SECTION – A

There are FOUR questions in this section. Answer any THREE.
Symbols indicate their usual meaning;

1. (a) State the assumptions of the cardinal theory of utility analysis. Illustrate the law of diminishing marginal utility.  
(b) Mathematically derive the equilibrium condition of the consumer for a single commodity under the cardinalist approach of utility analysis.  
(c) How would you derive the demand curve of the consumer based on the axiom of diminishing marginal utility.  

2. (a) Other than price, what are the determinants of supply of a commodity? Explain them in your own words.  
(b) Illustrate the mechanism by which market equilibrium of a commodity is established in the free market economy.  
(c) From the following demand and supply functions

\[ Q_D = 1550 - 55P_z \]
\[ Q_S = 760 + 25P_z \]

Find the equilibrium price and quantity of the commodity Z. If Government provides a subsidy of Tk. 3.25 per unit, what will be the new equilibrium price and quantity?  

3. (a) Define price elasticity and cross-price elasticity of demand. How would you derive the formulae for measuring these two types of elasticity of demand.  
(b) Distinguish between point elasticity and arch elasticity of demand.  
(c) Given the demand function of commodity X

\[ Q_{dx} = 1090 - 20P_X + 0.02M + 2.8P_y \]

Where, price of X, \( P_X = Tk. 55 \), price of Y, \( P_y = Tk. 68 \) and income of the consumer, \( M = 40000 \). Find the price elasticity and cross-price elasticity of X. State the implications of the results you have obtained.  

4. Write short notes on any THREE of the following:
(i) 'Change in demand' and 'change in quantity demanded'  
(ii) Substitution effect and income effect  
(iii) Indifference curve and budget line  
(iv) Fundamental economic problems that every economy has to face.

Contd ........... P/2
5. (a) Explain the following concepts: (3 1/2)
   (i) Gross National Product (GNP)
   (ii) Gross Domestic Product (GDP)
   (iii) Net National Product (NNP)
   (b) Explain the various methods of measuring national income of a country.
   (c) Discuss the general difficulties in the measurement of national income of a country.
   (d) Calculate national income from the following information:
       \[ \text{GNP} = \text{Tk. } 1,20,000 \text{ crore} \]
       \[ \text{Depreciation} = \text{Tk. } 10,000 \text{ crore} \]
       \[ \text{Indirect tax} = \text{Tk. } 13,000 \text{ crore} \]
       Subsidy is 20% of indirect tax.

6. (a) What is meant by the concept of long run in the theory of production? How would you derive a long run average cost (LAC) curve of a firm from its short run cost curves? Why is LAC curve often called the planning curve? (8)
   (b) Explain the circular flow of income and expenditure in a two sector economy.
   (c) Briefly explain the concept of inflation.
   (d) Briefly discuss the various policies for controlling inflation in a developing country like Bangladesh. (3 1/2)

7. (a) Make a comparison between perfectly competitive market and monopolistic market. (6)
   (b) What are the conditions of monopoly market? Explain the barriers which may prevent a firm to enter the monopoly industry. (3 1/2)
   (c) What is meant by the shut-down point of production of a firm? Explain graphically the shut-down point of production of a firm under perfect competition.
   (d) Given the following total revenue (TR) and total cost (TC) functions for a firm
       \[ \text{TR} = 4350Q - 13Q^2 \]
       \[ \text{TC} = Q^3 - 5.5Q^2 + 150Q + 675 \]
       where \( Q \) is the quantity of output.
       (i) Set up the profit function.
       (ii) Find out the quantity which makes the profit maximum.
       (iii) Calculate the maximum profit and verify that it is maximized.

8. (a) Explain the short run equilibrium of a firm under monopoly market. (8)
   (b) Write down the statement of application of Euler's theorem in the theory of distribution of production. How can you show the exhaustion of factor income according to Euler's theorem? (7)
   (c) What are the various returns to scale of production? Briefly explain them. (8 1/2)
1. (a) Figure 1 exhibits a phase diagram of Pb-Sn alloy system. Using it solve following problems:
   (i) What are the compositions and relative amounts of the phases that constitute the eutectic microstructure?
   (ii) For an alloy containing 30% Sn, what are the relative amounts of $\alpha$ and $\beta$ phases present at the eutectic temperature?
   (iii) Again for an alloy containing 30% Sn, what are the relative amounts of the eutectic and the proeutectic $\alpha$ phase present at the eutectic temperature?
   (b) Draw the microstructural changes of hypoeutectoid, eutectoid and hypereutectoid steels at different temperatures during slow cooling from austenitic temperature to room temperature.

