.52	0.48
5	0.91	0.82	0.75	0.68	0.62	0.57	0.52	0.48	0.44	0.40
6	0.89	0.79	0.70	0.63	0.56	0.51	0.46	0.41	0.37	0.33
7	0.87	0.76	0.67	0.58	0.51	0.45	0.40	0.35	0.31	0.28
8	0.85	0.73	0.63	0.54	0.47	0.40	0.35	0.31	0.27	0.23
9	0.84	0.70	0.59	0.50	0.42	0.36	0.31	0.26	0.23	0.19
10	0.82	0.68	0.56	0.46	0.39	0.32	0.27	0.23	0.19	0.16
15	0.74	0.56	0.42	0.32	0.24	0.18	0.14	0.11	0.08	0.06
20	0.67	0.46	0.31	0.21	0.15	0.10	0.07	0.05	0.04	0.03

Table 4: Discount factors for recurrent costs which have to be paid annually over a number of years, for various discount rates (zero inflation)

	DISCOUNT RATE %									
NUMBER OF YEARS	2	4	6	8	10	12	14	16	18	20
1	0.98	0.96	0.94	0.93	0.91	0.89	0.88	0.86	0.85	0.83
2	1.94	1.88	1.83	1.79	1.74	1.69	1.65	1.60	1.57	1.52
3	2.88	2.77	2.67	2.58	2.49	2.40	2.32	2.24	2.18	2.10
4	3.80	3.62	3.46	3.32	3.17	3.04	2.91	2.79	2.70	2.58
5	4.71	4.44	4.21	4.00	3.79	3.61	3.43	3.27	3.14	2.98
6	5.60	5.23	4.91	4.63	4.35	4.12	3.89	3.68	3.51	3.31
7	6.47	5.99	5.58	5.21	4.86	4.57	4.29	4.03	3.82	3.59
8	7.32	6.72	6.21	5.75	5.33	4.97	4.64	4.34	4.09	3.82
9	8.16	7.42	6.80	6.25	5.75	5.33	4.95	4.60	4.32	4.01
10	8.98	8.10	7.36	6.71	6.14	5.65	5.22	4.83	4.51	4.17
15	12.8	11.1	9.7	8.6	7.6	6.8	6.2	5.6	5.1	4.6
20	16.3	13.6	11.5	9.8	8.5	7.5	6.6	5.9	5.4	4.8

Table-5: The Equation of Time in Minutes.

Day of Month	January	February	March	April	May	June	July	August	September	October	November	December
1	−4	−14	−13	−4	+3	+2	−3	−6	0	+10	+16	+11
4	−5	−14	−12	−3	+3	+2	−4	−6	+1	+11	+16	+10
7	−6	−14	−11	−2	+3	+2	−5	−6	+2	+12	+16	+9
10	−8	−14	−10	−1	+4	+1	−5	−5	+3	+13	+16	+7
13	−9	−14	−10	−1	+4	0	−6	−5	+4	+14	+16	+6
16	−10	−14	−9	0	+4	0	−6	−4	+5	+14	+15	+4
19	−11	−14	−8	+1	+4	−1	−6	−4	+6	+15	+15	+3
22	−12	−14	−7	+1	+4	−2	−6	−3	+7	+15	+14	+2
25	−12	−13	−6	+2	+3	−2	−6	−2	+8	+16	+13	0
28	−13	−13	−5	+2	+3	−3	−6	−1	+9	+16	+12	−2

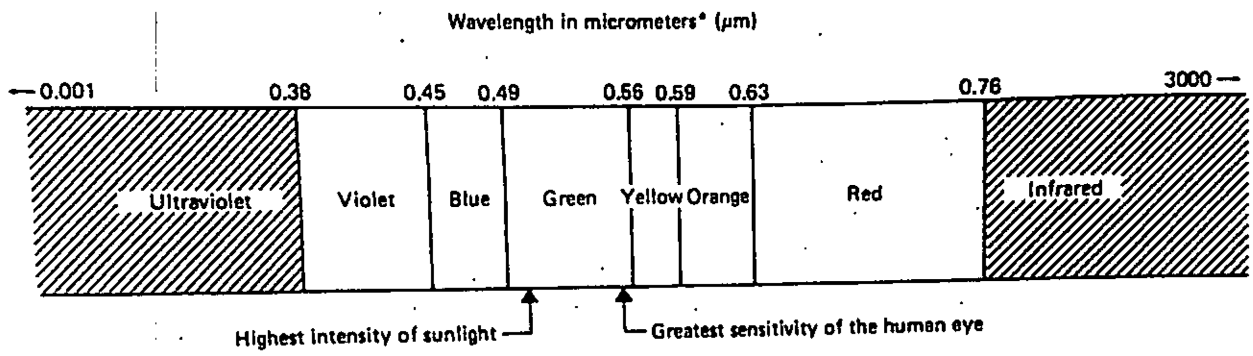


Fig.4: Wavelengths of visible, ultraviolet and infrared light.

Table 6: The functions $f(x)$.

x(μm-K)	$f(x)$	x(μm-K)	$f(x)$	x(μm-K)	$f(x)$
1100	0.001	4600	0.580	8100	0.860
1200	0.002	4700	0.594	8200	0.864
1300	0.004	4800	0.608	8300	0.868
1400	0.008	4900	0.621	8400	0.871
1500	0.013	5000	0.634	8500	0.875
1600	0.020	5100	0.646	8600	0.878
1700	0.029	5200	0.658	8700	0.881
1800	0.040	5300	0.669	8800	0.884
1900	0.052	5400	0.680	8900	0.887
2000	0.067	5500	0.691	9000	0.890
2100	0.083	5600	0.701	9100	0.893
2200	0.101	5700	0.711	9200	0.895
2300	0.120	5800	0.720	9300	0.898
2400	0.140	5900	0.730	9400	0.901
2500	0.161	6000	0.738	9500	0.903
2600	0.183	6100	0.746	9600	0.905
2700	0.205	6200	0.754	9700	0.908
2800	0.228	6300	0.762	9800	0.910
2900	0.251	6400	0.770	9900	0.912
3000	0.273	6500	0.776	10000	0.914
3100	0.296	6600	0.783	11000	0.932
3200	0.318	6700	0.790	12000	0.945
3300	0.340	6800	0.796	13000	0.955
3400	0.362	6900	0.802	14000	0.963
3500	0.383	7000	0.808	15000	0.969
3600	0.404	7100	0.814	16000	0.974
3700	0.424	7200	0.819	17000	0.978
3800	0.443	7300	0.824	18000	0.981
3900	0.462	7400	0.830	19000	0.983
4000	0.483	7500	0.834	20000	0.986
4100	0.499	7600	0.840	30000	0.995
4200	0.516	7700	0.844	40000	0.998
4300	0.533	7800	0.848	50000	0.999
4400	0.549	7900	0.852		
4500	0.564	8000	0.856		

L-4/T-2/ME

Date: ~~27/04/2024~~ 18|05|2024

BANGLADESH UNIVERSITY OF ENGINEERING AND TECHNOLOGY, DHAKA

L-4/T-2 B. Sc. Engineering Examinations 2021-2022

Sub: **ME 413** (Energy and Environment)

Full Marks: 210 Time: 3 Hours

The figures in the margin indicate full marks.

Symbols used have their usual meaning and interpretation.

USE SEPARATE SCRIPTS FOR EACH SECTION

SECTION – A

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

Assume reasonable values for missing data.

1. In a captive power plant, a 1500 KW natural gas generator is running at 75% load condition. By using the indirect method, (i) Calculate the combustion efficiency and electrical efficiency of the generator. (ii) Also, find the exhaust gas and jacket water heat recovery potential for the plant and (iii) If 15% of the exhaust gas is recovered, what will be the overall efficiency of the plant? **(35)**

   Consider the specific heat of the fuel and superheated steam as 0.23 kcal/kg.K and 0.45 kcal/kg.K respectively, GCV of natural gas = 12500 kcal/kg, mass of dry flue gas = 35.05 kg, Humidity Factor = 0.02 kg/kg of dry air.

   Generator Catalogue data:

   Fuel consumption at 75% load condition = 8570 kJ/kW-hr,

   Heat rejection to jacket water circuit = 810 KW.

   Also, consider some unaccounted loss of 1.5% and radiation heat loss of 3.5%.

   Ultimate analysis of fuel (weight %): 74.72% C, 23.3% H_2, 0.65% N_2, 1.23% O_2 and 0.1% S.

   Flue Gas analysis: 10.5% O_2, 6.2% CO_2, 744 ppm CO, Flue gas temperature 435°C and ambient temperature 32.2°C.

   You can use the equations provided at the end of the question.

2. (a) What is COP? What are the achievements of COP 28? **(5)**

   (b) "The Loss and Damage Fund recompenses the impoverished communities least responsible for climate change but suffering the most from its adverse effects." Explain the statement. How can Bangladesh access the fund? **(10)**

   (c) A textile plant, using furnace oil as fuel, produces steam at a rate of 30 TPH (ton per hour). **(20)**

   The plant has decided to switch over to natural gas as fuel. Determine the change in greenhouse gas emission due to the decision. The enthalpy of boiler feed water and steam is 60 kCal/kg and 660 kCal/kg, respectively. Annual operating hour is 8000. The other data are as follows:

   Furnace Oil

   GCV of furnace oil: 10200 kCal/kg

   % of carbon in furnace oil: 84%

   Efficiency of the furnace oil-fired boiler: 82%

   Natural Gas

   GCV of Natural Gas: 9500 kCal/kg

   % of carbon in Natural gas: 74%

   Efficiency of the natural gas-fired boiler: 86%

   Density of natural gas: 0.8 kg/m^3

Contd P/2

ME 413

3. (a) What is the physical meaning of Energy Return on Energy Invested (EROI)? For a hypothetical system, the delivered energy is 20 units and the energy input is 2 unit. What is the EROI of this system? **(5)**

(b) Goal 13 of SDG 2030 is "Climate Action". List some of the specific targets of this goal. **(5)**

(c) What do you understand by sustainability? What are the three pillars or foundations of sustainability and how do they affect each other? **(10)**

(d) What kind of battery is used in Tesla electric car? Illustrate a recycling process of the battery. **(15)**

4. (a) How does energy flow in an ecosystem? With the help of diagram(s), illustrate how the energy flow is different from the material flow in an ecosystem. **(10)**

(b) "Energy storage helps to integrate renewable energies into the existing energy system." Explain the statement. What are the roles energy storage systems can play? **(8)**

(c) Plastics pose a threat to the environment because the breakdown of different types of plastic leads to the release of various toxic chemicals. To quantify the impact of plastic on environment, you are asked to do Life Cycle Impact Assessment (LCIA) of a plastic bottle. You have to analyze 3 production paths. In case 1, raw materials are locally procured. In case 2, raw materials are transported by ship from another country, and in case 3, raw materials are transported by train from another country. After LCIA, you have found results as shown in Fig for Q. 4(c).

(i) What are the key steps you should follow to do LCIA of the plastic bottle? **(5)**

(ii) By analyzing Fig 4(c), which case seems environmentally favorable depending on impact categories? Why are there variations in impacts in different cases depending on impact categories? **(12)**

SECTION – B

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

5. (a) Taking the textile industry as an example, evaluate the importance of using effluent treatment plant (ETP) to reduce water pollution in Bangladesh. **(17)**

(b) Categorize the different levels of treatment in the ETP and with necessary diagram(s), describe the secondary treatment level. **(18)**

Contd P/3

ME 413

6. (a) Considering the "*time scale*" (the time between the first exposure and the time up to which the adverse effects of energy use can be detected) and "*length scale*" (the distance over which the harmful impact of energy use can be felt) of the impact of energy use on the environment, explain that some types of pollution (such as air pollution and radioactive pollution) have more profound consequences than the other types of pollution. **(10)**

(b) Justify the following statement- "Among the criteria air pollutants, particulate matter poses the most serious threat to health in Bangladesh". **(10)**

(c) Define GWP and ODP and evaluate their role in the development and use of different generations of refrigerants. **(15)**

7. (a) Summarize the effects of acid rain on plants and trees. Explain the "buffering ability" of an ecosystem to resist the effects of acid rain. **(17)**

(b) Compare the already observed effects of global warming with the future prediction. Describe the different pathways that the extent of global warming can take in the future and the factors influencing these pathways. **(18)**

8. (a) According to you, what are the most important current global energy issues? "Energy consumption is an indicator of economic growth of a nation"- Justify this statement. **(17)**

(b) Distinguish between the resource and reserve of petroleum fuels. Explain how petroleum resource and reserve amounts depend on the geological certainty and economic feasibility and hence show why petroleum reserve estimates are generally revised over time. **(18)**

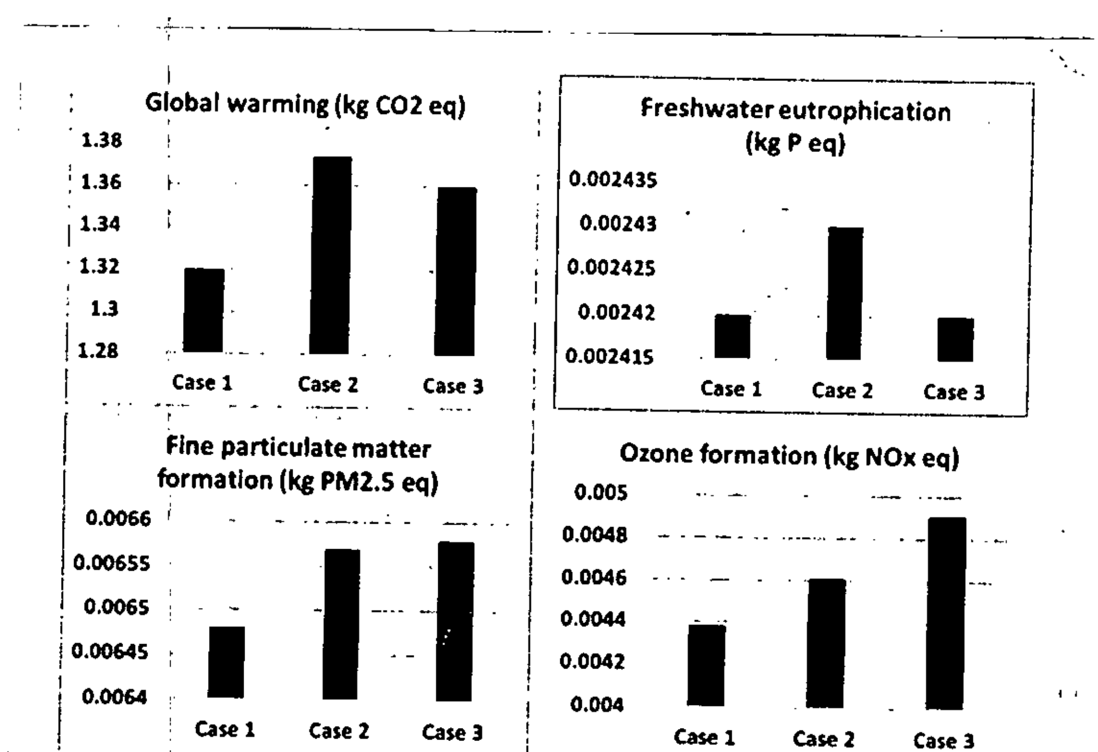


Fig. for Q. 4(c)

Formula for Question 1

Theoretical air required for combustion $= [(11.6 \times C) + \{34.8 \times (H_2 - O_2/8)\} + (4.35 \times S)]/100$ kg/kg of fuel

Where C, H_2, O_2 and S are the percentage of Carbon, Hydrogen, Oxygen and Sulphur present in the fuel.

$$\% \text{ Excess Air Supplied (EA)} = \frac{O_2\%}{21 - O_2\%} \times 100$$

$$\text{Actual mass of air supplied/ kg of fuel (AAS)} = \left\{1 + \frac{EA}{100}\right\} \times \text{Theoretical Air}$$

$$\% \text{ Heat loss due to dry flue gas} = \frac{m \times C_p \times (T_f - T_a)}{\text{GCV of fuel}} \times 100$$

$$\% \text{ Heat loss due to hydrogen in fuel } (H_2) = \frac{9 \times H_2 \times \{584 + C_p \times (T_f - T_a)\}}{\text{GCV of fuel}} \times 100$$

$$\% \text{ Heat loss due to moisture in air } (H_2O) = \frac{AAS \times \text{Humidity factor} \times C_p \times (T_f - T_a)}{\text{GCV of fuel}} \times 100$$

$$\% \text{ Heat loss due to partial conversion of C to CO} = \frac{\%CO \times C}{\%CO + \%CO_2} \times \frac{5654}{\text{GCV of fuel}} \times 100$$

$$\textit{Heat loss by jacket water} = \frac{\textit{Jacket water Heat Content}}{\textit{Input energy}} \times 100\%$$

$$\textit{Jacket water heat content}(kW) = \dot{m} \times C_p \times \Delta T$$

$$\textit{Input energy}(kW) = \frac{\textit{Fuel Consumption at Load condition}\left(\frac{kJ}{kWhr}\right) \times \textit{Rated Capacity of the generator}(kW)}{3600}$$

$$\textit{Potential Heat Recovery by Exhaust Gas} = \frac{\dot{m}C_p(T_f - T_a)}{\textit{GCV of fuel} \times \textit{Natural Gas Consumption } (kg/s)} \times 100 \times 0.7$$

L-4/T-2/ME Date: 22/04/2024

BANGLADESH UNIVERSITY OF ENGINEERING AND TECHNOLOGY, DHAKA

L-4/T-2 B.Sc. Engineering Examinations 2021-2022

Sub: **ME 423 (Fluids Engineering)**

Full Marks: 140 Time: 3 Hours

The figures in the margin indicate full marks.

Charts and Tables are given.

USE SEPARATE SCRIPTS FOR EACH SECTION

SECTION – A

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

1. (a) The pseudo-critical temperature and pressure of a natural gas mixture were calculated as 380°R and 675 psia, respectively. In the gas mixture, CO_2 content is 12% and H_2S is 22%. Determine **(10)**

(i) pseudo-critical temperature and pseudo-critical pressure of the gas mixture.

(ii) Using the Standing Katz compressibility chart, calculate the compressibility factor of the gas mixture at 100°F and 1200 psig.

