GUJARAT TECHNOLOGICAL UNIVERSITY
BE- SEMESTER–1 PAPER SOLUTION – WINTER 2024

Subject Name & Code:
Basic Mechanical Engineering- BE01000081

Q.1 **(a)** Explain with neat sketch: Open, Close and Isolated system. **03**

Answer:
Definition of System:
A **system** is a specified quantity of matter or a region in space selected for analysis. Everything outside the system is called the **surrounding**. The system is separated from its surroundings by **system boundary**, which may be real or imaginary.

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1. Open System:
An open system is one in which **both mass and energy** can cross the system boundary.
- Example: Boiler, human body, IC engine (during intake and exhaust).
- Heat and work transfer may occur.
- Mass enters or leaves the system.

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2. Closed System:
A closed system is one in which **only energy** (heat or work) can cross the system boundary, but **no mass** crosses the boundary.
- Example: Piston-cylinder arrangement (idealized without leakage).
- Mass remains constant.
- Heat/work may enter or leave.

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3. Isolated System:
An isolated system is one in which **neither mass nor energy** crosses the boundary.
- Example: Perfectly insulated thermos flask.
- No interaction with surroundings.
- Both mass and energy remain constant.

Neat Sketch:

(b) Find expression of work done and change in internal energy for adiabatic process. **04**

Answer:
Adiabatic Process:
An **adiabatic process** is a thermodynamic process in which **no heat is exchanged** between the system and its surroundings.
That is,

$$Q=0$$

From the **First Law of Thermodynamics**:

$$Q=\Delta U+W$$

Substitute $Q=0$:

$$0=\Delta U+W \Rightarrow \Delta U=-W0$$

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1. Work Done in Adiabatic Process:

For an adiabatic process involving an **ideal gas**, work done is given by:

$$W = \frac{P_2V_2 - P_1V_1}{1-\gamma}$$

Alternatively, using the relation $PV\gamma=\text{constant}$, the work can also be written in terms of **initial and final volumes** as:

$$W = \frac{P_1V_1 - P_2V_2}{\gamma-1}$$

Where:

- $P1, V1$: Initial pressure and volume
- $P2, V2$: Final pressure and volume
- $\gamma=Cp/Cv$: Ratio of specific heats

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2. Change in Internal Energy:

Change in internal energy is:

$$\Delta U=mCv(T2-T1)$$

Where:

- m: Mass of gas
- Cv: Specific heat at constant volume
- T1,T2: Initial and final temperatures

Also, since $Q=0$, from first law:

$$\Delta U=-W$$

Conclusion:

- Work done in adiabatic process:

$$W = \frac{P_1V_1 - P_2V_2}{\gamma-1}$$

- Change in internal energy:

$$\Delta U=-W=mCv(T2-T1)$$

These expressions are fundamental in analyzing adiabatic processes in thermodynamic systems like engines and compressors.

(c) Discuss the primary causes of global warming. What are impacts of global warming? **07**

Answer:

Introduction:

Global warming refers to the **gradual increase in the average temperature of the Earth's atmosphere and oceans**, mainly due to human activities. It is a major environmental concern worldwide.

Primary Causes of Global Warming:

1. **Greenhouse Gas Emissions:**
   - The main cause of global warming is the increase in **greenhouse gases** such as **carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), and fluorinated gases**.
   - These gases trap heat in the atmosphere, creating the **greenhouse**

effect.

2. **Burning of Fossil Fuels:**
    - Combustion of coal, oil, and natural gas for power generation, transportation, and industry releases large amounts of $\mathbf{CO_2}$.
3. **Deforestation:**
    - Cutting down forests reduces the number of trees that can absorb $\mathbf{CO_2}$, increasing the concentration of carbon dioxide in the atmosphere.
4. **Industrialization:**
    - Factories and industrial activities emit greenhouse gases and also contribute to **air pollution**, further warming the environment.
5. **Agricultural Activities:**
    - Livestock farming produces **methane**, a potent greenhouse gas. Use of nitrogen-based fertilizers increases $\mathbf{N_2O}$ emissions.
6. **Waste Management:**
    - Landfills produce methane during the decomposition of organic waste under anaerobic conditions.

Impacts of Global Warming:

1. **Rising Sea Levels:**
    - Melting of glaciers and polar ice caps causes sea levels to rise, leading to **coastal flooding** and erosion.
2. **Extreme Weather Conditions:**
    - Increased frequency of **heatwaves, droughts, floods**, and **cyclones**.
3. **Disruption of Ecosystems:**
    - Many plant and animal species face **extinction** due to changes in temperature and habitat.
4. **Glacier Melting:**
    - Himalayan and polar glaciers are shrinking rapidly, affecting water availability in many regions.
5. **Impact on Agriculture:**
    - Changes in rainfall patterns and increased temperatures **reduce crop yields** and affect food security.
6. **Health Problems:**
    - Higher temperatures increase the risk of **heatstroke, respiratory problems**, and the spread of **vector-borne diseases** such as malaria and dengue.
7. **Ocean Acidification:**
    - Increased CO_2 is absorbed by oceans, making them more acidic and affecting **marine life** like corals and shellfish.