2. (a) A tensile test is carried out on a specimen of mild steel of gauge length 40 mm and diameter 7.42 mm. The results are listed in Table 1. At fracture the final length of the specimen is 40.90 mm. Using the load-extension data of Table 1 complete parts (i) through (v).
   (i) Plot the load vs extension graph.
   (ii) Compute the modulus of elasticity.
   (iii) The stress at the limit of proportionality.
   (iv) Determine the ultimate tensile strength of this specimen.
   (v) Compute the percentage elongation.
   (b) Derive the following equations:
      (i) True stress, $\sigma_T = \sigma(1 + \varepsilon)$
      (ii) True strain, $\varepsilon_T = \ln(1 + \varepsilon)$
      (iii) Modulus of resilience, $U_r = \frac{\sigma^2}{2E}$

3. (a) Normalizing produces a finer and more abundant pearlite in the structure than is obtained by annealing—why?
   (b) Name two important characteristics of martensitic transformation of steel.
   (c) What are the effects of tempering on structure and properties of quenched steel.
   (d) Why is an alloy having two phase structure prone to corrosion? Explain briefly how you can protect this alloy.

Contd ............ P/2
4. (a) Write down the reactions taking place in different zones in blast furnace during the extraction of iron. (12)
   (b) Explain the basic principle of gas cleaning devices of blast furnace with suitable figures. (13)
   (c) Describe, with necessary figures how cracks, blow holes and internal cracks are located by the method of radiographic inspection. (10)

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

5. (a) What is the purpose of surface hardening? Explain how a hard surface on a low carbon gear part would be produced. (20)
   (b) Outline the strengthening methods of copper alloys. (10)
   (c) How aluminium is produced from aluminium ore. (5)

6. (a) Describe how steel is produced using Linz-Donawitz process. (18)
   (b) Compare acid Beseemer and basic Beseemer processes of steel making. (9)
   (c) Why an electric furnace is now-a-days used during steel making process? (8)

7. (a) Classify cast iron according to its microstructure. (6)
   (b) Describe the process of producing ferritic malleable cast iron showing the microstructural changes that occur during the process. (21)
   (c) What are the roles of silicon and magnesium in producing nodular cast iron. (8)

8. (a) Mention different types of stainless steel along with their composition, properties and uses. (18)
   (b) Write short notes on (i) water-hardening tool steel and (ii) shock-resisting tool steel. (6+6)
   (c) List five advantages of alloy steel. (5)
Figure 1 The Lead-Tin (Pb-Sn) phase diagram

Table 1 Load–extension data of tensile testing of mild steel.

<table>
<thead>
<tr>
<th>Load (kN)</th>
<th>0</th>
<th>10</th>
<th>17</th>
<th>25</th>
<th>30</th>
<th>34</th>
<th>37.5</th>
<th>38.5</th>
<th>36</th>
<th>Fracture</th>
</tr>
</thead>
<tbody>
<tr>
<td>Extension (mm)</td>
<td>0</td>
<td>0.05</td>
<td>0.08</td>
<td>0.11</td>
<td>0.14</td>
<td>0.20</td>
<td>0.40</td>
<td>0.60</td>
<td>0.90</td>
<td></td>
</tr>
</tbody>
</table>
1. (a) Solve the following differential equation by the method based on the factorization of the operator:
\[(x + 1)D^2 - (3x + 4)D + 3\] \[y = (3x + 2)e^{3x}\]
(b) Solve the differential equation:
\[x^2 \frac{d^2 y}{dx^2} + 3x \frac{dy}{dx} + y = \frac{1}{(1-x)^2} \]

2. Apply method of Fröhbenius to obtain two linearly independent solutions valid about \(x = 0\) for the following differential equation:
\[x^2 \frac{d^2 y}{dx^2} + x \frac{dy}{dx} + (x^2 - 1)y = 0.\]