Use the following equation for your calculation:

adjustment factor, $\varepsilon = 120\left(A^{0.9} - A^{1.6}\right) + 15\left(B^{0.5} - B^{4.0}\right)$

where the symbols have their usual meaning.

(b) A natural gas pipeline, NPS 20 with 0.50 in. wall thickness, 70 miles long, transports 250 MMSCFD. The specific gravity of gas is 0.60 and viscosity is 0.000008 lb/ft-s. Calculate friction factor and transmission factor using the Colebrook equation. Assume absolute pipe roughness = 750 μin and compressibility factor = 0.94. The base temperature and base pressure are 60°F and 14.7 psia, respectively. What is the upstream pressure for an outlet pressure of 800 psig? **(25)**

What is the erosional velocity for this pipeline based on the above data.

Following standard relations are given for your calculation:

General flow equation, $Q = 38.77F\left(\frac{T_b}{P_b}\right)\left(\frac{P_1^2 - P_2^2}{GT_f LZ}\right)^{0.5} D^{2.5}$

Reynolds number, $\mathrm{Re} = 0.000478\left(\frac{P_b}{T_b}\right)\left(\frac{GQ}{\mu D}\right)$

Modified Colebrook - White equation, $\frac{1}{\sqrt{f}} = -2Log_{10}\left(\frac{e}{3.7D} + \frac{2.825}{\mathrm{Re}\sqrt{f}}\right)$

Compressibility factor, $Z = \frac{1}{\left[1 + \left(\frac{P_{avg}\, 344{,}400(10)^{1.785G}}{T_f^{\,3.825}}\right)\right]}$ (CNGA method)

Average gas pressure, $P_{avg} = \frac{2}{3}\left(P_1 + P_2 - \frac{P_1 P_2}{P_1 + P_2}\right)$

where the symbols have their usual meaning.

contd..... P/2

2. (a) A 150 mi long natural gas pipeline consists of several injections and deliveries as shown in Figure for Q. 2(a). The pipeline is NPS 20, has 0.500 in. wall thickness, and has an inlet volume of 250 MMSCFD. At points B (milepost 20) and C (milepost 80), 50 MMSCFD and 70 MMSCFD, respectively, are delivered. At D (milepost 100), gas enters the pipeline at 60 MMSCFD. All streams of gas may be assumed to have a specific gravity of 0.65 and a viscosity of 8.0×10^{-6} lb/ft-s. The pipe is internally coated (to reduce friction), resulting in an absolute roughness of 150 μ in. Assume a constant gas flow temperature of 60°F and base pressure and base temperature of 14.7 psia and 60°F, respectively. Use a constant compressibility factor of 0.85 throughout. Neglect elevation differences along the pipeline. **(20)**

(i) Using the AGA equation, calculate the pressures along the pipeline at points A, B, C, and D for a minimum delivery pressure of 300 psig at the terminus E. Assume a drag factor = 0.96.

(ii) What diameter pipe will be required for section DE if the required delivery pressure at E is increased to 500 psig? The inlet pressure at A remains the same as calculated above.

Use the following equations for your calculation:

General flow equation, $Q = 38.77F\left(\frac{T_b}{P_b}\right)\left(\frac{P_1^2 - P_2^2}{GT_f LZ}\right)^{0.5} D^{2.5}$

Reynolds number, $Re = 0.000478\left(\frac{P_b}{T_b}\right)\left(\frac{GQ}{\mu D}\right)$

AGA equation:

Von Karman rough pipe flow equation: $F = 4\,\mathrm{Log}_{10}\left(\frac{3.7D}{e}\right)$

for partially turbulent zone, $F = 4D_f\,\mathrm{Log}_{10}\left(\frac{Re}{1.4125F_t}\right)$

and

$F_t = 4\,\mathrm{Log}_{10}\left(\frac{Re}{F_t}\right) - 0.6$

where the symbols have their usual meaning

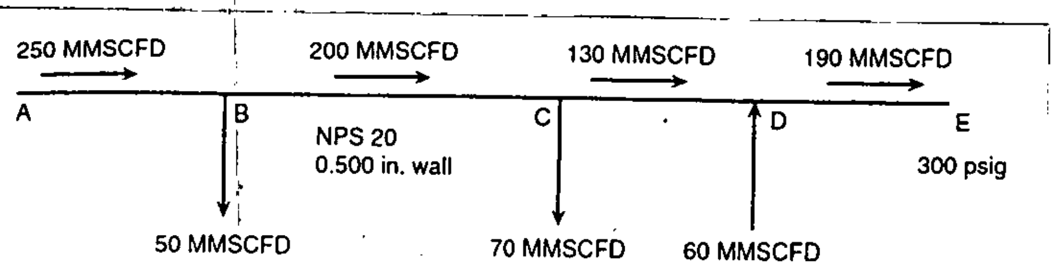


Fig. for Q. 2(a)

(Continuation Q. No. 2)

(b) A gas pipeline consists of two parallel pipes, as shown in fig. for Q. 2(b). It is designed to operate at a flow rate of 100 MMSCFD. The first pipe segment AB is 12 miles long and consists of NPS 16, 0.250 in. wall thickness pipe. The loop BCE is 24 mi long and consists of NPS 14, 0.250 in. wall thickness pipe. The loop BDE is 48 miles long and consists of NPS 12, 0.250 in. wall thickness pipe. Assuming a gas gravity of 0.6, calculate the pressures at the beginning and the end of the pipe loops and the flow rates through them. The inlet pressure at A = 1200 psig. The gas flowing temperature = 80°F, base temperature = 60°F, and base pressure = 14.73 psia. The compressibility factor Z = 0.92. Use the General Flow equation with Colebrook friction factor f = 0.015. **(15)**

$$\frac{Q_1}{Q_2}=\left(\frac{L_2}{L_1}\right)^{0.5}\left(\frac{D_1}{D_2}\right)^{2.5}$$

General flow equation, $Q=77.54\left(\frac{T_b}{P_b}\right)\left(\frac{P_1^2-P_2^2}{GT_fLZf}\right)^{0.5}D^{2.5}$

where the symbols have their usual meaning.

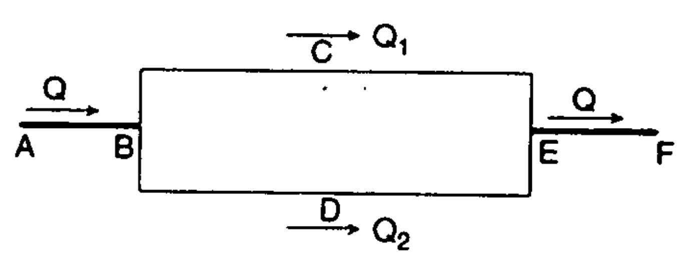


Fig. for Q. 2(b)

3. (a) A gas transmission pipeline is 240 mi long, NPS 30, 0.500 in. wall thickness, with an origin compressor station at Payson and two intermediate compressor stations tentatively located at Williams (milepost 80) and Snowflake (milepost 160), as shown in Fig. for Q. 3(a). There are no intermediate glow deliveries or injections, and the inlet flow rate of 900 MMSCFD at Payson equals the delivery flow rate at Douglas. The delivery pressure required in Douglas is 600 psig and the MOP of the pipeline is 1400 psig throughout. Neglect the effects of elevation and assume constant gas flow temperature of 80°F and constant values of transmission factor F = 20 and compressibility factor Z = 0.85 throughout the pipeline. The gas gravity = 0.6, base pressure = 14.7 psia, and base temperature = 60°F. Use a polytropic compression coefficient of 1.38 and a compression efficiency of 0.9. **(20)**

Contd............ P/4

ME 423

(Continuation Q. No. 3(a))

Determine HP required for hydraulically balanced and imbalanced cases in making decision on location of compression stations.

General flow equation, $Q = 77.54\left(\frac{T_b}{P_b}\right)\left(\frac{P_1^2 - P_2^2}{GT_f LZf}\right)^{0.5} D^{2.5}$

$$HP = 0.0857\left(\frac{\gamma}{\gamma - 1}\right) QT_1\left(\frac{Z_1 + Z_2}{2}\right)\left(\frac{1}{\eta_a}\right)\left[\left(\frac{P_2}{P_1}\right)^{\frac{\gamma-1}{\gamma}} - 1\right]$$

where the symbols have their usual meaning.

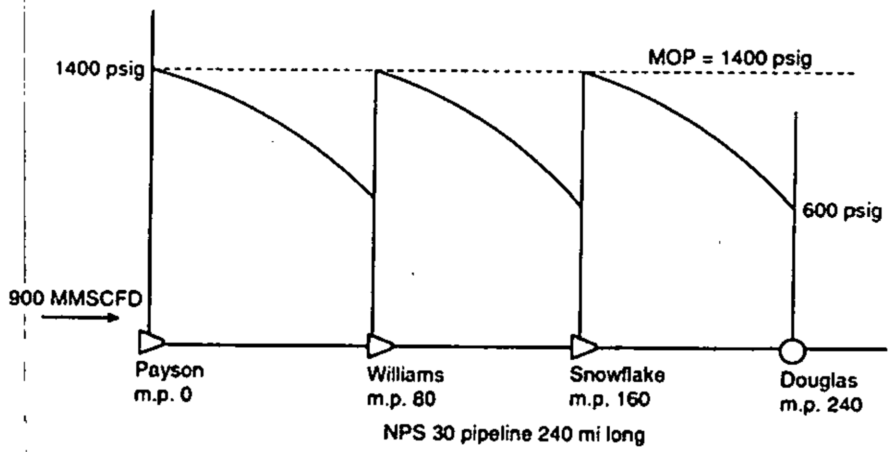


Fig. for Q. 3(a)

(b) A natural gas pipeline, NPS 16, 0.250 in. wall thickness, 50 mi long, with a branch pipe (NPS 8, 0.250 in. wall thickness, 15 mi long) as shown in Fig. for Q. 3(b) is used to transport 100 MMSCFD gas (specific gravity = 0.6 and viscosity = 0.000008 lb/ft-s) from A to B. At B, a delivery of 30 MMSCFD occurs into the branch pipe BE. The delivery pressure at E must be maintained at 300 psig. The remaining volume is shipped to the terminus C at a delivery pressure of 600 psig. Assume a constant gas temperature of 60°F and a pipeline efficiency of 0.95. The base pressure and temperature are 14.7 psia and 60°F, respectively. The compressibility factor, Z can be assumed as 0.88.

(i) Using Panhandle A equation, calculate the inlet pressure required at A. **(15)**

(ii) Is a pressure regulator required at E?

(iii) If the inlet flow at station A drops to 60 MMSCFD, what is the impact in the branch pipeline BE if the flow rate of 30 MMSCFD is maintained?

Neglect elevation effects in your calculations.

Panhandle A equation :

$$Q = 435.87\,E\left(\frac{T_b}{P_b}\right)^{1.0788}\left(\frac{P_1^2 - e^s P_2^2}{G^{0.8539} T_f L_e Z}\right)^{0.5394} D^{2.6182} \quad \text{(USCS units)}$$

Contd P/5

(Continuation Q. No. 3(b))

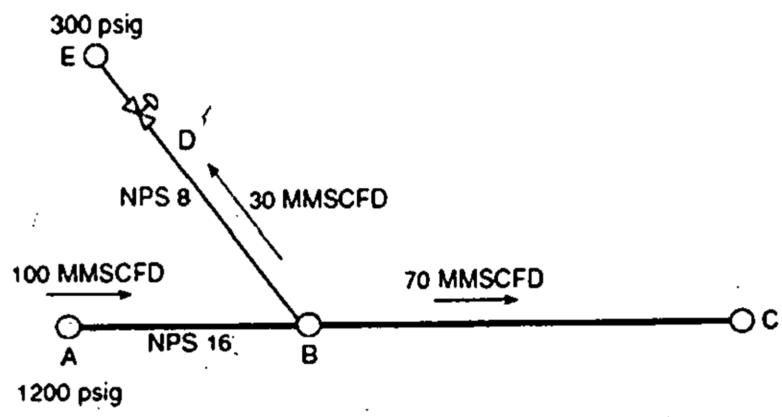


Fig. for Q. 3(b)

4. (a) A NPS 22 STD Schedule ASTM A 106 Grade B pipe is used to transport natural gas with design pressure of 12 barg. The design temperature of gas is 120°C. Determine the Maximum Allowable Operating Pressure (MAOP) of the gas pipeline considering: **(15)**

(i) ASME B31.8 standard and

(ii) ASME B31.1 standard

Also determine the factor of safety for the cases of both standards.

Note: 1 psi = 6.895 kPa; take A = 1.6 mm

ASME B31.8 standard: $P = \left(\frac{2St}{D}\right) \times E \times F \times T$

ASME B31.1 standard: $P = \frac{2SEW(t_m - A)}{D_O - 2y(t_m - A)}$

where the symbols have their usual meaning.

Mandatory Appendix and other data for ASTM standards are given.

(b) List the names of NDE frequently used for gas pipeline inspection. Briefly discuss how the hydrotest is performed in gas pipeline for leak tightness test. **(10)**

(c) What do you mean by gas pipeline pigging? **(5)**

9d) What are the major components of capital cost for a gas pipeline project? **(5)**

SECTION – B

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

Assume any reasonable value for missing data. Moody diagram is supplied.

5. (a) The pump (80% efficient) is needed in the piping system as shown in Fig. for Q. 5(a). **(18)**

(i) Estimate the flow rate and the power required by the pump.

(ii) Sketch the EGL and HGL.

(iii) If cavitation is possible, determine the maximum distance from the reservoir to locate the pump.

Given that vapor pressure of water at 15°C is 1702 Pa and kinematic viscosity is 1.14×10^{-6} m^2/s.

(b) A farmer wants you to design his irrigation pipe line so that it can be used in the winter to generate electricity for his home. He wants to run a 22 kW turbine-generator (70% efficient) form 0.06 m^3/s stream. The PVC pipe line is 1050 m long, and the upstream end is 80 m above the turbine. What pipe diameter should be selected? The temperature of water is 15°C. **(17)**

6. (a) A simple-stage Ingersot-Dressor 15H277 pump, outfitted with longest impeller (Reference as Fig. for Q. 6(a) for pump characteristics curve), is used to pump water form a reservoir at elevation 1350 ft to another reservoir at elevation 1425 ft . The pipe line is 6000 ft long and 18 in diameter with an equivalent sand grain roughness of 0.015 in. Take $\nu = 1.14 \times 10^{-5}$ ft^2/s. Neglecting local losses, compute the discharge in the pipe line. **(17)**

(b) Determine the flow distribution of water in the system as shown in Fig. for Q. 6(b). Assume constant friction factor, f = 0.02. The head-discharge relation for the pump is $H_p = 60 - 10\,Q^2$, where Hp is in meters and the discharge is in m^3/s. **(18)**

7. (a) What is water hammer? With the concept of water hammer derive an expression of pressure head developed by sudden decrease in velocity of the pipe line. **(18)**

(b) A plastic supply pipe in a building water system is anchored at both ends and has expansion joints along its entire length. The line is 800 ft long, 6.00 inches inside diameter with a 0.20 inch wall thickness. The modulus of elasticity for this material is 500000 lb/in^2. Water in the pipe normally flows at 10 ft/s, and the system valves are designed to close very quickly. **(17)**

(i) If $\mu = 0.5$ for this material, what is the wave speed?

(ii) If the steady state pressure in the pipe is about 100 lb/in^2, estimate the maximum pressure that could occur in the system under the worst water hammer conditions?

(iii) What would be the streams in the pipe walls under these conditions?

Contd............ P/7

8 (a) What is surging? Water is flowing through the valve at the downstream end as shown in Fig. for Q. 8(a) with a velocity Vo. Suddenly the valve is opened to a new position. With this consideration derive an expression for time to reach the steady state flow condition. **(18)**

(b) Gasoline is supplied by gravity without pumping form a storage tank through a 850 m long 50 mm diameter nearly horizontal pipe into a tanker truck. There is a quick-acting valve at the end of the pipe. The difference in elevations of gasoline between the reservoir and the truck tank is 8 m. Initially, the valve is partially closed so that K = 275. Then the operator decides to increase the discharge by opening the valve quickly to the position where K = 5. Assuming an incompressible fluid and an inelastic piping system, determine the new steady-state discharge and the time it takes to reach 98% of that value. Assume $f = 0.016$. **(17)**

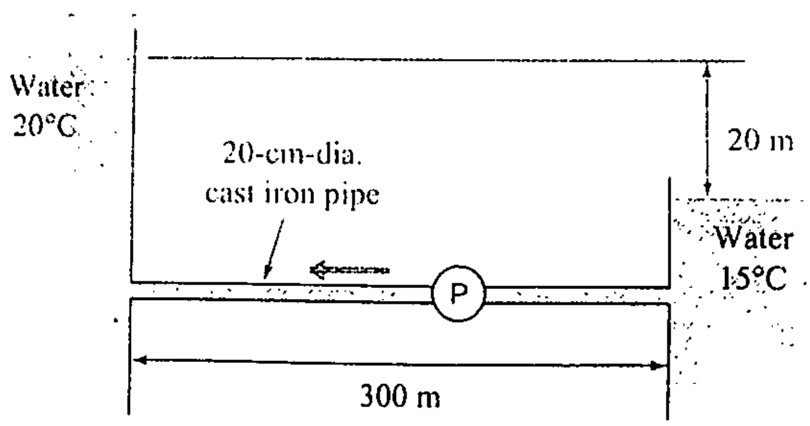


Fig. for Q. 5(a)

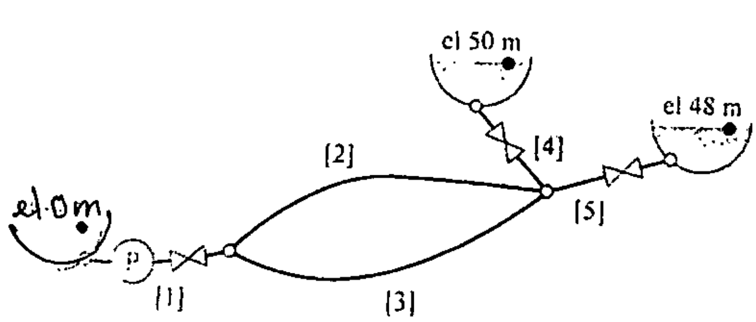


Fig. for Q. 6(b)

Pipe	L (m)	D (mm)	ΣK
1	100	350	2
2	750	200	0
3	850	200	0
4	500	200	2
5	350	250	2

Reqd. Parameter for Q. 6(b)

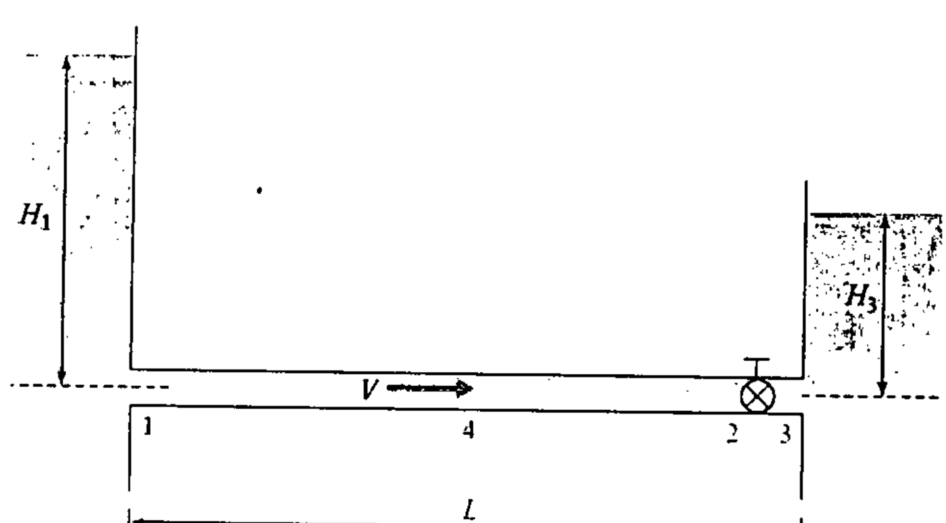
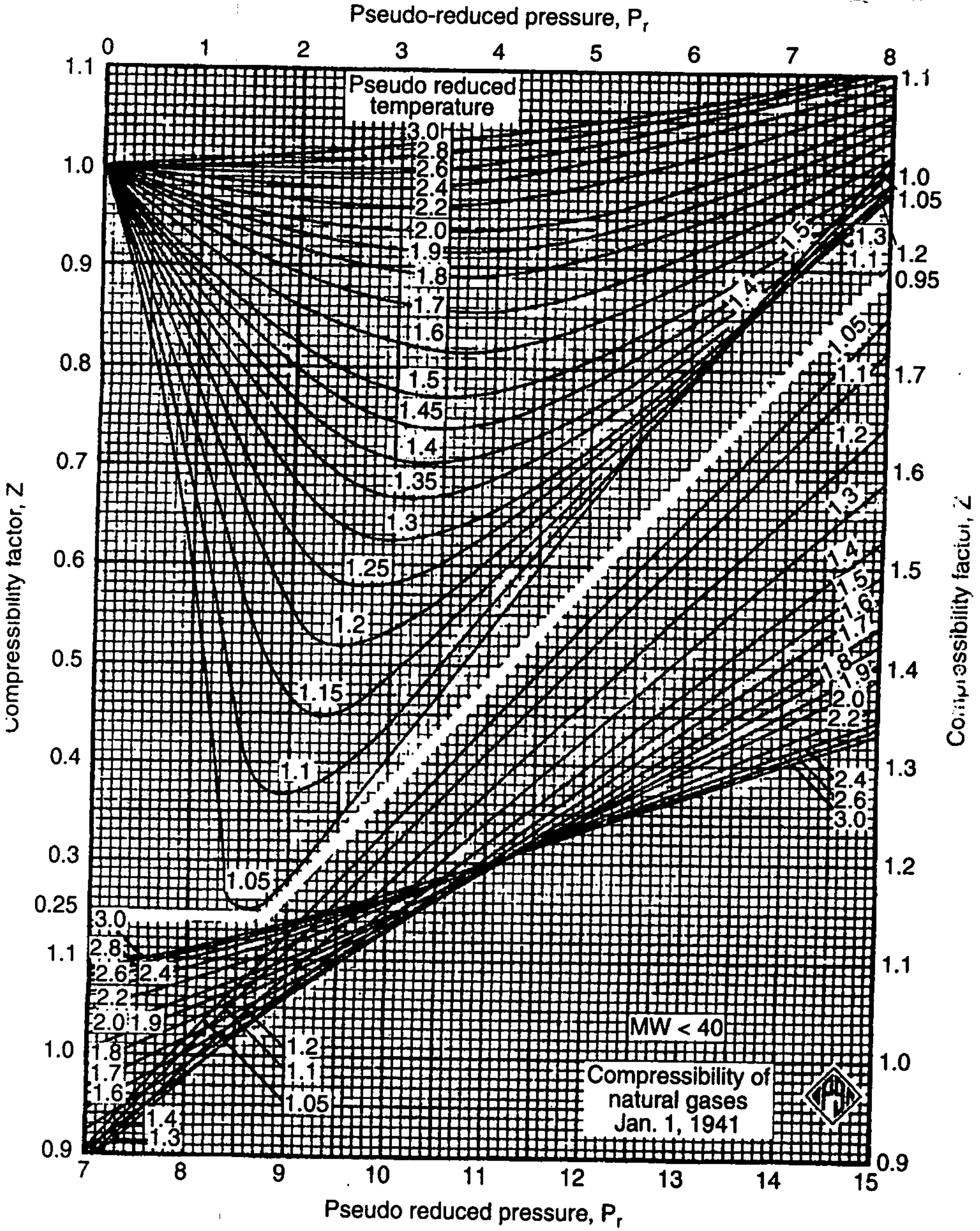


Fig. for Q. 8(a)



ure 1.2 Compressibility factor chart for natural gases. (From Gas Processors Suppliers Association, *Eng. Data Book*, Vol. II. With permission.)

=9=

MANDATORY APPENDIX D
SPECIFIED MINIMUM YIELD STRENGTH FOR STEEL PIPE COMMONLY USED IN PIPING SYSTEMS[1]

Table D-1 Specified Minimum Yield Strength for Steel Pipe Commonly Used in Piping Systems

Spec. No.	Grade	Type [Note (1)]	SMYS, psi	(MPa)
API 5L [Note (2)]	A25	BW, ERW, S	25,000	(172)
API 5L [Note (2)]	A	ERW, S, DSA	30,000	(207)
API 5L [Note (2)]	B	ERW, S, DSA	35,000	(241)
API 5L [Note (2)]	×42	ERW, S, DSA	42,000	(290)
API 5L [Note (2)]	×46	ERW, S, DSA	46,000	(317)
API 5L [Note (2)]	×52	ERW, S, DSA	52,000	(359)
API 5L [Note (2)]	×56	ERW, S, DSA	56,000	(386)
API 5L [Note (2)]	×60	ERW, S, DSA	60,000	(414)
API 5L [Note (2)]	×65	ERW, S, DSA	65,000	(448)
API 5L [Note (2)]	×70	ERW, S, DSA	70,000	(483)
API 5L [Note (2)]	×80	ERW, S, DSA	80,000	(552)
ASTM A 53	Type F	BW	25,000	(172)
ASTM A 53	A	ERW, S	30,000	(207)
ASTM A 53	B	ERW, S	35,000	(241)
ASTM A 106	A	S	30,000	(207)
ASTM A 106	B	S	35,000	(241)
ASTM A 106	C	S	40,000	(276)
ASTM A 134	...	EFW	[Note (3)]	
ASTM A 135	A	ERW	30,000	(207)
ASTM A 135	B	ERW	35,000	(241)
ASTM A 139	A	EFW	30,000	(207)
ASTM A 139	B	EFW	35,000	(241)
ASTM A 139	C	EFW	42,000	(290)
ASTM A 139	D	EFW	46,000	(317)
ASTM A 139	E	EFW	52,000	(359)
ASTM A 333	1	S, ERW	30,000	(207)
ASTM A 333	3	S, ERW	35,000	(241)
ASTM A 333	4	S	35,000	(241)
ASTM A 333	6	S, ERW	35,000	(241)
ASTM A 333	7	S, ERW	35,000	(241)
ASTM A 333	8	S, ERW	75,000	(517)
ASTM A 333	9	S, ERW	46,000	(317)
ASTM A 381	Class Y-35	DSA	35,000	(241)
ASTM A 381	Class Y-42	DSA	42,000	(291)
ASTM A 381	Class Y-46	DSA	46,000	(317)
ASTM A 381	Class Y-48	DSA	48,000	(331)
ASTM A 381	Class Y-50	DSA	50,000	(345)

[1] See para. 841.1.

Table D-1 Specified Minimum Yield Strength for Steel Pipe Commonly Used in Piping Systems (Cont'd)

Spec. No.	Grade	Type [Note (1)]	SMYS, psi	(MPa)
ASTM A 381	Class Y-52	DSA	52,000	(359)
ASTM A 381	Class Y-56	DSA	56,000	(386)
ASTM A 381	Class Y-60	DSA	60,000	(414)
ASTM A 381	Class Y-65	DSA	65,000	(448)
ASTM A 984	35	ERW	35,000	(241)
ASTM A 984	50	ERW	50,000	(345)
ASTM A 984	60	ERW	60,000	(414)
ASTM A 984	70	ERW	70,000	(483)
ASTM A 984	80	ERW	80,000	(552)
ASTM A 1005	35	DSA	35,000	(241)
ASTM A 1005	50	DSA	50,000	(345)
ASTM A 1005	60	DSA	60,000	(414)
ASTM A 1005	70	DSA	70,000	(483)
ASTM A 1005	80	DSA	80,000	(552)
ASTM A 1006	35	LW	35,000	(241)
ASTM A 1006	50	LW	50,000	(345)
ASTM A 1006	60	LW	60,000	(414)
ASTM A 1006	70	LW	70,000	(483)
ASTM A 1006	80	LW	80,000	(552)

GENERAL NOTE: This table is not complete. For the minimum specified yield strength of other grades and grades in other approved specifications, refer to the particular specification.

NOTES:

(1) Abbreviations: BW = furnace buttwelded; DSA = double submerged-arc welded; EFW = electric fusion welded; ERW = electric resistance welded; FW = flash welded; S = seamless; LW = laser welded.

(2) Intermediate grades are available in API 5L.

(3) See applicable plate specification for SMYS.

Long-Term Hydrostatic Strength Values for Thermoplastic Pipes Covered by ASTM D 2513. The values apply only to materials and pipes meeting all the requirements of the basic materials and ASTM D 2513. They are based on engineering test data obtained in accordance with ASTM D 1599 and analyzed in accordance with ASTM D 2837. A list of commercial compounds meeting these requirements is published yearly by the Plastics Pipe Institute.

Plastic Pipe Material Designation (D 2513)	Long-Term Hydrostatic Strength at 73°F (23°C) psi	(MPa)
PB 2110	2,000	(13.8)
PE 2406	1,250	(8.6)
PE 3408	1,600	(11.0)
PVC 1120	4,000	(27.6)
PVC 1220	4,000	(27.6)
PVC 2110	2,000	(13.8)
PVC 2116	3,150	(21.7)

Long-Term Hydrostatic Strength for Reinforced Thermosetting Pipes Covered by ASTM D 2517 is 11,000 psi (75.8 MPa). The values apply only to materials and pipes meeting all the requirements of the basic materials and ASTM D 2517. They are based on engineering test data obtained in accordance with ASTM D 1599 and analyzed in accordance with ASTM D 2837.

Table 841.1.7-1 Longitudinal Joint Factor, *E*

Spec. No.	Pipe Class	*E* Factor
ASTM A 53	Seamless	1.00
	Electric-Resistance-Welded	1.00
	Furnace-Butt Welded, Continuous Weld	0.60
ASTM A 106	Seamless	1.00
ASTM A 134	Electric-Fusion Arc-Welded	0.80
ASTM A 135	Electric-Resistance-Welded	1.00
ASTM A 139	Electric-Fusion Arc-Welded	0.80
ASTM A 333	Seamless	1.00
	Electric-Resistance-Welded	1.00
ASTM A 381	Submerged-Arc-Welded	1.00
ASTM A 671	Electric-Fusion-Welded	
	Classes 13, 23, 33, 43, 53	0.80
	Classes 12, 22, 32, 42, 52	1.00
ASTM A 672	Electric-Fusion-Welded	
	Classes 13, 23, 33, 43, 53	0.80
	Classes 12, 22, 32, 42, 52	1.00
ASTM A 691	Electric-Fusion-Welded	
	Classes 13, 23, 33, 43, 53	0.80
	Classes 12, 22, 32, 42, 52	1.00
ASTM A 984	Electric-Resistance-Welded	1.00
ASTM A 1005	Double Submerged-Arc-Welded	1.00
ASTM A 1006	Laser Beam Welded	1.00
API 5L	Electric Welded	1.00
	Seamless	1.00
	Submerged-Arc Welded (Longitudinal Seam or Helical Seam)	1.00
	Furnace-Butt Welded, Continuous Weld	0.60

GENERAL NOTE: Definitions for the various classes of welded pipe are given in para. 804.7.3.

Table 841.1.6-1 Basic Design Factor, *F*

Location Class	Design Factor, *F*
Location Class 1, Division 1	0.80
Location Class 1, Division 2	0.72
Location Class 2	0.60
Location Class 3	0.50
Location Class 4	0.40

Table 841.1.8-1 Temperature Derating Factor, *T*, for Steel Pipe

Temperature, °F (°C)	Temperature Derating Factor, *T*
250 (121) or less	1.000
300 (149)	0.967
350 (177)	0.933
400 (204)	0.900
450 (232)	0.867

GENERAL NOTE: For intermediate temperatures, interpolate for derating factor.

Table A-1 Carbon Steel

Spec. No.	Grade	Type or Class	Nominal Composition	P-No.	Notes	Specified Minimum Tensile, ksi	Specified Minimum Yield, ksi	E or F
Seamless Pipe and Tube								
A53	A	S	C	1	(2)	48	30	1.00
	B	S	C-Mn	1	(2)	60	35	1.00
A106	A	...	C-Si	1	(2)	48	30	1.00
	B	...	C-Si	1	(2)	60	35	1.00
	C	...	C-Si	1	(2)	70	40	1.00
A179	...	...	C	1	(1) (2) (5)	(47)	26	1.00
A192	...	...	C-Si	1	(2) (5)	(47)	26	1.00
A210	A-1	...	C-Si	1	(2)	60	37	1.00
	C	...	C-Mn-Si	1	(2)	70	40	1.00
A333	1	...	C-Mn	1	(1)	55	30	1.00
	6	...	C-Mn-Si	1	...	60	35	1.00
A369	FPA	...	C-Si	1	(2)	48	30	1.00
	FPB	...	C-Mn	1	(2)	60	35	1.00
API 5L	A	...	C	1	(1) (2) (14)	48	30	1.00
	B	...	C-Mn	1	(1) (2) (14)	60	35	1.00
Furnace Butt Welded Pipe								
A53	...	F	C	1	(4)	48	30	0.60
API 5L	A25	I & II	C	1	(1) (4) (14)	45	25	0.60
Electric Resistance Welded Pipe and Tube								
A53	A	E	C	1	(2)	48	30	0.85
	B	E	C-Mn	1	(2)	60	35	0.85
A135	A	...	C	1	(1) (2)	48	30	0.85
	B	...	C-Mn	1	(1) (2)	60	35	0.85
A178	A	...	C	1	(2) (5)	(47)	26	0.85
	C	...	C	1	(2)	60	37	0.85
A214	...	...	C	1	(1) (2) (5)	(47)	26	0.85
A333	1	...	C-Mn	1	(1)	55	30	0.85
	6	...	C-Mn-Si	1	...	60	35	0.85
API 5L	A25	I & II	C	1	(1) (14)	45	25	0.85
	A	...	C	1	(1) (2) (14)	48	30	0.85
	B	...	C-Mn	1	(1) (2) (14)	60	35	0.85
A587	...	...	C	1	(1) (2)	48	30	0.85

= 13 =

Table A-1 Carbon Steel (Cont'd)

Maximum Allowable Stress Values in Tension, ksi, for Metal Temperature, °F, Not Exceeding											
100	200	300	400	500	600	650	700	750	800	Grade	Spec. No.
Seamless Pipe and Tube											
13.7	13.7	13.7	13.7	13.7	13.7	13.7	12.5	10.7	9.0	A	A53
17.1	17.1	17.1	17.1	17.1	17.1	17.1	15.6	13.0	10.8	B	
13.7	13.7	13.7	13.7	13.7	13.7	13.7	12.5	10.7	9.3	A	A106
17.1	17.1	17.1	17.1	17.1	17.1	17.1	15.6	13.0	10.8	B	
20.0	20.0	20.0	20.0	20.0	20.0	19.8	18.3	14.8	12.0	C	
13.4	13.4	13.4	13.4	13.4	13.3	12.8	12.4	10.7	9.2	...	A179
13.4	13.4	13.4	13.4	13.4	13.3	12.8	12.4	10.7	9.0	...	A192
17.1	17.1	17.1	17.1	17.1	17.1	17.1	15.6	13.0	10.8	A-1	A210
20.0	20.0	20.0	20.0	20.0	20.0	19.8	18.3	14.8	12.0	C	
15.7	15.7	15.7	15.7	15.7	15.3	14.8	...	...	...	1	A333
17.1	17.1	17.1	17.1	17.1	17.1	17.1	15.6	...	...	6	
13.7	13.7	13.7	13.7	13.7	13.7	13.7	12.5	10.7	9.0	FPA	A369
17.1	17.1	17.1	17.1	17.1	17.1	17.1	15.6	13.0	10.8	FPB	
13.7	13.7	13.7	13.7	13.7	13.7	13.7	12.5	10.7	9.0	A	API 5L
17.1	17.1	17.1	17.1	17.1	17.1	17.1	15.6	13.0	10.8	B	
Furnace Butt Welded Pipe											
8.2	8.2	8.2	8.2	8.2	8.2	8.2	7.5	...	...	...	A53
7.7	7.7	7.7	7.7	...	...	...	...	...	...	A25	API 5L
Electric Resistance Welded Pipe and Tube											
11.7	11.7	11.7	11.7	11.7	11.7	11.7	10.6	9.1	7.7	A	A53
14.6	14.6	14.6	14.6	14.6	14.6	14.6	13.3	11.1	9.2	B	
11.7	11.7	11.7	11.7	11.7	11.7	11.7	10.6	9.1	7.9	A	A135
14.6	14.6	14.6	14.6	14.6	14.6	14.6	13.3	11.1	9.2	B	
11.4	11.4	11.4	11.4	11.4	11.3	10.9	10.5	9.1	7.7	A	A178
14.6	14.6	14.6	14.6	14.6	14.6	14.6	13.3	11.1	9.2	C	
11.4	11.4	11.4	11.4	11.4	11.3	10.9	10.5	9.1	7.8	...	A214
13.4	13.4	13.4	13.4	13.4	13.0	12.6	...	...	...	1	A333
14.6	14.6	14.6	14.6	14.6	14.6	14.6	13.3	...	...	6	
10.9	10.9	10.9	10.9	...	...	...	...	...	...	A25	API 5L
11.7	11.7	11.7	11.7	11.7	11.7	11.7	10.6	9.1	7.7	A	
14.6	14.6	14.6	14.6	14.6	14.6	14.6	13.3	11.1	9.2	B	
11.7	11.7	11.7	11.7	11.7	11.7	11.7	10.6	9.1	7.8	...	A587