3. (a) When \(n\) is a positive integer, show that
\[\exp \left(\frac{1}{2} x \left( z - \frac{1}{z} \right) \right) = \sum_{n=-\infty}^{\infty} z^n J_n(x).\]
(b) Using the definition \(J_\alpha(bx) = \frac{1}{\pi} \int_0^\pi \cos(bx \sin \theta) d\theta\), if \(a > 0\), prove that
\[\int_0^\infty e^{-ax} J_\alpha(bx) dx = \frac{1}{\sqrt{a^2 + b^2}}.\]

4. (a) Prove the Rodrigues’s formula for Legendre function
\[P_n(x) = \frac{1}{2^n n!} \frac{d^n}{dx^n} (x^2 - 1)^n,\]
hence show that
\[\int_{-1}^{1} x^m P_n(x) dx = 0 \text{ where } m < n.\]
(b) Show that \(P_n(x) = \frac{1}{\pi} \int_0^\pi \frac{d\theta}{[x + \sqrt{(x^2 - 1)} \cos \theta]^{n+1}}, \text{ where } n \text{ is a positive integer.}\)
There are **FOUR** questions in this section. Answer any **THREE**.

5. (a) Find the value of $p$ so that the vectors $2\mathbf{i} - j + k$, $i + 2j - 3k$ and $3i + pj + 5k$ are coplanar.

(b) Show that $\mathbf{a} \times (\mathbf{b} \times \mathbf{c}) = (\mathbf{a} \cdot \mathbf{c})\mathbf{b} - (\mathbf{a} \cdot \mathbf{b})\mathbf{c}$ and hence simplify $i \times (\mathbf{a} \times i) + j \times (\mathbf{a} \times j) + k \times (\mathbf{a} \times k)$

(c) Find the equation of the plane through the point $i + 2j - k$ which is perpendicular to the line of intersection of the planes $\mathbf{r} \cdot (3\mathbf{i} - j + k) = 1$ and $\mathbf{r} \cdot (i + 4j - 2k) = 2$.

6. (a) Verify the expression $\frac{d}{dt} \left[ \mathbf{r} \cdot d^2 \mathbf{r} \right] = \left[ \mathbf{r} \cdot \frac{d}{dt} \mathbf{r} \right] d^3 \mathbf{r}$ for the vector function $\mathbf{r} = (a \cos t) \mathbf{i} + (a \sin t) \mathbf{j} + (at \tan a) \mathbf{k}$.

(b) If $u = x + y + z$, $v = x^2 + y^2 + z^2$ and $w = xy + yz + zx$, find the value of $[\text{grad } u \text{ grad } v \text{ grad } w]$.

(c) If $\mathbf{r}$ is solenoidal, find the value of $n$, where $\mathbf{r} = x\mathbf{i} + y\mathbf{j} + z\mathbf{k}$.

7. (a) If $\mathbf{F} = (3x^2 + 6y)\mathbf{i} - 14yz\mathbf{j} + 20xz^2 \mathbf{k}$, evaluate $\int_C \mathbf{F} \cdot d\mathbf{r}$ where $C$ is the straight line joining the points $(0, 0, 0)$ to $(1, 1, 1)$.

(b) Find the circulation of $\mathbf{F}$ round the curve $C$ where $\mathbf{F} = y\mathbf{i} + z\mathbf{j} + x\mathbf{k}$ and $C$ is the circle $x^2 + y^2 = 1$, $z = 0$.

(c) Evaluate $\iint_S \mathbf{F} \cdot \mathbf{n} \, dS$, where $\mathbf{F} = x^2\mathbf{i} + y^2\mathbf{j} + z^2\mathbf{k}$ and $S$ is that portion of the plane of $x + y + z = 1$ which lies in the first octant.

8. (a) State Gauss's divergence theorem and verify this theorem for the vector function $\mathbf{F} = 4x\mathbf{i} - 2y^2\mathbf{j} + x^2\mathbf{k}$ taken over the region bounded by $x^2 + y^2 = 4$, $z = 0$ and $z = 3$.