Table A-1 Carbon Steel (Cont'd)

Spec. No.	Grade	Type or Class	Nominal Composition	P-No.	Notes	Specified Minimum Tensile, ksi	Specified Minimum Yield, ksi	E or F
Electric Fusion Welded Pipe — Filler Metal Added								
A134	A283A	...	C	1	(1) (7)	45	24	0.80
	A283B	...	C	1	(1) (7)	50	27	0.80
	A283C	...	C	1	(1) (7)	55	30	0.80
	A283D	...	C	1	(1) (7)	60	33	0.80
A134	A285A	...	C	1	(1) (2) (8)	45	24	0.80
	A285B	...	C	1	(1) (2) (8)	50	27	0.80
	A285C	...	C	1	(1) (2) (8)	55	30	0.80
A139	A	...	C	1	(1) (2) (14)	48	30	0.80
	B	...	C-Mn	1	(1) (2) (14)	60	35	0.80
API 5L	A	...	C	1	(1) (2) (14)	48	30	0.90
	B	...	C-Mn	1	(1) (2) (14)	60	35	0.90
A671	CA55	10,13	C	1	(1) (2) (15)	55	30	0.90
	CA55	11,12	C	1	(1) (2) (15)	55	30	1.00
	CA55	20,23,30,33	C	1	(1) (2)	55	30	0.90
	CA55	21,22,31,32	C	1	(1) (2)	55	30	1.00
A671	CB60	10,13	C-Si	1	(1) (2) (15)	60	32	0.90
	CB60	11,12	C-Si	1	(1) (2) (15)	60	32	1.00
	CB60	20,23,30,33	C-Si	1	(1) (2)	60	32	0.90
	CB60	21,22,31,32	C-Si	1	(1) (2)	60	32	1.00
A671	CB65	10,13	C-Si	1	(1) (2) (15)	65	35	0.90
	CB65	11,12	C-Si	1	(1) (2) (15)	65	35	1.00
	CB65	20,23,30,33	C-Si	1	(1) (2)	65	35	0.90
	CB65	21,22,31,32	C-Si	1	(1) (2)	65	35	1.00
A671	CB70	10,13	C-Si	1	(1) (2) (15)	70	38	0.90
	CB70	11,12	C-Si	1	(1) (2) (15)	70	38	1.00
	CB70	20,23,30,33	C-Si	1	(1) (2)	70	38	0.90
	CB70	21,22,31,32	C-Si	1	(1) (2)	70	38	1.00
A671	CC60	10,13	C-Mn-Si	1	(1) (2) (15)	60	32	0.90
	CC60	11,12	C-Mn-Si	1	(1) (2) (15)	60	32	1.00
	CC60	20,23,30,33	C-Mn-Si	1	(1) (2)	60	32	0.90
	CC60	21,22,31,32	C-Mn-Si	1	(1) (2)	60	32	1.00
A671	CC65	10,13	C-Mn-Si	1	(1) (2) (15)	65	35	0.90
	CC65	11,12	C-Mn-Si	1	(1) (2) (15)	65	35	1.00
	CC65	20,23,30,33	C-Mn-Si	1	(1) (2)	65	35	0.90
	CC65	21,22,31,32	C-Mn-Si	1	(1) (2)	65	35	1.00
A671	CC70	10,13	C-Mn-Si	1	(1) (2) (15)	70	38	0.90
	CC70	11,12	C-Mn-Si	1	(1) (2) (15)	70	38	1.00
	CC70	20,23,30,33	C-Mn-Si	1	(1) (2)	70	38	0.90
	CC70	21,22,31,32	C-Mn-Si	1	(1) (2)	70	38	1.00

Table A-1 Carbon Steel (Cont'd)

Maximum Allowable Stress Values in Tension, ksi, for Metal Temperature, °F, Not Exceeding											
100	200	300	400	500	600	650	700	750	800	Grade	Spec. No.
							Electric Fusion Welded Pipe — Filler Metal Added				
10.3	10.3	10.3	10.3	10.3	9.8	9.5	...	...	...	A283A	A134
11.4	11.4	11.4	11.4	11.4	11.0	10.7	...	...	...	A283B	
12.6	12.6	12.6	12.6	12.6	12.3	11.9	...	...	...	A283C	
13.7	13.7	13.7	13.7	13.7	13.5	13.0	...	...	...	A283D	
10.3	10.3	10.3	10.3	10.3	9.8	9.5	9.2	8.6	6.6	A285A	A134
11.4	11.4	11.4	11.4	11.4	11.0	10.7	10.0	8.8	6.5	A285B	
12.6	12.6	12.6	12.6	12.6	12.3	11.9	11.5	10.4	8.6	A285C	
11.0	11.0	11.0	11.0	11.0	11.0	11.0	10.0	8.6	7.4	A	A139
13.7	13.7	13.7	13.7	13.7	13.7	13.7	12.5	10.4	8.6	B	
12.3	12.3	12.3	12.3	12.3	12.3	12.3	11.3	9.6	8.3	A	API 5L
15.4	15.4	15.4	15.4	15.4	15.4	15.4	14.0	11.7	9.7	B	
14.1	14.1	14.1	14.1	14.1	13.8	13.3	12.9	11.7	9.7	CA55	A671
15.7	15.7	15.7	15.7	15.7	15.3	14.8	14.3	13.0	10.8	CA55	
14.1	14.1	14.1	14.1	14.1	13.8	13.3	12.9	11.7	9.7	CA55	
15.7	15.7	15.7	15.7	15.7	15.3	14.8	14.3	13.0	10.8	CA55	
15.4	15.4	15.4	15.4	15.4	14.7	14.2	13.7	11.7	9.7	CB60	A671
17.1	17.1	17.1	17.1	17.1	16.4	15.8	15.3	13.0	10.8	CB60	
15.4	15.4	15.4	15.4	15.4	14.7	14.2	13.7	11.7	9.7	CB60	
17.1	17.1	17.1	17.1	17.1	16.4	15.8	15.3	13.0	10.8	CB60	
16.7	16.7	16.7	16.7	16.7	16.1	15.6	15.0	12.5	10.3	CB65	A671
18.6	18.6	18.6	18.6	18.6	17.9	17.3	16.7	13.9	11.4	CB65	
16.7	16.7	16.7	16.7	16.7	16.1	15.6	15.0	12.5	10.3	CB65	
18.6	18.6	18.6	18.6	18.6	17.9	17.3	16.7	13.9	11.4	CB65	
18.0	18.0	18.0	18.0	18.0	17.5	16.9	16.3	13.3	10.8	CB70	A671
20.0	20.0	20.0	20.0	20.0	19.4	18.8	18.1	14.8	12.0	CB70	
18.0	18.0	18.0	18.0	18.0	17.5	16.9	16.3	13.3	10.8	CB70	
20.0	20.0	20.0	20.0	20.0	19.4	18.8	18.1	14.8	12.0	CB70	
15.4	15.4	15.4	15.4	15.4	14.7	14.2	13.7	11.7	9.7	CC60	A671
17.1	17.1	17.1	17.1	17.1	16.4	15.8	15.3	13.0	10.8	CC60	
15.4	15.4	15.4	15.4	15.4	14.7	14.2	13.7	11.7	9.7	CC60	
17.1	17.1	17.1	17.1	17.1	16.4	15.8	15.3	13.0	10.8	CC60	
16.7	16.7	16.7	16.7	16.7	16.1	15.6	15.0	12.5	10.3	CC65	A671
18.6	18.6	18.6	18.6	18.6	17.9	17.3	16.7	13.9	11.4	CC65	
16.7	16.7	16.7	16.7	16.7	16.1	15.6	15.0	12.5	10.3	CC65	
18.6	18.6	18.6	18.6	18.6	17.9	17.3	16.7	13.9	11.4	CC65	
18.0	18.0	18.0	18.0	18.0	17.5	16.9	16.3	13.3	10.8	CC70	A671
20.0	20.0	20.0	20.0	20.0	19.4	18.8	18.1	14.8	12.0	CC70	
18.0	18.0	18.0	18.0	18.0	17.5	16.9	16.3	13.3	10.8	CC70	
20.0	20.0	20.0	20.0	20.0	19.4	18.8	18.1	14.8	12.0	CC70	

Table A-1 Carbon Steel (Cont'd)

Spec. No.	Grade	Type or Class	Nominal Composition	P-No.	Notes	Specified Minimum Tensile, ksi	Specified Minimum Yield, ksi	E or F
Electric Fusion Welded Pipe — Filler Metal Added (Cont'd)								
A671	CK75	10,13	C-Mn-Si	1	(1) (2) (15)	75	42	0.90
	CK75	11,12	C-Mn-Si	1	(1) (2) (15)	75	42	1.00
	CK75	20,23,30,33	C-Mn-Si	1	(1) (2)	75	40	0.90
	CK75	21,22,31,32	C-Mn-Si	1	(1) (2)	75	40	1.00
A671	CD70	10,13	C-Mn-Si	1	(1) (2) (15)	70	50	0.90
	CD70	11,12	C-Mn-Si	1	(1) (2) (15)	70	50	1.00
	CD70	20,23,30,33	C-Mn-Si	1	(1) (3)	70	50	0.90
	CD70	21,22,31,32	C-Mn-Si	1	(1) (3)	70	50	1.00
A671	CD80	10,13	C-Mn-Si	1	(1) (15)	80	60	0.90
	CD80	11,12	C-Mn-Si	1	(1) (15)	80	60	1.00
	CD80	20,23	C-Mn-Si	1	(1) (3)	80	60	0.90
	CD80	21,22	C-Mn-Si	1	(1) (3)	80	60	1.00
A672	A45	10,13	C	1	(1) (2) (15)	45	24	0.90
	A45	11,12	C	1	(1) (2) (15)	45	24	1.00
	A45	20,23,30,33	C	1	(1) (2)	45	24	0.90
	A45	21,22,31,32	C	1	(1) (2)	45	24	1.00
A672	A50	10,13	C	1	(1) (2) (15)	50	27	0.90
	A50	11,12	C	1	(1) (2) (15)	50	27	1.00
	A50	20,23,30,33	C	1	(1) (2)	50	27	0.90
	A50	21,22,31,32	C	1	(1) (2)	50	27	1.00
A672	A55	10,13	C	1	(1) (2) (15)	55	30	0.90
	A55	11,12	C	1	(1) (2) (15)	55	30	1.00
	A55	20,23,30,33	C	1	(1) (2)	55	30	0.90
	A55	21,22,31,32	C	1	(1) (2)	55	30	1.00
A672	B55	10,13	C	1	(1) (2) (15)	55	30	0.90
	B55	11,12	C	1	(1) (2) (15)	55	30	1.00
	B55	20,23,30,33	C	1	(1) (2)	55	30	0.90
	B55	21,22,31,32	C	1	(1) (2)	55	30	1.00
A672	B60	10,13	C	1	(1) (2) (15)	60	32	0.90
	B60	11,12	C	1	(1) (2) (15)	60	32	1.00
	B60	20,23,30,33	C	1	(1) (2)	60	32	0.90
	B60	21,22,31,32	C	1	(1) (2)	60	32	1.00
A672	B65	10,13	C	1	(1) (2) (15)	65	35	0.90
	B65	11,12	C	1	(1) (2) (15)	65	35	1.00
	B65	20,23,30,33	C	1	(1) (2)	65	35	0.90
	B65	21,22,31,32	C	1	(1) (2)	65	35	1.00
A672	B70	10,13	C	1	(1) (2) (15)	70	38	0.90
	B70	11,12	C	1	(1) (2) (15)	70	38	1.00
	B70	20,23,30,33	C	1	(1) (2)	70	38	0.90
	B70	21,22,31,32	C	1	(1) (2)	70	38	1.00

Table A-1 Carbon Steel (Cont'd)

Maximum Allowable Stress Values in Tension, ksi, for Metal Temperature, °F, Not Exceeding											
100	**200**	**300**	**400**	**500**	**600**	**650**	**700**	**750**	**800**	**Grade**	**Spec. No.**
						Electric Fusion Welded Pipe — Filler Metal Added (Cont'd)					
19.3	19.3	19.3	19.3	19.3	19.3	18.7	17.6	*14.1*	*11.3*	CK75	A671
21.4	21.4	21.4	21.4	21.4	21.4	20.8	19.6	*15.7*	*12.6*	CK75	
19.3	19.3	19.3	19.3	19.3	18.4	17.8	17.2	*14.1*	*11.3*	CK75	
21.4	21.4	21.4	21.4	21.4	20.4	19.8	19.1	*15.7*	*12.6*	CK75	
18.0	18.0	17.7	17.6	17.6	17.6	17.6	...	...	...	CD70	A671
20.0	20.0	19.7	19.5	19.5	19.5	19.5	...	...	...	CD70	
18.0	18.0	17.7	17.6	17.6	17.6	17.6	...	...	...	CD70	
20.0	20.0	19.7	19.5	19.5	19.5	19.5	...	...	...	CD70	
20.6	20.6	20.3	20.1	20.1	20.1	20.1	...	...	...	CD80	A671
22.9	22.9	22.6	22.3	22.3	22.3	22.3	...	...	...	CD80	
20.6	20.6	20.3	20.1	20.1	20.1	20.1	...	...	...	CD80	
22.9	22.9	22.6	22.3	22.3	22.3	22.3	...	...	...	CD80	
11.6	11.6	11.6	11.6	11.6	11.0	10.7	10.3	*9.6*	*8.1*	A45	A672
12.9	12.9	12.9	12.9	12.9	12.3	11.9	11.5	*10.7*	*9.0*	A45	
11.6	11.6	11.6	11.6	11.6	11.0	10.7	10.3	*9.6*	*8.1*	A45	
12.9	12.9	12.9	12.9	12.9	12.3	11.9	11.5	*10.7*	*9.0*	A45	
12.9	12.9	12.9	12.9	12.9	12.4	12.0	*11.3*	*10.1*	*8.6*	A50	A672
14.3	14.3	14.3	14.3	14.3	13.8	13.3	*12.5*	*11.2*	*9.6*	A50	
12.9	12.9	12.9	12.9	12.9	12.4	12.0	*11.3*	*10.1*	*8.6*	A50	
14.3	14.3	14.3	14.3	14.3	13.8	13.3	*12.5*	*11.2*	*9.6*	A50	
14.1	14.1	14.1	14.1	14.1	13.8	13.3	12.9	*10.9*	*9.2*	A55	A672
15.7	15.7	15.7	15.7	15.7	15.3	14.8	14.3	*12.1*	*10.2*	A55	
14.1	14.1	14.1	14.1	14.1	13.8	13.3	12.9	*10.9*	*9.2*	A55	
15.7	15.7	15.7	15.7	15.7	15.3	14.8	14.3	*12.1*	*10.2*	A55	
14.1	14.1	14.1	14.1	14.1	13.8	13.3	12.9	*10.9*	*9.2*	B55	A672
15.7	15.7	15.7	15.7	15.7	15.3	14.8	14.3	*12.1*	*10.2*	B55	
14.1	14.1	14.1	14.1	14.1	13.8	13.3	12.9	*10.9*	*9.2*	B55	
15.7	15.7	15.7	15.7	15.7	15.3	14.8	14.3	*12.1*	*10.2*	B55	
15.4	15.4	15.4	15.4	15.4	14.7	14.2	13.7	*11.7*	*9.7*	B60	A672
17.1	17.1	17.1	17.1	17.1	16.4	15.8	15.3	*13.0*	*10.8*	B60	
15.4	15.4	15.4	15.4	15.4	14.7	14.2	13.7	*11.7*	*9.7*	B60	
17.1	17.1	17.1	17.1	17.1	16.4	15.8	15.3	*13.0*	*10.8*	B60	
16.7	16.7	16.7	16.7	16.7	16.1	15.6	15.0	*12.5*	*10.3*	B65	A672
18.6	18.6	18.6	18.6	18.6	17.9	17.3	16.7	*13.9*	*11.4*	B65	
16.7	16.7	16.7	16.7	16.7	16.1	15.6	15.0	*12.5*	*10.3*	B65	
18.6	18.6	18.6	18.6	18.6	17.9	17.3	16.7	*13.9*	*11.4*	B65	
18.0	18.0	18.0	18.0	18.0	17.5	16.9	16.3	*13.3*	*10.8*	B70	A672
20.0	20.0	20.0	20.0	20.0	19.4	18.8	18.1	*14.8*	*12.0*	B70	
18.0	18.0	18.0	18.0	18.0	17.5	16.9	16.3	*13.3*	*10.8*	B70	
20.0	20.0	20.0	20.0	20.0	19.4	18.8	18.1	*14.8*	*12.0*	B70	

Table A-1 Carbon Steel (Cont'd)

Spec. No.	Grade	Type or Class	Nominal Composition	P-No.	Notes	Specified Minimum Tensile, ksi	Specified Minimum Yield, ksi	E or F
Electric Fusion Welded Pipe — Filler Metal Added (Cont'd)								
A672	C55	10,13	C	1	(1) (2) (15)	55	30	0.90
	C55	11,12	C	1	(1) (2) (15)	55	30	1.00
	C55	20,23,30,33	C	1	(1) (2)	55	30	0.90
	C55	21,22,31,32	C	1	(1) (2)	55	30	1.00
A672	C60	10,13	C	1	(1) (2) (15)	60	32	0.90
	C60	11,12	C	1	(1) (2) (15)	60	32	1.00
	C60	20,23,30,33	C	1	(1) (2)	60	32	0.90
	C60	21,22,31,32	C	1	(1) (2)	60	32	1.00
A672	C65	10,13	C	1	(1) (2) (15)	65	35	0.90
	C65	11,12	C	1	(1) (2) (15)	65	35	1.00
	C65	20,23,30,33	C	1	(1) (2)	65	35	0.90
	C65	21,22,31,32	C	1	(1) (2)	65	35	1.00
A672	C70	10,13	C	1	(1) (2) (15)	70	38	0.90
	C70	11,12	C	1	(1) (2) (15)	70	38	1.00
	C70	20,23,30,33	C	1	(1) (2)	70	38	0.90
	C70	21,22,31,32	C	1	(1) (2)	70	38	1.00
A672	D70	10,13	C-Mn-Si	1	(1) (15)	70	50	0.90
	D70	11,12	C-Mn-Si	1	(1) (15)	70	50	1.00
	D70	20,23,30,33	C-Mn-Si	1	(1) (3)	70	50	0.90
	D70	21,22,31,32	C-Mn-Si	1	(1) (3)	70	50	1.00
A672	D80	10,13	C-Mn-Si	1	(1) (15)	80	60	0.90
	D80	11,12	C-Mn-Si	1	(1) (15)	80	60	1.00
	D80	20,23	C-Mn-Si	1	(1) (3)	80	60	0.90
	D80	21,22	C-Mn-Si	1	(1) (3)	80	60	1.00
A672	N75	10,13	C-Mn-Si	1	(1) (2) (15)	75	42	0.90
	N75	11,12	C-Mn-Si	1	(1) (2) (15)	75	42	1.00
	N75	20,23,30,33	C-Mn-Si	1	(1) (2)	75	40	0.90
	N75	21,22,31,32	C-Mn-Si	1	(1) (2)	75	40	1.00
A691	CMSH-70	10,13	C-Mn-Si	1	(1) (15)	70	50	0.90
	CMSH-70	11,12	C-Mn-Si	1	(1) (15)	70	50	1.00
	CMSH-70	20,23,30,33	C-Mn-Si	1	(1) (3)	70	50	0.90
	CMSH-70	21,22,31,32	C-Mn-Si	1	(1) (3)	70	50	1.00
A691	CMSH-80	10,13	C-Mn-Si	1	(1) (15)	80	60	0.90
	CMSH-80	11,12	C-Mn-Si	1	(1) (15)	80	60	1.00
	CMSH-80	20,23	C-Mn-Si	1	(1) (3)	80	60	0.90
	CMSH-80	21,22	C-Mn-Si	1	(1) (3)	80	60	1.00
A691	CMS-75	10,13	C-Mn-Si	1	(1) (2) (15)	75	42	0.90
	CMS-75	11,12	C-Mn-Si	1	(1) (2) (15)	75	42	1.00
	CMS-75	20,23,30,33	C-Mn-Si	1	(1) (2)	75	40	0.90
	CMS-75	21,22,31,32	C-Mn-Si	1	(1) (2)	75	40	1.00

Table A-1 Carbon Steel (Cont'd)

Maximum Allowable Stress Values in Tension, ksi, for Metal Temperature, °F, Not Exceeding											
100	200	300	400	500	600	650	700	750	800	Grade	Spec. No.
					Electric Fusion Welded Pipe — Filler Metal Added (Cont'd)						
14.1	14.1	14.1	14.1	14.1	13.8	13.3	12.9	*10.9*	*9.2*	C55	A672
15.7	15.7	15.7	15.7	15.7	15.3	14.8	14.3	*12.1*	*10.2*	C55	
14.1	14.1	14.1	14.1	14.1	13.8	13.3	12.9	*10.9*	*9.2*	C55	
15.7	15.7	15.7	15.7	15.7	15.3	14.8	14.3	*12.1*	*10.2*	C55	
15.4	15.4	15.4	15.4	15.4	14.7	14.2	13.7	*11.7*	*9.7*	C60	A672
17.1	17.1	17.1	17.1	17.1	16.4	15.8	15.3	*13.0*	*10.8*	C60	
15.4	15.4	15.4	15.4	15.4	14.7	14.2	13.7	*11.7*	*9.7*	C60	
17.1	17.1	17.1	17.1	17.1	16.4	15.8	15.3	*13.0*	*10.8*	C60	
16.7	16.7	16.7	16.7	16.7	16.1	15.6	15.0	*12.5*	*10.3*	C65	A672
18.6	18.6	18.6	18.6	18.6	17.9	17.3	16.7	*13.9*	*11.4*	C65	
16.7	16.7	16.7	16.7	16.7	16.1	15.6	15.0	*12.5*	*10.3*	C65	
18.6	18.6	18.6	18.6	18.6	17.9	17.3	16.7	*13.9*	*11.4*	C65	
18.0	18.0	18.0	18.0	18.0	17.5	16.9	16.3	*13.3*	*10.8*	C70	A672
20.0	20.0	20.0	20.0	20.0	19.4	18.8	18.1	*14.8*	*12.0*	C70	
18.0	18.0	18.0	18.0	18.0	17.5	16.9	16.3	*13.3*	*10.8*	C70	
20.0	20.0	20.0	20.0	20.0	19.4	18.8	18.1	*14.8*	*12.0*	C70	
18.0	18.0	17.7	17.6	17.6	17.6	17.6	...	...	...	D70	A672
20.0	20.0	19.7	19.5	19.5	19.5	19.5	...	...	...	D70	
18.0	18.0	17.7	17.6	17.6	17.6	17.6	...	...	...	D70	
20.0	20.0	19.7	19.5	19.5	19.5	19.5	...	...	...	D70	
20.6	20.6	20.3	20.1	20.1	20.1	20.1	...	...	...	D80	A672
22.9	22.9	22.6	22.3	22.3	22.3	22.3	...	...	...	D80	
20.6	20.6	20.3	20.1	20.1	20.1	20.1	...	...	...	D80	
22.9	22.9	22.6	22.3	22.3	22.3	22.3	...	...	...	D80	
19.3	19.3	19.3	19.3	19.3	18.4	17.8	17.2	*14.1*	*11.3*	N75	A672
21.4	21.4	21.4	21.4	21.4	20.4	19.8	19.1	*15.7*	*12.6*	N75	
19.3	19.3	19.3	19.3	19.3	18.4	17.8	17.2	*14.1*	*11.3*	N75	
21.4	21.4	21.4	21.4	21.4	20.4	19.8	19.1	*15.7*	*12.6*	N75	
18.0	18.0	17.7	17.6	17.6	17.6	17.6	...	...	...	CMSH-70	A691
20.0	20.0	19.7	19.5	19.5	19.5	19.5	...	...	...	CMSH-70	
18.0	18.0	17.7	17.6	17.6	17.6	17.6	...	...	...	CMSH-70	
20.0	20.0	19.7	19.5	19.5	19.5	19.5	...	...	...	CMSH-70	
20.6	20.6	20.3	20.1	20.1	20.1	20.1	...	...	...	CMSH-80	A691
22.9	22.9	22.6	22.3	22.3	22.3	22.3	...	...	...	CMSH-80	
20.6	20.6	20.3	20.1	20.1	20.1	20.1	...	...	...	CMSH-80	
22.9	22.9	22.6	22.3	22.3	22.3	22.3	...	...	...	CMSH-80	
19.3	19.3	19.3	19.3	19.3	18.4	17.8	17.2	*14.1*	*11.3*	CMS-75	A691
21.4	21.4	21.4	21.4	21.4	20.4	19.8	19.1	*15.7*	*12.6*	CMS-75	
19.3	19.3	19.3	19.3	19.3	18.4	17.8	17.2	*14.1*	*11.3*	CMS-75	
21.4	21.4	21.4	21.4	21.4	20.4	19.8	19.1	*15.7*	*12.6*	CMS-75	

Table A-1 Carbon Steel (Cont'd)

Spec. No.	Grade	Type or Class	Nominal Composition	P-No.	Notes	Specified Minimum Tensile, ksi	Specified Minimum Yield, ksi	E or F
Copper Brazed Tubing								
A254	...	...	C	...	(1) (9) (10)	42	25	1.00
Plate								
A36	...	...	C-Mn-Si	1	(1) (7) (11)	58	36	0.92
A283	A	...	C	1	(1) (7)	45	24	0.92
	B	...	C	1	(1) (7)	50	27	0.92
	C	...	C	1	(1) (7)	55	30	0.92
	D	...	C	1	(1) (7)	60	33	0.92
A285	A	...	C	1	(2)	45	24	1.00
	B	...	C	1	(2)	50	27	1.00
	C	...	C	1	(2)	55	30	1.00
A299	...	...	C-Mn-Si	1	(2) (13)	75	40	1.00
	...	...	C-Mn-Si	1	(2) (12)	75	42	1.00
A515	60	...	C-Si	1	(2)	60	32	1.00
	65	...	C-Si	1	(2)	65	35	1.00
	70	...	C-Si	1	(2)	70	38	1.00
A516	55	...	C-Si	1	(2)	55	30	1.00
	60	...	C-Mn-Si	1	(2)	60	32	1.00
	65	...	C-Mn-Si	1	(2)	65	35	1.00
	70	...	C-Mn-Si	1	(2)	70	38	1.00
Forgings								
A105	...	...	C-Si	1	(2)	70	36	1.00
A181	...	60	C-Si	1	(2)	60	30	1.00
	...	70	C-Si	1	(2)	70	36	1.00
A350	LF2	1	C-Mn-Si	1	(2)	70	36	1.00
	LF2	2	C-Mn-Si	1	(2)	70	36	1.00
Wrought Fittings (Seamless and Welded)								
A234	WPB	...	C-Si	1	(2)	60	35	1.00
	WPC	...	C-Si	1	(2)	70	40	1.00
Castings								
A216	WCA	...	C-Si	1	(2) (6)	60	30	0.80
	WCB	...	C-Si	1	(2) (6)	70	36	0.80
	WCC	...	C-Mn-Si	1	(2) (6)	70	40	0.80
Bars and Shapes								
A36	...	...	C-Mn-Si	1	(1) (2)	58	36	1.00
A992	...	...	C-Mn-Si	1	(1) (2)	65	50	1.00

Table A-1 Carbon Steel (Cont'd)

Maximum Allowable Stress Values in Tension, ksi, for Metal Temperature, °F, Not Exceeding											
100	200	300	400	500	600	650	700	750	800	Grade	Spec. No.
										Copper Brazed Tubing	
6.0	5.5	4.8	3.0	...	...	...	...	...	...	...	A254
											Plate
15.2	15.2	15.2	15.2	15.2	15.2	15.2	...	...	...	...	A36
11.8	11.8	11.8	11.8	11.8	11.3	10.9	...	...	...	A	A283
13.1	13.1	13.1	13.1	13.1	12.7	12.3	...	...	...	B	
14.5	14.5	14.5	14.5	14.5	14.1	13.6	...	...	...	C	
15.8	15.8	15.8	15.8	15.8	15.5	15.0	...	...	...	D	
12.9	12.9	12.9	12.9	12.9	12.3	11.9	11.5	*10.7*	*8.3*	A	A285
14.3	14.3	14.3	14.3	14.3	13.8	13.3	*12.5*	*11.0*	*9.4*	B	
15.7	15.7	15.7	15.7	15.7	15.3	14.8	14.3	*13.0*	*10.8*	C	
21.4	21.4	21.4	21.4	21.4	20.4	19.8	19.1	*15.7*	*12.6*	...	A299
21.4	21.4	21.4	21.4	21.4	21.4	20.8	*19.6*	*15.7*	*12.6*	...	
17.1	17.1	17.1	17.1	17.1	16.4	15.8	15.3	*13.0*	*10.8*	60	A515
18.6	18.6	18.6	18.6	18.6	17.9	17.3	16.7	*13.9*	*11.4*	65	
20.0	20.0	20.0	20.0	20.0	19.4	18.8	18.1	*14.8*	*12.6*	70	
15.7	15.7	15.7	15.7	15.7	15.3	14.8	14.3	*13.0*	*10.8*	55	A516
17.1	17.1	17.1	17.1	17.1	16.4	15.8	15.3	*13.0*	*10.8*	60	
18.6	18.6	18.6	18.6	18.6	17.9	17.3	16.7	*13.9*	*11.4*	65	
20.0	20.0	20.0	20.0	20.0	19.4	18.8	18.1	*14.8*	*12.0*	70	
											Forgings
20.0	20.0	20.0	20.0	19.6	18.4	17.8	17.2	*14.8*	*12.0*	...	A105
17.1	17.1	17.1	17.1	16.3	15.3	14.8	14.3	*13.0*	*10.8*	...	A181
20.0	20.0	20.0	20.0	19.6	18.4	17.8	17.2	*14.8*	*12.0*	...	
20.0	20.0	20.0	20.0	19.6	18.4	17.8	17.2	*14.8*	*12.0*	LF2	A350
20.0	20.0	20.0	20.0	19.6	18.4	17.8	17.2	*14.8*	*12.0*	LF2	
								Wrought Fittings (Seamless and Welded)			
17.1	17.1	17.1	17.1	17.1	17.1	17.1	*15.6*	*13.0*	*10.8*	WPB	A234
20.0	20.0	20.0	20.0	20.0	20.0	19.8	*18.3*	*14.8*	*12.0*	WPC	
											Castings
13.7	13.7	13.7	13.7	13.0	12.2	11.8	11.4	*10.4*	*8.6*	WCA	A216
16.0	16.0	16.0	16.0	15.7	14.7	14.2	13.8	*11.8*	*9.6*	WCB	
16.0	16.0	16.0	16.0	16.0	16.0	15.8	*14.6*	*11.8*	*9.6*	WCC	
										Bars and Shapes	
16.6	16.6	16.6	16.6	16.6	16.6	16.6	*15.6*	*13.0*	*10.8*	...	A36
18.6	18.6	18.6	18.6	18.6	18.6	18.6	*16.9*	*13.9*	*11.4*	...	A992

Table A-1 Carbon Steel (Cont'd)

(18)

GENERAL NOTES:
(a) The tabulated specifications are ANSI/ASTM or ASTM, except API 5L. For ASME BPVC applications, see related specifications in ASME BPVC, Section II.
(b) The stress values in this Table may be interpolated to determine values for intermediate temperatures.
(c) The P-Numbers indicated in this Table are identical to those adopted by ASME BPVC. Qualification of welding procedures, welders, and welding operators is required and shall comply with ASME BPVC (Section IX) except as modified by para. 127.5.
(d) Tensile strengths and allowable stresses shown in "ksi" are "thousands of pounds per square inch."
(e) The materials listed in this Table shall not be used at design temperatures above those for which allowable stress values are given except as permitted by para. 122.6.2(g).
(f) The tabulated stress values are $S \times E$ (weld joint efficiency factor) or $S \times F$ (material quality factor), as applicable. Weld joint efficiency factors are shown in Table 102.4.3-1.
(g) Pressure–temperature ratings of piping components, as published in standards referenced in this Code, may be used for components meeting the requirements of those standards. The allowable stress values given in this Table are for use in designing piping components which are not manufactured in accordance with referenced standards.
(h) All the materials listed are classified as ferritic (see Table 104.1.2-1).
(i) The tabulated stress values that are shown in italics are at temperatures in the range where creep and stress rupture strength govern the selection of stresses.
(j) See para. 124.1.2 for lower temperature limits.

NOTES:
(1) THIS MATERIAL IS NOT ACCEPTABLE FOR CONSTRUCTION OF PRESSURE-RETAINING PARTS OF BOILER EXTERNAL PIPING — SEE FIGURE 100.1.2-1, FIGURE 100.1.2-2, FIGURE 100.1.2-3, FIGURE 100.1.2-4, FIGURE 100.1.2-5, FIGURE 100.1.2-6, AND FIGURE 100.1.2-7.
(2) Upon prolonged exposure to temperatures above 800°F (427°C), the carbide phase of carbon steel may be converted to graphite.
(3) The allowable stress values given are for pipe fabricated from plate not exceeding 2½ in. in thickness.
(4) This material shall not be used for flammable fluids. Refer to para. 105.2.1(a).
(5) Tensile value in parentheses is expected minimum.
(6) The 0.80 material quality factor for casting may be increased in accordance with para. 102.4.6.
(7) The stress values for structural quality plate include a material quality factor of 0.92. The allowable stresses for A283 Grade D and A36 plate have been limited to 12.7 ksi.
(8) These stress values are permitted only if killed or semikilled steels are used.
(9) A254 is copper brazed (not welded) steel pipe.
(10) For saturated steam at 250 psi (406°F), the values given for 400°F may be used.
(11) The allowable stress values listed in MSS SP-58 for this material may be used for pipe supporting elements designed in accordance with MSS SP-58.
(12) These values apply to material less than or equal to 1 in. thick.
(13) These values apply to material greater than 1 in. thick.
(14) This material is not listed in ASME BPVC, Section IX. However, weld procedures shall be qualified in accordance with the P-Number shown. See para. 127.5.1.
(15) This material shall not be used in nominal wall thicknesses exceeding ¾ in.
(16) These allowable stress values are for pipe made using a butt-welded joint process. Pipe made by other processes shall not be used.

Table 102.4.7-1 Weld Strength Reduction Factors to Be Applied When Calculating the Minimum Wall Thickness or Allowable Design Pressure of Components Fabricated With a Longitudinal Seam Fusion Weld

Steel Group	Weld Strength Reduction Factor for Temperature, °F (°C) [Notes (1)–(7)]										
	700 (371)	750 (399)	800 (427)	850 (454)	900 (482)	950 (510)	1,000 (538)	1,050 (566)	1,100 (593)	1,150 (621)	1,200 (649)
CrMo [Notes (8), (9), (10)]	...	...	1.00	0.95	0.91	0.86	0.82	0.77	0.73	0.68	0.64
CSEF (N+T) [Notes (8), (11), (12)]	...	...	...	...	...	1.00	0.95	0.91	0.86	0.82	0.77
CSEF (Sub Crit) [Notes (8), (13)]	...	...	...	...	1.00	0.50	0.50	0.50	0.50	0.50	0.50
Austenitic stainless (incl. 800H & 800HT) [Notes (14), (15)]	...	...	...	...	...	1.00	0.95	0.91	0.86	0.82	0.77
Autogenously welded austenitic stainless [Note (16)]	...	...	...	...	...	1.00	1.00	1.00	1.00	1.00	1.00

NOTES:

(1) NP = not permitted.