(b) Use Green's theorem to evaluate $\oint_C [(x^2 + y^2)dx - 2xydy]$, where $C$ is the rectangle bounded by $y = 0, x = 0, y = b, x = a$.
1. (a) A steel bar, 1 m in length and 35 mm × 35 mm in cross section, is rigidly attached to a wall at its right end as shown in Fig. for Q. No. 1(a). Its other end is 0.5 mm from another rigid wall. If a 120 kN axial force is attached to the bar at its mid-point and the temperature is increased by 60°C, what will the unit stress be in each portion of the bar? (E = 207 GN/m², α = 0.0000117/°C) (20)

(b) Fig. for Q. No. 1(b) shows a homogenous rigid block weighing 12 kips that is supported by three symmetrically placed rods. The lower ends of the rods were at the same level before the block was attached. Determine the stress in each rod after the block is attached and the temperature of all bars increased by 100°F. Use the following data: (15)

<table>
<thead>
<tr>
<th>Rod Type</th>
<th>A (in²)</th>
<th>E (psi)</th>
<th>α (°F)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Each steel rod</td>
<td>0.75</td>
<td>29 × 10⁶</td>
<td>6.5 × 10⁻⁶</td>
</tr>
<tr>
<td>Bronze rod</td>
<td>1.50</td>
<td>12 × 10⁶</td>
<td>10.0 × 10⁻⁶</td>
</tr>
</tbody>
</table>

2. (a) Determine the shear force and bending moment as functions of x, for the loaded cantilever beam as shown in Fig. for Q. No. 2(a). (15)

(b) A compound beam ABCDE as shown in Fig. for Q. No. 2(b), consists of two beams (AD and DE) joined by a hinged connection at D. The hinge can transmit a shear force but not a bending moment. The loads on the beam consist of a 4 kN force at the end of a bracket attached at point B and a 2 kN force at the midpoint of beam DE. Draw the shear force and bending moment diagrams for this compound beam. (20)

3. (a) Distinguish between the followings: (20)

(i) Engineering stress and True stress
(ii) Ductile material and brittle material
(iii) Modulus of toughness and modulus of resilience, and
(iv) Proportional limit and elastic limit.

(b) Assume that you have been given three circular column sections X, Y and Z. Diameter of the columns are d₁, d₂ and d₃ respectively (d₁ < d₂ < d₃). All of these columns have equal length. X is fixed supported at both ends. Y and Z are hinge supported at both ends. Which of these three columns will you recommend for design as compression member? Give reasons for your answer. (15)

4. (a) Determine the forces in members DF, EF and GE of the truss as shown in Fig. for Q. No. 4(a). (20)

(b) What is buckling? Discuss the mechanism of buckling for a tall slender column. (15)
SECTION – B

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

5. (a) A beam has a hinge support at 'A' and roller supports at 'C' and 'D' as shown in Fig. for Q. No. 5(a). An internal hinge is also placed at B. Determine the reactions at A, C and D.

(b) Define principal stresses and principal planes. Show that the sum of normal stresses on any two mutually perpendicular planes remain constant for any angle (θ).

6. (a) Find the maximum tensile and compressive flexure stresses for the cantilever beam as shown in Fig. for Q. No. 6(a).

(b) A 15 ft-beam simply supported at the ends carries a concentrated load of 9000 lb at midspan. Select the lightest 'S' section that can be employed using an allowable stress of 18 ksi. What is the actual maximum stress in the beam selected?

7. (a) The hydrofoil boat has an A-36 steel propeller shaft that is 100 ft long. It is connected to an in-line diesel engine that delivers a maximum power of 2500 HP and causes the shaft to rotate at 1700 rpm. If the outer diameter of the shaft is 8 in. and the wall thickness is 3/8 in., determine the maximum shear stress developed in the shaft. Also, what is the "wind up" or angle of twist in the shaft at full power?

(b) The Aluminium rod AB (G-26 GPa) as shown in Fig. for Q. No. 7(b), is bonded to the brass rod BD (G-39 GPa). Knowing that portion CD of the brass rod is hollow and has an inner diameter of 40 mm, determine the angle of twist at 'A'.

8. (a) Determine by double-integration method the slope and elastic-curve equation for a cantilever beam uniformly loaded. Also find the maximum deflection.