(2) Longitudinal welds in pipe for materials not covered in this Table operating in the creep regime are not permitted. For the purposes of this Table, the start of the creep range is the highest temperature where the nonitalicized stress values end in Mandatory Appendix A for the base material involved.

(3) All weld filler metal shall be a minimum of 0.05% C for CrMo and CSEF materials, and 0.04% C for austenitic stainless in this Table.

(4) Materials designed for temperatures below the creep range [see Note (2)] may be used without consideration of the WSRF or the rules of this Table. All other Code rules apply.

(5) Longitudinal seam welds in CrMo and CSEF materials shall be subjected to, and pass, a 100% volumetric examination (RT or UT). For materials other than CrMo and CSEF, see para. 123.4(b).

(6) At temperatures below those where WSRFs are tabulated, a value of 1.0 shall be used for the factor, *W*, where required by the rules of this Code Section. However, the additional rules of this Table and Notes do not apply.

(7) Carbon steel pipes and tubes are exempt from the requirements of para. 102.4.7 and this Table.

(8) Basicity index of SAW flux ≥ 1.0.

(9) The CrMo steels include ½Cr–½Mo, 1Cr–½Mo, 1¼Cr–½Mo–Si, 2¼Cr–1Mo, 3Cr–1Mo, and 5Cr–½Mo. Longitudinal welds shall be normalized, normalized and tempered, or subjected to proper subcritical PWHT for the alloy.

(10) Longitudinal seam fusion welded construction is not permitted for C–½Mo steel for operation in the creep range [see Notes (2) and (4)].

(11) The CSEF (creep strength enhanced ferritic) steels include Grades 91, 92, 911, 122, and 23.

(12) N+T = normalizing + tempering PWHT.

(13) Sub Crit = subcritical PWHT is required. No exemptions from PWHT are permitted. The PWHT time and temperature shall meet the requirements of Table 132.1.1-1; the alternate PWHT requirements of Table 132.1.1-2 are not permitted.

(14) WSRFs have been assigned for austenitic stainless (including 800H and 800HT) longitudinally welded pipe up to 1,500°F as follows:

Temperature, °F	Temperature, °C	Weld Strength Reduction Factor
1,250	677	0.73
1,300	704	0.68
1,350	732	0.64
1,400	760	0.59
1,450	788	0.55
1,500	816	0.5

(15) Certain heats of the austenitic stainless steels, particularly for those grades whose creep strength is enhanced by the precipitation of temper-resistant carbides and carbo-nitrides, can suffer from an embrittlement condition in the weld heat affected zone that can lead to premature failure of welded components operating at elevated temperatures. A solution annealing heat treatment of the weld area mitigates this susceptibility.

(16) Autogenous SS welded pipe (without weld filler metal) has been assigned a WSRF up to 1,500°F of 1.00, provided that the product is solution annealed after welding and receives nondestructive electric examination, in accordance with the material specification.

ASME B31.1-2018

Table 104.1.2-1 Values of *y*

Material	Temperature, °F (°C)							
	900 (482) and Below	950 (510)	1,000 (538)	1,050 (566)	1,100 (593)	1,150 (621)	1,200 (649)	1,250 (677) and Above
Ferritic steels	0.4	0.5	0.7	0.7	0.7	0.7	0.7	0.7
Austenitic steels	0.4	0.4	0.4	0.4	0.5	0.7	0.7	0.7
Nickel alloy UNS No. N06690	0.4	0.4	0.4	0.4	0.5	0.7	0.7	...
Nickel alloys UNS Nos. N06617, N08800, N08810, N08825	0.4	0.4	0.4	0.4	0.4	0.4	0.5	0.7
Cast iron	0.0	...	...	...	...	...	...	...
Other metals [Note (1)]	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4

GENERAL NOTES:

(a) The value of *y* may be interpolated between the 50°F (27.8°C) incremental values shown in the Table.

(b) For pipe with a D_o/t_m ratio less than 6, the value of *y* for ferritic and austenitic steels designed for temperatures of 900°F (480°C) and below shall be taken as

$$y = \frac{d}{d + D_o}$$

NOTE: (1) Metals listed in Mandatory Appendix A that are not covered by the categories of materials listed above.

AMERICAN STANDARD STEEL PIPE ASME B36.10

= 24 =

Nominal Size		Outside Diameter	Nominal Wall Thickness & Weight for Welded & Seamless Steel Pipe ASME B36.10										Dimensions (mm) Weight (kg/m)			
DN	NPS	mm	STD	EXTRA STRONG	XX STRONG	SCHED 10	SCHED 20	SCHED 30	SCHED 40	SCHED 60	SCHED 80	SCHED 100	SCHED 120	SCHED 140	SCHED 160
6	1/8	10.3	1.73 0.37	2.41 0.47	-	-	-	-	SAME AS STANDARD W.T. (Std. W.T.)	-	SAME AS EXTRA STRONG W.T. (X.S.)	-	-	-	-
8	1/4	13.7	2.24 0.63	3.02 0.80											
10	3/8	17.1	2.31 0.84	3.20 1.10	-	-	-	-		-		-	-	-	-
15	1/2	21.3	2.77 1.27	3.73 1.62	7.47 2.55										4.78 1.95
20	3/4	26.7	2.87 1.69	3.91 2.20	7.82 3.64	-	-	-		-		-	-	-	5.56 2.90
25	1	33.4	3.38 2.50	4.55 3.24	9.09 5.45										6.35 4.24
32	1-1/4	42.2	3.56 3.39	4.85 4.47	9.7 7.77	-	-	-		-		-	-	-	6.35 5.61
40	1-1/2	48.3	3.68 4.05	5.08 5.41	10.15 9.56										7.14 7.25
50	2	60.3	3.91 5.44	5.54 7.48	11.07 13.44	-	-	-		-		-	-	-	8.74 11.11
65	2-1/2	73.0	5.16 8.63	7.01 11.41	14.02 20.39										9.53 14.92
80	3	88.9	5.49 11.29	7.62 15.27	15.24 27.67	-	-	-		-		-	-	-	11.13 21.35
90	3-1/2	101.6	5.74 13.57	8.08 18.63											
100	4	114.3	6.02 16.07	8.56 22.32	17.12 41.03	-	-	-		-		-	11.13 28.32	-	13.49 33.54
125	5	141.3	6.55 21.77	9.53 30.97	19.05 57.43								12.7 40.28		15.88 49.11
150	6	168.3	7.11 28.26	10.97 42.56	21.95 79.22	-	-	-		-		-	14.27 54.20	-	18.26 67.56
200	8	219.1	8.18 42.55	12.7 64.64	22.23 107.92		6.35 33.31	7.04 36.81		10.31 53.08		15.09 75.92	18.26 90.44	20.62 100.92	23.01 111.27
250	10	273.1	9.27 60.31	12.7 81.55	25.4 155.15	-	6.35 41.77	7.8 51.03		XS 81.55	15.09 96.01	18.26 114.75	21.44 133.06	XXS 155.15	28.58 172.33
300	12	323.9	9.53 73.88	12.7 97.46	25.4 186.97		6.35 49.73	8.38 65.20	10.31 79.73	14.27 108.96	17.48 132.08	21.44 159.91	XXS 186.97	28.58 208.14	33.32 238.76
350	14	355.6	9.53 81.33	12.7 107.10	-	6.35 54.59	7.92 67.90	Std.W.T. 81.33	11.13 94.55	15.09 126.70	19.05 158.10	23.83 194.96	27.79 224.65	31.75 253.56	35.71 281.70
400	16	406.4	9.53 93.27	12.7 123.30		6.35 62.64	7.92 77.83	Std.W.T. 93.27	XS 123.30	16.66 160.12	21.44 203.53	26.19 245.56	30.96 286.64	36.53 333.19	40.49 365.35
450	18	457	9.53 105.16	12.7 139.15	-	6.35 70.57	7.92 87.71	11.13 122.38	14.27 155.80	19.05 205.74	23.83 254.55	29.36 309.62	34.93 363.56	39.67 408.26	45.24 459.37
500	20	508	9.53 117.15	12.7 155.12		6.35 78.55	Std.W.T. 117.15	XS 155.12	15.09 183.42	20.62 247.83	26.19 311.17	32.54 381.53	38.1 441.49	44.45 508.11	50.01 564.81
550	22	559	9.53 129.13	12.7 171.09	-	6.35 86.54	Std.W.T. 129.13	XS 171.09	-	22.23 294.25	28.58 373.83	34.93 451.42	41.28 527.05	47.63 600.63	53.98 672.26
600	24	610	9.53 141.12	12.7 187.06		6.35 94.53	Std.W.T. 141.12	14.27 209.64	17.48 255.41	24.61 355.26	30.96 442.08	38.89 547.71	46.02 640.03	52.37 720.15	59.54 808.22
650	26	660	9.53 152.87	12.7 202.72	-	7.92 127.36	XS 202.72	-	-	-	-	-	-	-	-
700	28	711	9.53 164.85	12.7 218.69		7.92 137.32	XS 218.69	15.88 271.21							
750	30	762	9.53 176.84	12.7 234.67	-	7.92 147.28	XS 234.67	15.88 292.18	-	-	-	-	-	-	-
800	32	813	9.53 188.82	12.7 250.64		7.92 157.24	XS 250.64	15.88 312.15	17.48 342.91						
850	34	864	9.53 200.31	12.7 266.61	-	7.92 167.20	XS 266.61	15.88 332.12	17.48 364.90	-	-	-	-	-	-
900	36	914	9.53 212.56	12.7 282.27		7.92 176.96	XS 282.27	15.88 351.7	19.05 420.42						
1050	42	1067	9.53 248.52	12.7 330.19	-	-	-	-	-	-	-	-	-	-	-

Formula used to attain approximate mass in kilograms per metre (kg/m) for Steel Round Pipe and Tubing

$m = (D - t)\, t \times 0.02466$

Where: m = mass to the nearest 0.01 kg/m
D = Outside Diameter in millimetres
(To nearest 0.1mm for OD up to 406.4mm)
(To nearest 1.0mm for OD 457mm and above)
t = Wall Thickness to nearest 0.01mm

EXAMPLE: Nominal Size DN300 NPS12, OD = 323.9mm, W.T. = 9.53mm

Step 1: 323.9 − 9.53 = 314.37
Step 2: 314.37 x 9.53 = 2995.9461
Step 3: 2995.9461 x 0.02466 = 73.88kg/m

Table 1: Friction factors for Darcy-Weisbach equation

Laminar	$f = 64/Re$	$Re < 2100$
Smooth pipe	$1/\sqrt{f} = 2\log_{10}\left(Re\sqrt{f}\right) - 0.8$	$Re > 4000$ and $e/D \to 0$
Transitional Colebrook-White Eq.	$\dfrac{1}{\sqrt{f}} = 1.14 - 2\log_{10}\left(\dfrac{e}{D} + \dfrac{9.35}{Re\sqrt{f}}\right)$	$Re > 4000$
Wholly Rough	$\dfrac{1}{\sqrt{f}} = 1.14 - 2\log_{10}\left(\dfrac{e}{D}\right)$	$Re > 4000$

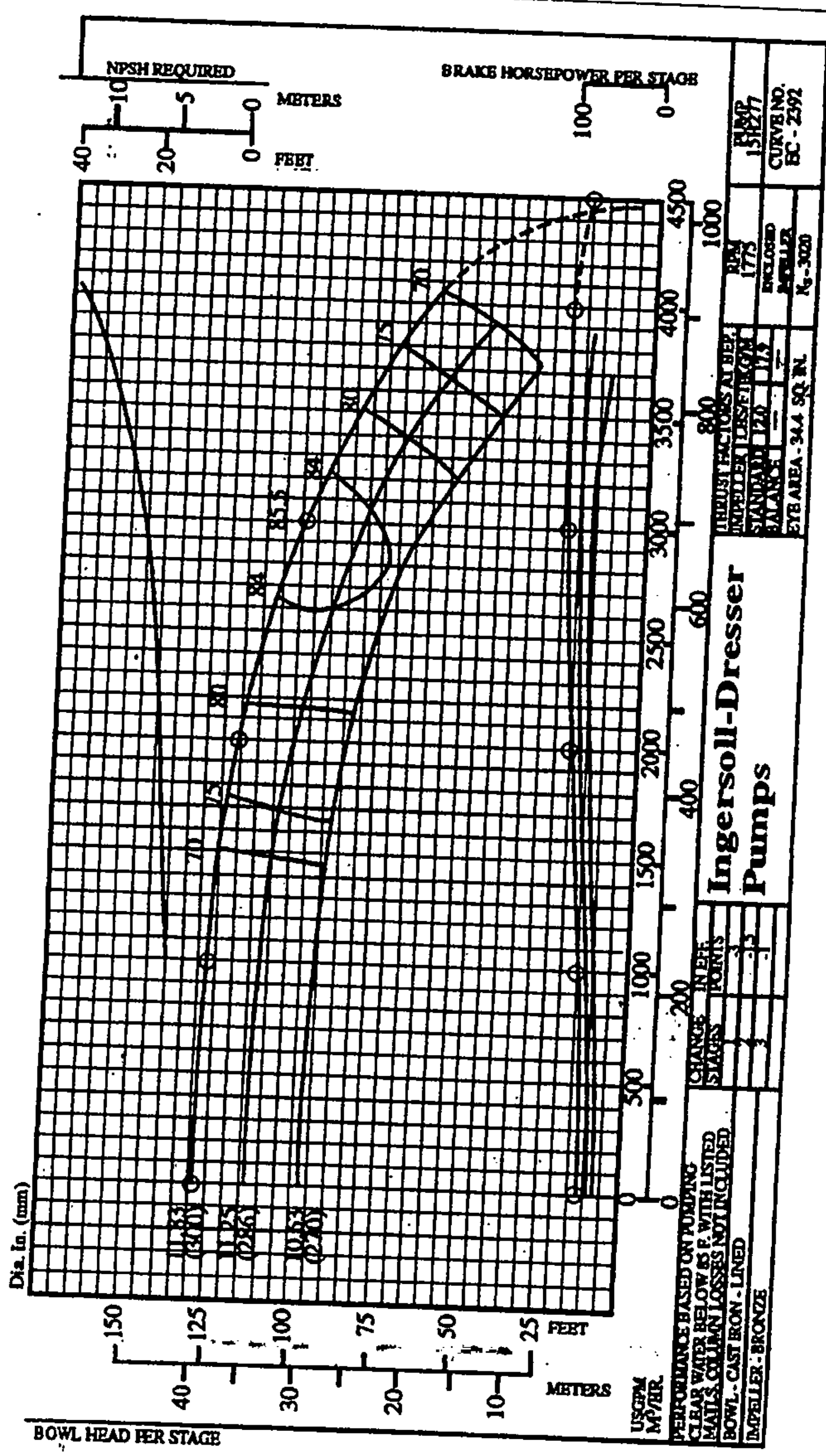


Fig. for Q. 6(a)

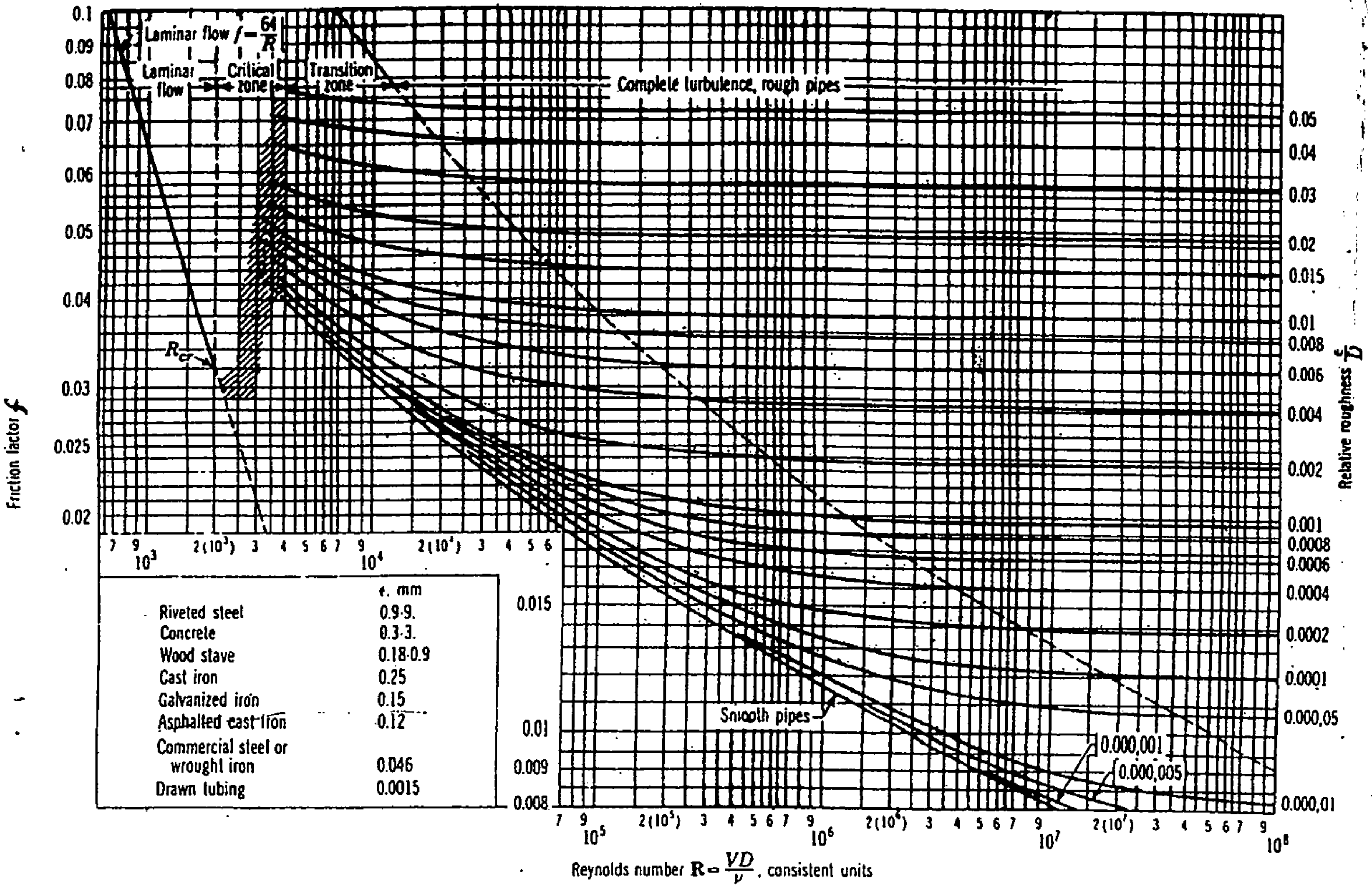


Figure Moody diagram.

L-4/T-2/ME Date: ~~27/04/2024~~ 18/05/2024

BANGLADESH UNIVERSITY OF ENGINEERING AND TECHNOLOGY, DHAKA

L-4/T-2 B. Sc. Engineering Examinations 2021-2022

Sub: **ME 427** (Applied Engineering Mathematics)

Full Marks: 210 Time: 3 Hours

The figures in the margin indicate full marks.

Symbols have their usual meaning.

USE SEPARATE SCRIPTS FOR EACH SECTION

SECTION – A

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

1. (a) With neat sketches, describe the details of the following finite elements: **(17)**

(i) Pipe-flow element, (ii) Shaft element

Derive the following element stiffness matrix equations:

(i) Pipe-flow element by direct approach

(ii) Shaft element by minimum potential energy method

(b) Suggest a set of shape functions suitable for a quadratic bar element. For the element, mathematically show the following: **(18)**

(i) Field variable can be expressed as a product of shape function matrix and element nodal unknown vector.

(ii) Element stress varies linearly within the element.

2. (a) With necessary mathematical details, determine the element characteristic matrix equations for the following problems: **(18)**

(i) Heat conduction in solids with a uniform volumetric heat sink.

(ii) An axially loaded member subjected to a temperature change.

(b) For the bar assemblage shown in Fig. Q. 2(b), determine by FEM the reactions at the fixed supports and stresses in each bar. The Aluminum bar is subjected to a temperature drop of 10°C. **(17)**

Date for Aluminum bar:	Brass bar:
$E_1 = 70$ GPa	$E_2 = 100$ GPa
$A_1 = 12\times10^{-4}\ m^2$	$A_2 = 6\times10^{-4}\ m^2$
$\alpha_1 = 23\times10^{-6} / °C$	$\alpha_2 = 20\times10^{-6} / °C$

3. (a) Establish the governing differential equation for the beam-column shown in Fig. Q. 3(a), using **(18)**

(i) mechanics of materials approach

(ii) variational approach

(b) For the spring assemblage shown in Fig. Q. 3(b), find by FEM **(17)**

(i) the global stiffness matrix equation

(ii) the nodal displacements

(iii) the support reactions

(iv) the local element forces

Node 1 is fixed while node 5 is given a fixed, known displacement δ = 20 mm. The spring constants are all equal to K = 200 kN/m.

Contd P/2

ME 427

4. For the symmetrically loaded simply-supported uniform beam shown in Fig. Q. 4, answer the following: **(35)**
   (a) derive the functional for the beam.
   (b) find the solution of deflection and bending moment using variational approach (use one-parameter approximate solution).
   (c) discuss the accuracy of the approximate solutions with reference to exact analytical solutions of the beam.
   (d) suggest an effective way to improve the accuracy of the approximate solutions.

SECTION – B

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

5. (a) Give a classification of engineering problems based on governing differential equations. **(10)**
   (b) Consider that the equation for the x-component of strain in a body is given by, **(15)**

$$\frac{\partial u}{\partial x} - \frac{1}{2}\left[\left(\frac{\partial u}{\partial x}\right)^2 + \left(\frac{\partial v}{\partial y}\right)^2 + \left(\frac{\partial \omega}{\partial z}\right)^2\right] = F(x, y, z)$$

   (i) Determine the order and degree of the differential equation.
   (ii) Comment on the homogeneity and linearity of the differential equation.
   (c) What are the different types of boundary conditions used for boundary value problems? Give suitable examples. **(10)**

6. (a) With suitable engineering examples, explain the concept of geometric and material nonlinearity. **(10)**
   (b) Give the physical interpretation of the following BVP with a simple sketch: **(10)**

$$u_{xx} + u_{yy} = 0; \quad 0 < x < 1, \quad 0 < y < 1$$

$$\left.\begin{array}{l} u_y(x,0) - h\left[u(x,0) - 2\right] = 0 \\ u(x,1) = 1 \end{array}\right\} \quad 0 < x < 1$$

$$\left.\begin{array}{l} u_x(0,y) = 0 \\ u_x(1,y) = 0 \end{array}\right\} \quad 0 < y < 1$$

   (c) The mathematical model of an initial value problem is given below: **(15)**

$$\frac{dy}{dx} + 2y = x^3 e^{-2x}; \qquad y(0) = 1$$

Find approximate values of y at x = 0.1 and 0.2 using the 4th order RK method for a step size of 0.1.

7. (a) Compare and contrast finite-difference and finite-element methods with reference to discretization and relative merits and demerits. Give an example of a physical problem where the FDM technique is difficult to apply. **(10)**

(b) A 10 cm diameter steel sphere of thermal conductivity 40 W/(m.°C) is heated electrically by the passage of electric current, which generates energy within the sphere at a rate of 40×10^6 W/m^3. Heat is dissipated from the surface of the sphere by convection with a coefficient of 400 W/(m^2.°C) into an ambient of 20°C. By dividing the radius into five equal segments, describe the complete finite-difference scheme for determining the radial temperature distribution in the sphere. **(25)**

8. (a) Consider a standard cantilever beam under a uniform loading. The free end of the beam is resting on a transverse spring. Give the numerical modeling of the boundary conditions at both ends of the beam. **(15)**

(b) With neat sketches, give the details of the following coordinate systems with the necessary transformation equations: **(10)**

(i) Cylindrical coordinate system

(ii) Spherical coordinate system

Also, write the general heat-conduction equation for solids with reference to the above coordinate systems.

(c) Describe the procedures for solving eigenvalue problems using the finite difference method with an appropriate example. **(10)**

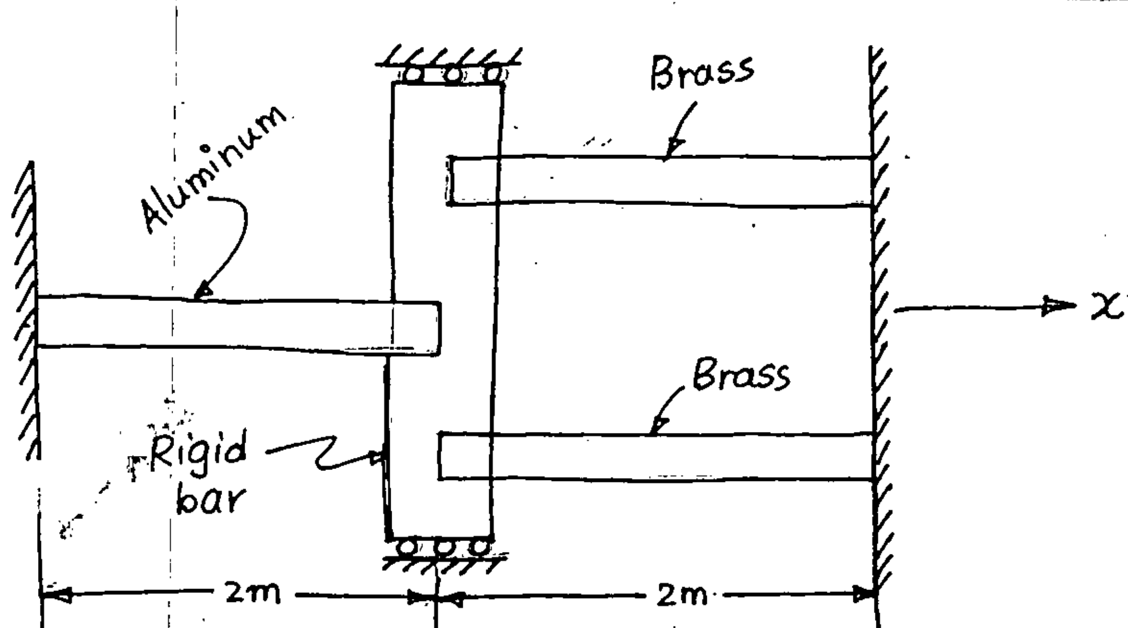


Fig. Q2(b)

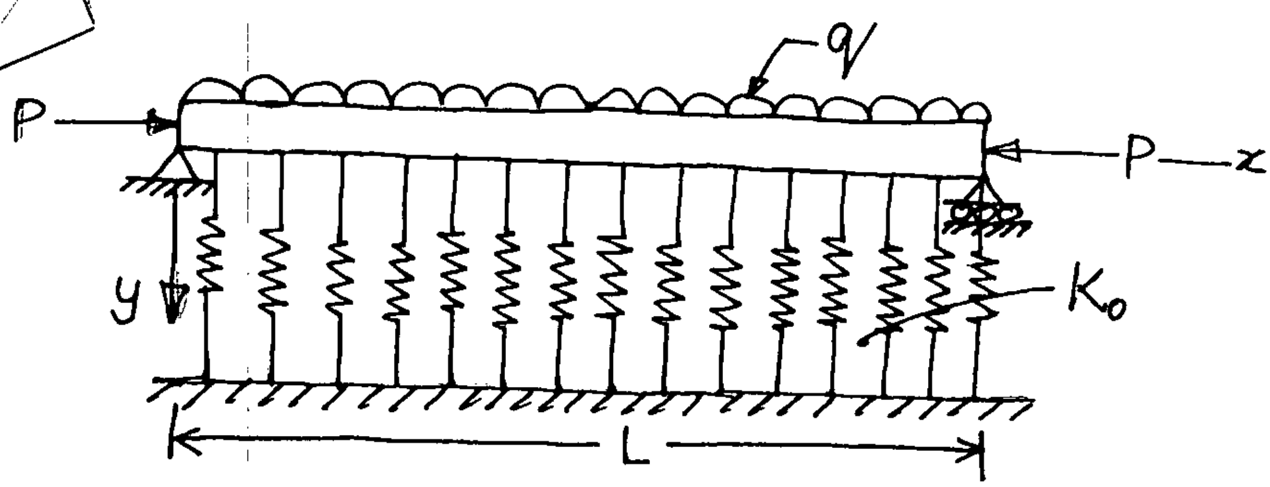


Fig. Q3(a)

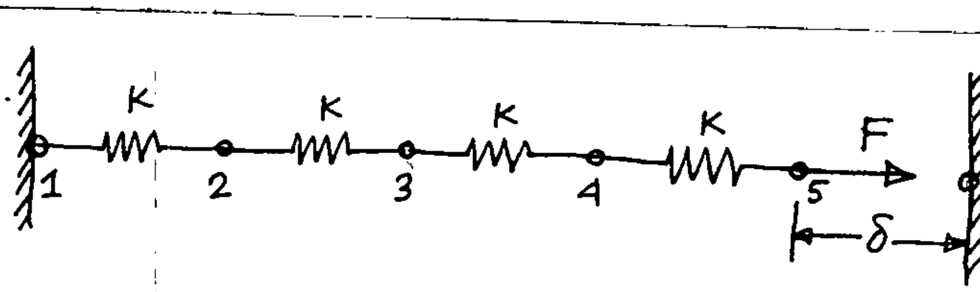


Fig. Q3(b)

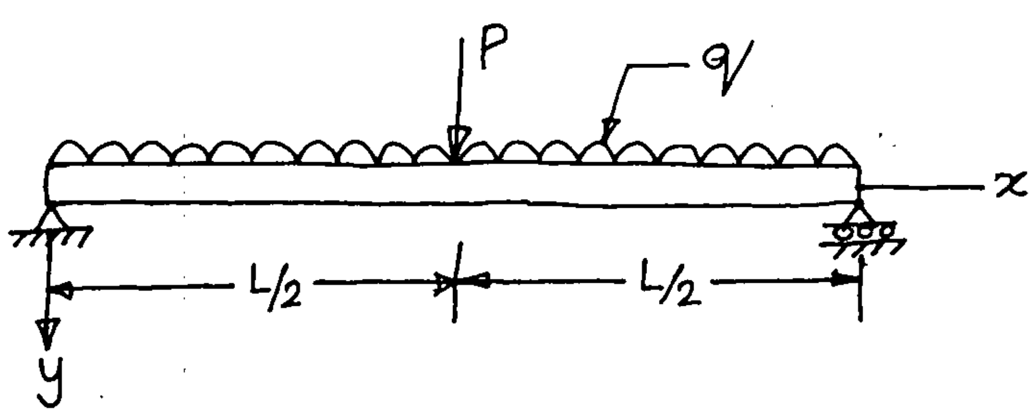


Fig. Q4

L-4/T-2/ME Date: 22/04/2024

BANGLADESH UNIVERSITY OF ENGINEERING AND TECHNOLOGY, DHAKA

L-4/T-2 B.Sc. Engineering Examinations 2021-2022

Sub: **ME 471 (Bio-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 any **THREE** questions.

1. (a) Explain the biomechanical properties of the cortical and trabecular bone with their stress-strain diagram. How does age affect the biomechanical properties of cortical and trabecular bone? **(12)**

   (b) Discuss the modes of failure by which cracks grow in bones and lead to catastrophic failure. **(8)**

   (c) With a neat sketch explain the anisotropic behavior of human bone. **(7)**

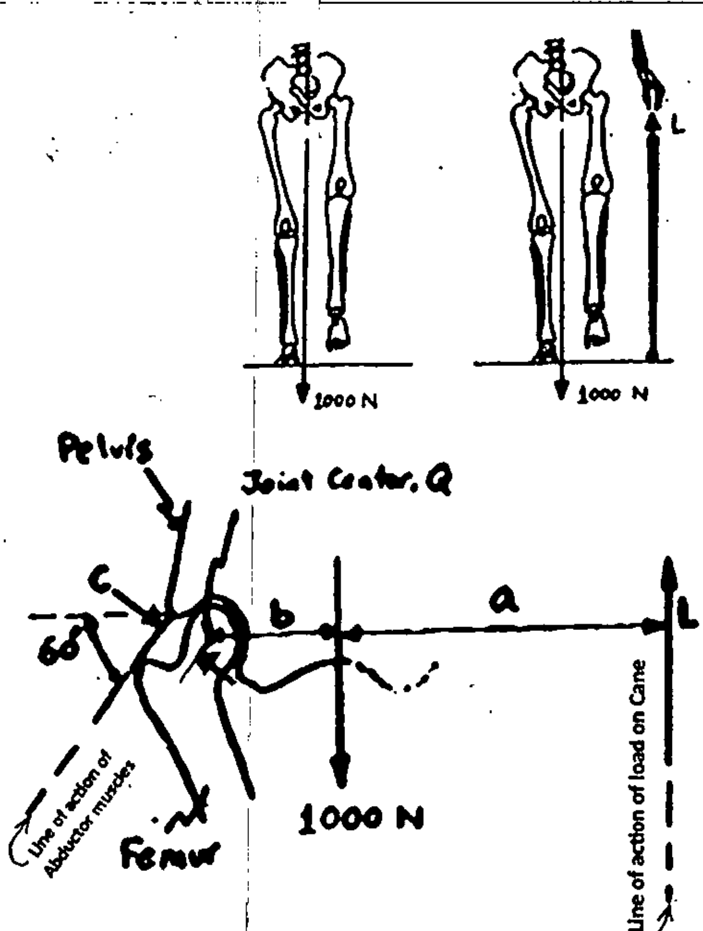
   (d) "Bone is a viscoelastic material" - what does it mean? **(8)**

2. (a) Discuss the effects of exercise on the health of articular cartilage. **(5)**

   (b) Define Range of Motion (ROM). What factors affect the ROM of a joint? **(6)**

   (c) Draw the free-body diagrams of the elbow and ankle joints and explain how the joint reaction force (JRF) can be estimated. **(10)**

   (d) The patient shown schematically in Fig. For Q. 2(d) has pain in the hip joint and is advised by his doctor to use a cane. If the cane were used as shown in the figure, calculate the reduction in abductor muscle force and hip joint reaction force magnitudes on the right hip due to the use of the cane. A detailed view of the hip joint is shown in the figure. Assume that the hip joint reaction force acts through the joint center (point Q). **(14)**



Data:
c = 50 mm
b = 100 mm
a = 300 mm
L = 100 N

Fig. for Q. 2(d)

Contd............ Page/2

3. (a) Explain why the lungs tend to collapse. **(10)**

(b) Discuss how particles are transported in the respiratory system based on the flow conditions defined by the Strokes number, St. Why is particle pollution from fine particulates (PM 2.5) a concern for human lung? **(12)**

(c) During an experiment, a subject breathes in normally from the atmosphere but breaches out into a special device that collects the water in each exhaled breath. At the end of the experiment, the collected mass of water is 1.499 g. During the experiment, the ambient air had the composition shown in Table for Q. 3(c). How many breaths did the subjects take during the experiment? Make and state necessary assumptions. **(13)**

Table for Q. 3(c)

Gas	**Molar fraction in ambient air (%)**
N_2	75.85
O_2	20.11
CO_2	0.04
H_2O	4.00
Total	100.00

4. (a) Explain the different forms of muscle work and their different forms of muscle contraction. **(12)**

(b) Discuss the effects of mechanical properties of muscles on the force production by examining the (i) force-length relationship, (ii) load-velocity relationship. **(12)**

(c) Explain the effects of (i) fatigue, and (ii) vibration on the force production in muscles. **(11)**

SECTION – B

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

5. (a) How is blood composed of? Draw a typical flow centre for whole blood and briefly discuss its rheological behavior. **(12)**

(b) What do you mean by hematocrit? How does it affect on the viscosity of whole blood? **(8)**

(c) Using the fundamental concepts of fluid dynamics, explain how the pressure drop can be estimated due to formation of atherosclerotic plaque in artery. **(8)**

(d) What are the functions of the circulation in relation to human physiology? **(7)**

Contd............ Page/3

6. (a) How do the vessel sections of an artery, a vein and a capillary differ from each other? **(5)**

(b) Draw and explain a typical pressure-volume loop of a healthy heart. Indicate the stroke volume in the loop. **(10)**

(c) Define vascular resistance and capacitance. Using lumped parameter model of systemic circulation show how the blood flow can be expressed in terms of filling pressure, mean systolic filling pressure including vascular resistance and capacitance. **(15)**

(d) How does the lumped parameter model of Q. 6(c) reduce to Windkessel model? **(5)**

7. (a) Write short notes on: **(10)**

i) Law of heart

ii) Contractility of the Heart

(b) Discuss the measurement constraints associated with the biomedical instrumentation. **(10)**

(c) What do you mean by "equilibrium potential" and "action potential" in relation to the electrical activity of cells? **(5)**

(d) Briefly explain the working principle of EEG. How does it differ from ENG? **(10)**

8. (a) Schematically show the basis components of a 5^{th} generation CT scan system. **(10)**

(b) How does ultrasound interact with tissue regarding clinical diagnosis? How will this interaction affect the quality of biomedical imaging? **(10)**

(c) Explain the working principle of MRI. List the names of specific patients to whom the MRI scan shall not be performed. **(15)**

L-4/T-2/ME Date: ~~27/04/2024~~ 18|05|2024

BANGLADESH UNIVERSITY OF ENGINEERING AND TECHNOLOGY, DHAKA

L-4/T-2 B. Sc. Engineering Examinations 2021-2022

Sub: **ME 475** (Mechatronics)

Full Marks: 210 Time: 3 Hours

The figures in the margin indicate full marks.