(b) A simply supported beam is loaded as shown in Fig. for Q. No. 8(b). Find the deflection at the centre of the beam.
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Fig. for Q. no. 1(a)

x-Area = 120 kN
35 mm x 35 mm

0.5 m
0.5 m

Fig. for Q. no. 1(b)

Fig. for Q. no. 2(a)

3 kN/m
3 kN
4.5 kN/m
4 kN/m

Fig. for Q. no. 2(b)

Fig. for Q. no. 4(a)

4 panels at 4 m = 16 m
Fig. for Q. No. 5(a)

Fig. for Q. No. 6(a)

Fig. for Q. No. 7(b)

Fig. for Q. No. 8(b)
<table>
<thead>
<tr>
<th>Designation</th>
<th>Area $A$</th>
<th>Depth $d$</th>
<th>Flange</th>
<th>Web</th>
<th>Elastic Properties</th>
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<td></td>
<td>In.$^2$</td>
<td>In.</td>
<td>Width $b_f$</td>
<td>Thickness $t_f$</td>
<td>Width $b_w$</td>
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<td></td>
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<td>In.</td>
<td>In.</td>
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<td>13.86</td>
<td>6.733</td>
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</tbody>
</table>

Table for Q. No. 6(b)
SECTION A
There are **FOUR** questions in this section. Answer any **THREE**.
Assume reasonable value for any missing data.

1. (a) A propulsion engine is capable of developing 28,000 brake horse power at 100 rev/min. The engine is of the two stroke type and has 8 cylinders. Calculate the volume of fuel injected per stroke at full power and at 32 rev/min. The specific fuel consumption is 155 and 200 gm/bhp.hr at 100 and 32 rev/min, respectively. Specific gravity of fuel is 0.96 g/cc at 15°C. [Assume that Power, P varies as (rev/min)^3]
(b) Compare the following modes of intermixing the air and fuel charges
   (i) Direct injection
   (ii) Turbulence chamber.
(c) What do you understand by SAE number?

2. (a) A fuel contains 86% Carbon and 14% Hydrogen by weight. Predict on the air fuel ratio (AFR) of the engine considering the proportion of oxygen in air is 23.2% by weight.
(b) Briefly explain the two shapes of cross section of connecting rod of a diesel engine.
(c) What evidence can you find from exhaust smoke colour?

3. (a) A pickup truck has a 5 litre V6, SI engine operating at 2400 RPM. The compression ratio is 10.2:1, the volumetric efficiency is 0.91, and the bore and stroke are related as stroke \( S = 0.92 \) B. Calculate:
   (i) stroke length.
   (ii) average piston speed.
   (iii) clearance volume of one cylinder.
   (iv) Air flow rate into engine.
(b) Demonstrate the effect of engine speed equivalence ratio and displacement of engine on brake specific fuel consumption.
(c) What is cetane number? What reference fuels are used to determine it?
4. (a) A five-cylinder, 3.5 liter SI engine operates on a four stroke cycle at 2500 RPM. At
this condition, the mechanical efficiency of the engine is 62% and 1000 J of indicated
work are produced each cycle in each cylinder. Calculate:
(i) Indicated mean effective pressure
(ii) Brake mean effective pressure
(iii) Friction mean effective pressure
(iv) Brake power
(v) Torque
(b) What is afterburning, and how is it caused? What effects does afterburning have on
an engine?
(c) Why is it necessary to remove all the water and solid impurities from a fuel before
using it in an engine?

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

5. (a) How would you categorize lubrication systems in Internal Combustion Engines?
Make a distinction among different types of lubrication systems.
(b) What facts can you compile for Diesel Engines?
(c) Discuss in brief combustion process of diesel engine.

6. (a) Explain the principle of operation of turbo charger and supercharger.
(b) Identify the different components of water cooling system and discuss in-depth the
working principle of Radiator and Thermostat Valve.
(c) Summarize functions of several types of Renewable and Alternative Energy sources
that are in use today.

7. (a) A 500 BHP diesel engine has a ηха of 40%. It is water cooled which takes away
25% of the total heat input. If temperature rises of the cooling water is to be maximum
of 30°F. What should be the minimum flow of water in gallon/hr/BHP?
(b) What elements would you consider when selecting a nozzle for an injector?
(c) Write short notes on following:
   (i) Cylinder Liners
   (ii) Piston Rings

8. (a) With neat sketch differentiate between common rail system and unit injection
system.
(b) Discuss the effects of turbine temperature and atmospheric conditions on gas
turbine engine.
(c) Estimate the cfm of cooling air per hp, if it takes 30% of the fuel energy, whereas
efficiency of engine is ηха = 35%, Cр = 0.4 BTU, ΔT = 130°F. Specific weight of air is
13.7 cft/lb.