Assume any data if necessary. Symbols used have their usual meaning.

USE SEPARATE SCRIPTS FOR EACH SECTION

SECTION – A

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

1. (a) With a block diagram show different module of a typical mechatronic system and describe their functions. **(17)**

   (b) Identify different module of a modern electronic-controlled split-type air conditioning system in context of your answer of Q. 1(a) and explain their functions. **(10)**

   (c) List the different types of actuators used in mechatronic systems. **(8)**

2. (a) Describe the working principle of a 'linear' motor. Mention some of its applications. **(13)**

   (b) How does a successive-approximation ADC work? – Describe in brief. **(12)**

   (c) In telephony, the bandwidth allocated for human voice-frequency transmission is usually 4 kHz. During telephonic conversation, the sound pressure level normally varies between 0 to 60 dB. What will be the sampling rate of an ADC to faithfully record the telephonic conversation? Also find the required bit-size of the ADC for detecting a change of 0.5 dB in conversation. **(10)**

3. (a) Why are PLCs used in industry automation instead of microcontroller-based system like Arduino? **(8)**

   (b) Develop a PLC ladder logic diagram to be used for the security control of a warehouse as follows: **(18)**

   (i) A motion sensor at the entry of the warehouse, detects any motion and energizes a momentary switch, I1, a timer function, T1 and a counter function, C1.

   (ii) The switch, I1 puts a security light, L1 ON momentarily. Then the light remains ON for the next 30 seconds.

   (iii) In case of total inactivity, the light goes OFF after 30 seconds, the timer, T1 and the counter, C1 are reset.

   (iv) If the motion sensor detects multiple motions in 30 seconds and counting exceeds 10, then C1 triggers a buzzer, B1.

   (v) The buzzer, B1 is de-energized by an emergency push-button switch, I2.

   (vi) When I2 is pushed, the light goes OFF, the timer, T1 and the counter, C1 are reset.

   (c) What is 'PLC SCADA' System? What are the benefits of using PLC SCADA? **(9)**

Contd P/2

4. (a) What is 'Degrees of Freedom' (DoF) in robot design? How many DoF does a human hand possess? **(8)**
   (b) Define a 'SCARA' robot. List its advantages. **(12)**
   (c) Illustrate the functioning of 'Computer Vision'. **(15)**

SECTION – B

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

5. (a) Classify voltage and current sources in electrical circuits. **(8)**
   (b) What is the condition for maximum power transfer between an electric power source and an electric load? Does this condition also maximize efficiency? **(10)**
   (c) Find out the power of the 6V source of Figure for Q. No. 5(c) using the source transformation method. **(10)**

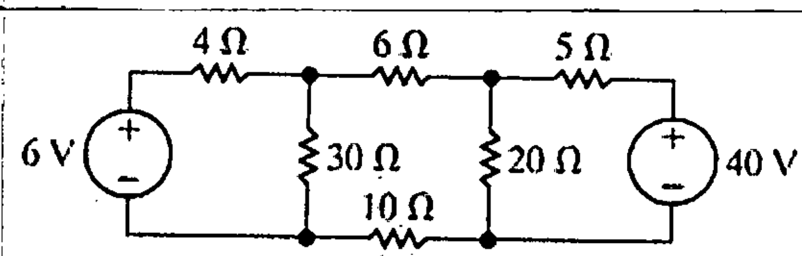


Figure for Q. No. 5(c)

   (d) Determine the voltage across R_c (Figure for Q. No. 5(d)) following Kirchhoff's voltage law. **(7)**

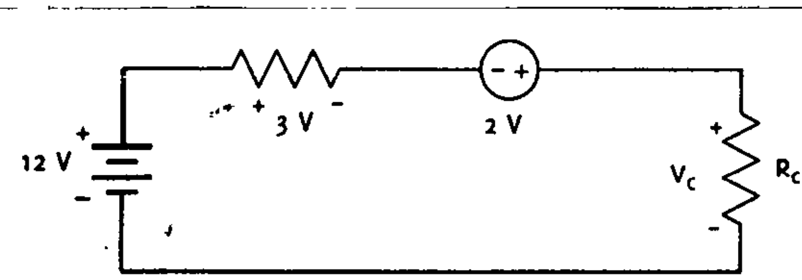


Figure for Q. No. 5(d)

6. (a) Draw a circuit diagram to implement the "PID" controller using op-amps. **(8)**
   (b) Discuss the application of op-Amp as a voltage follower. **(8)**
   (c) Distinguish between the following: **(10)**
      (i) Inverting and Non-inverting amplifier
      (ii) Low-pass and high-pass filter.
   (d) Draw a typical connection of an 'op-amp' for its use as an inverting summing amplifier. Using two 'golden' rules of op-amp, derive its input/output relationship for the above case. **(9)**

ME 475

7. (a) Draw the more simplified logic circuit of the following (Figure for Q. No. 7(a)): **(10)**

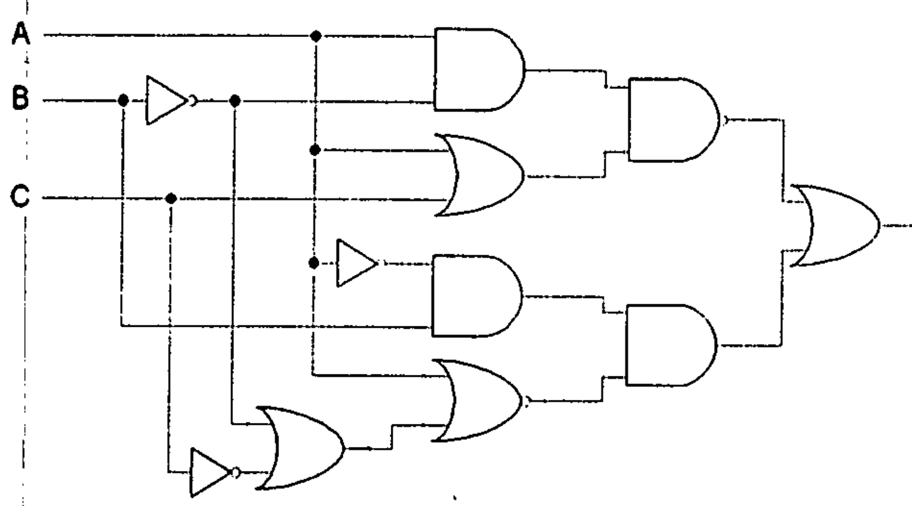


Figure for Q. No. 7(a)

(b) Draw the logic circuit for the Boolean equation: **(10)**

(i) Q = AB + BC (B + C)

(ii) Q = XZ + Z (X + XY)

Simplify the equation and draw the simplified logic circuit.

(c) A motor is controlled based on signals from three sensors, as shown below (Figure for Q. No. 7 (c)). Using K-mapping to develop a simplified logic circuit for the motor's control. **(15)**

Sensor-1	Sensor-2	Sensor-3	Motor
OFF	OFF	OFF	ON
OFF	OFF	ON	OFF
OFF	ON	OFF	ON
OFF	ON	ON	OFF
ON	OFF	OFF	ON
ON	OFF	ON	OFF
ON	ON	OFF	ON
ON	ON	ON	OFF

Figure for Q. No. 7 (c)

8. (a) Differentiate between microprocessor and microcontroller. **(10)**

(b) Why is Arduino preferred over many other microcontrollers? **(10)**

(c) What are the functions of the 'kernel' of an OS? What is HAL? **(8)**

(d) Classify the signal filters. **(7)**

L-4/T-2/ME **Date : 24/03/2024**

BANGLADESH UNIVERSITY OF ENGINEERING AND TECHNOLOGY, DHAKA

L-4/T-2 B. Sc. Engineering Examinations 2021-2022

Sub : **IPE 481** (Industrial Management)

Full Marks : 280 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 any **THREE**.

Make appropriate assumptions for any missing data.

1. (a) Describe the functions of management. Discuss the managerial levels in an organization and explain which type of skill is important for different levels of management based on the task they perform. **(12)**

(b) 'Leaders like Mashrafe Bin Mortaza comes once in a while' - explain which theory of leadership supports this statement. What are the assumptions and limitations of this theory? Compare this theory with the behavioral theory of leadership. **(15)**

(c) A new author sets three criteria for selecting a publisher for an OR textbook: royalty percentage (R), marketing (M) and advanced payment (A). Two publishers, H and P, have expressed their interest in publishing the book. Using the following comparison matrices, rank the two publishers. **($19\frac{2}{3}$)**

$$P = \begin{matrix} \\ R \\ M \\ A \end{matrix}\begin{pmatrix} R & M & A \\ 1 & 1 & \frac{1}{4} \\ 1 & 1 & \frac{1}{5} \\ 4 & 5 & 1 \end{pmatrix} \quad A_R = \begin{matrix} \\ H \\ P \end{matrix}\begin{pmatrix} H & P \\ 1 & \frac{1}{2} \\ 2 & 1 \end{pmatrix} \quad A_M = \begin{matrix} \\ H \\ P \end{matrix}\begin{pmatrix} H & P \\ 1 & \frac{1}{2} \\ 2 & 1 \end{pmatrix} \quad A_A = \begin{matrix} \\ H \\ P \end{matrix}\begin{pmatrix} H & P \\ 1 & 1 \\ 1 & 1 \end{pmatrix}$$

2. (A) Explain the Herzberg's motivation-hygiene theory. Differentiate it with the traditional view. Discuss the relevance of this theory in context of the engineering students in Bangladesh. **(12)**

(b) Describe the possible communication barriers in a Bangladeshi muti-national company where the decision-making process is data-driven, fast paced with reward opportunities if succeeded. Discuss how these barriers can be overcome in that organization. **(15)**

(c) A company owns a tract of land that may contain oil. A consulting geologist has reported that he believes there is 1 chance in 4 of oil. Because of this prospect, another oil company has offered to purchase the land for $90,000. However, the company itself is considering holding the land in order to drill for oil itself. The cost of drilling is $100,000. If oil is found, the resulting expected revenue will be $800,000.

Contd P/2

IPE 481

Contd ... Q. No. 2 (c)

A seismic survey, which costs $30,000, is performed to obtain sounds to indicate whether the geological structure is favorable for to the presence of oil. Based on past experience, if there is oil, then the probability of unfavorable seismic sound is 0.4; whereas, if there is no oil, then the probability of unfavorable seismic sound is 0.8. Draw the decision tree and find out the final decision whether to drill or to sell the land. **($19\frac{2}{3}$)**

3. (a) Differentiate between industrial and consumer marketing. Highlight the pros and cons of both. **(12)**

(b) Explain the purpose of an advertising plan. Prepare the STP analysis of developing an advertising plan for a new restaurant in the saturated culinary industry of Bangladesh. **(15)**

(c) Describe the dimensions of product mix the marketing. Illustrate the ways of enlarging the product line of a company. 'A' is a premium panjabi brand which has recently introduced other lifestyle categories like footwares, bags, watches, home decors etc. As per the ways you have explained, explain where does A sit. Justify your answer. **($19\frac{2}{3}$)**

4. (a) Compare between the production concept and product concept of marketing. Evaluate which of these concepts can explain the marketing activities of Apple iPhone. **(12)**

(b) Discuss the rationale behind using multiple marketing channels for the same product. Explain the five factors influencing the design and selection of marketing channels. **(15)**

(c) Explain the S-curve of technological progress. Determine the current stage of technological progress of online based ed-tech companies in Bangladesh and propose the competitive strategies to be imparted by them based on their technological progress. **($19\frac{2}{3}$)**

SECTION – B

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

5. Due to erratic sales of its sole product--a high-capacity battery for laptop computers–PEM Inc., bas been experiencing difficulty for some time. The company's contribution format income statement for the most recent month is given below: **($46\frac{2}{3}$)**

Sales (19,500 units × $30 per unit)	$585,000
Variable expenses...........................	409,500
Contribution margin..........................	175,500
Fixed expenses................................	180,000
Net operating loss............................	$ (4,500)

Contd P/3

IPE 481
Contd ... Q. No. 5

(a) Compute the company's CM ratio and its break-even point in both units and dollars.

(b) The president believes that a $16,000 increase in the monthly advertising budget, combined with an intensified effort by the sales staff, will result in an $80,000 increase in monthly sales. If the president is right, what will be the effect on the company's monthly net operating income or loss? (Use the incremental approach in preparing your answer.)

(c) Refer to the original data. The sales manager is convinced that a 10% reduction in the selling price, combined with an increase of $60,000 in the monthly advertising budget, will cause unit sales to double. What will the new contribution format income statement look like if these changes are adopted?

(d) Refer to the original data. The Marketing Department thinks a fancy new laptop computer battery package would help sales. The new package would increase packaging costs by 75 cents per unit. Assuming no other changes, how many units would have to be sold each month to earn a profit of $9,750?

(e) Refer to the original data. The company could reduce variable costs by $3 per unit by automating certain operations. However, fixed costs would increase by $72,00 each month.

(i) Compute the new CM ratio and the new break-even point in both units and dollars.

(ii) Assume that the company expects to sell 26,000 units next month. Prepare two contribution format income statements, one assuming that operations are not automated and one assuming that they are. (Show data on a per unit and percentage basis, as well as in total, for each alternative.)

(iii) Would you recommend that the company automate its operations? Explain.

6. JBL Corporation produces and sells a single product, a high-end stereo system. Selected cost and operating data relating to the product for two years are given below. All money amounts are in the unit of US dollars ($): **($46\frac{2}{3}$)**

	US $
Selling price per unit	65
Manufacturing costs:	
Variable per unit produced:	
Direct materials	13
Direct labor	8
Variable overhead	4
Fixed per year	125,000
Selling and administrative costs:	
Variable per unit sold	5
Fixed per year	65,000

IPE 481

Contd ... Q. No. 6

	Year 1 (Units)	Year 2 (Units)
Units in the beginning inventory	0	2,000
Units produced during the year	10,000	6,000
Units sold during the year	8,000	8,000
Units in ending inventory	2,000	0

Do the following:

(a) Assume the company uses absorption costing.

(i) Compute the unit product cost in each year.

(ii) Prepare an income statement for each year.

(b) Assume the company uses variable costing.

(i) Compute the unit product cost in each year.

(ii) Prepare an income statement for each year.

(c) Reconcile the variable costing and absorption costing net operating incomes.

7. The marketing department of Reber Crop. has submitted the following sales forecast for the upcoming fiscal year: **(46 $\frac{2}{3}$)**

	1st Quarter	2nd Quarter	3rd Quarter	4th Quarter
Budgeted unit sales.....	8,000	7,000	6,000	7,000

The company expects to start the first quarter with 1,600 units in finished goods inventory. Management desires an ending finished goods inventory in each quarter equal to 20% of the next quarter's budgeted sales. The desired ending finished goods inventory for the fourth quarter is 1,700 units. In addition, the beginning raw materials inventory for the first quarter is budgeted to be 3,120 pounds, and the beginning accounts payable for the first quarter is budgeted $14,820. Each unit requires 2 pounds of raw materials, which costs $4.00 per pound. Management desires to end each quarter with an inventory of raw materials equal to 20% of the following quarter's production needs. The desired ending inventory for the fourth quarter is 3,140 pounds. Management plans to pay for 75% of raw material purchases acquired in the quarter and 25% in the following quarter.

Required:

(a) Prepare the company's production budget for the upcoming fiscal year.

(b) Prepare the company's direct materials budget and schedule of expected cash disbursements for purchases of materials for the upcoming fiscal year.

8. (a) The state is considering two proposals for increasing the capacity of the main drainage canal in an agricultural region. They can select only one. Which one should they select? **(16 $\frac{2}{3}$)**

Contd P/5

IPE 481

Contd ... Q. No. 8 (a)

Proposal A requires dredging the canal. The state is planning to purchase the dredging equipment and accessories for $650,000. The equipment is expected to have a 10-year life with a $17,000 salvage value. The annual operating costs are estimated to total $50,000. To control weeds in the canal itself and along the banks, environmentally safe herbicides will be sprayed during the irrigation season. The yearly cost of the weed control program is expected to be $120,000.

Proposal B is to line the canal walls with concrete at an initial cost of $4 million. The lining is assumed to be permanent, but minor maintenance will be required every year at a cost of $5000. In addition, lining repairs will have to be made every 5 years at a cost of $30,000.

(b) Redflex Traffic Systems manages red light camera systems that take photographs of vehicles that run red lights. Red light violations in El paso, TX, result in fines of $75 per incident. A two-month trial period revealed that the police department could expect to issue 300 citations per month per intersection. If Redflex offered to install camera systems at 10 intersections, how much could the police department afford to spend on the project if it wanted to recover its investment in 2 years at an interest rate of 12% per year compounded quarterly? **(15)**

(c) Ford Automobiles is considering investing in a new manufacturing facility that will cost $10 million. The facility is expected to have a useful life of 20 years and generate annual revenue of $4 million with an annual operating cost of $ 1.5 million. The facility will also require a major renovation at the end of the tenth year, which will cost $5 million. At the end of the 20-year useful life, the facility can be sold for $1 million. Assuming a required rate of return of 12% what is the annual worth of the investment in the facility? Should the company invest in the facility? **(15)**