Q.2 **(a)** Write the statements for Boyle's law, Charles's law and Gay-Lussac’s law. **03**

Answer:
1. Boyle’s Law:
Statement:
At constant temperature, the pressure of a given mass of gas is inversely proportional to its volume.
Mathematical form:

$$P \propto \frac{1}{V} \quad \text{or} \quad PV = \text{constant} \quad (T = \text{constant})$$

2. Charles's Law:
Statement:
At constant pressure, the volume of a given mass of gas is directly proportional to its absolute temperature.
Mathematical form:

$$V \propto T \quad \text{or} \quad \frac{V}{T} = \text{constant} \quad (P = \text{constant})$$

3. Gay-Lussac's Law (Pressure Law):
Statement:
At constant volume, the pressure of a given mass of gas is directly proportional to its absolute temperature.
Mathematical form:

$$P \propto T \quad \text{or} \quad \frac{P}{T} = \text{constant} \quad (V = \text{constant})$$

Conclusion:
These three gas laws describe the behavior of gases under different sets of constant conditions and are fundamental to the study of thermodynamics.

(b) What do you mean by non metallic materials? Name any three non metallic materials and state its practical importance. **04**

Answer:
Definition of Non-Metallic Materials:
Non-metallic materials are materials that **do not contain metal elements** and **do not possess metallic properties** such as conductivity, ductility, or luster. These materials are usually **insulating, brittle**, and resistant to **corrosion** and **chemical attacks**. They are widely used in various engineering and industrial applications where metallic properties are not required.

Examples of Non-Metallic Materials and Their Practical Importance:

1. **Rubber:**
   - **Importance:** Used in manufacturing of tires, seals, gaskets, belts, and shock absorbers due to its high **elasticity and flexibility**.
2. **Plastic (Polymer):**
   - **Importance:** Extensively used in **packaging, piping, insulation, gears, and household items** due to its **light weight, corrosion resistance, and moldability**.
3. **Ceramics:**
   - **Importance:** Used in **electrical insulators, cutting tools, tiles, and refractory materials** due to their **high hardness, heat resistance, and electrical insulation** properties.

Conclusion:
Non-metallic materials play a vital role in modern engineering applications where **light weight, corrosion resistance, and insulation properties** are essential. Their use continues to grow in automotive, aerospace, electrical, and construction industries.

(c) With a neat sketch explain Throttling calorimeter. **07**

Answer:
Throttling Calorimeter:
A **throttling calorimeter** is a device used to **determine the dryness fraction** of **wet steam** (i.e., steam containing moisture). It works on the principle of **throttling process**, which is a constant enthalpy (isenthalpic) process.

Principle:

- During throttling, **enthalpy remains constant**:

  h1=h2

- If the steam after throttling becomes **superheated**, its **dryness fraction** can be calculated using steam tables and the superheated temperature.

Construction:

- The apparatus consists of:
  - A **steam inlet pipe** connected to the main steam line.
  - A **throttling orifice or nozzle** which reduces the pressure suddenly.
  - A **pressure gauge** to measure pressure after throttling.
  - A **thermometer** or thermocouple to measure temperature after throttling.
  - An **insulated chamber** to minimize heat losses.

Working:

1. **Wet steam** from the main steam line enters the **throttling calorimeter**.
2. It passes through a **small orifice** where pressure drops suddenly (throttling).
3. After throttling, steam becomes **superheated**, and its **pressure and temperature** are measured.
4. Since no heat or work is added, the **enthalpy before and after throttling remains the same**.
5. Using the data and steam tables, the **dryness fraction (x)** of the steam is calculated.

Neat Labeled Sketch of Throttling Calorimeter:

Calculation:
Let:

- P2: Pressure after throttling
- T2: Temperature after throttling
- h2: Enthalpy after throttling (from superheated steam tables)
- h1=hf + xhfg: Enthalpy of wet steam before throttling

Then:

$$h_1 = h_2 \Rightarrow h_f + xh_{fg} = h_2 \Rightarrow x = \frac{h_2 - h_f}{h_{fg}}$$

Where:

- hf: Enthalpy of saturated liquid
- hfg: Latent heat of vaporization
- x: Dryness fraction of steam

Conclusion:
A **throttling calorimeter** is a simple and effective device used to **determine the quality (dryness fraction)** of steam using the **isenthalpic process** principle. It is especially useful in **steam power plants** and **thermal laboratories**.

OR

(c) 5 kg of air is heated from 25^0 C to 150^0 C. Determine: (i) specific heats, (ii) change in internal energy, (iii) change in enthalpy and (iv) heat supplied. Assume R = 0.287 kJ/kgK and γ = 1.4 for air and work done = 500 kJ. **07**

Answer:
(i) Specific Heats of Air:
We use the following thermodynamic relations:

$$C_p = \frac{\gamma R}{\gamma - 1}, \quad C_v = \frac{R}{\gamma - 1}$$

- $C_v = \frac{0.287}{1.4-1} = \frac{0.287}{0.4} = 0.7175\,\mathrm{kJ/kg}$\cdotpK
- $C_p = \gamma \cdot C_v = 1.4 \times 0.7175 = 1.0045\,\mathrm{kJ/kg}$\cdotpK

(ii) Change in Internal Energy (ΔU\Delta UΔU):

$$\Delta U = m \cdot C_v \cdot (T_2 - T_1)$$

$$\Delta U = 5 \cdot 0.7175 \cdot (1773 - 298) = 5 \cdot 0.7175 \cdot 1475$$

$$\Delta U = 5 \cdot 1058.31 = \boxed{5291.55\,\mathrm{kJ}}$$

(iii) Change in Enthalpy (ΔH\Delta HΔH):

$$\Delta H = m \cdot C_p \cdot (T_2 - T_1)$$

$$\Delta H = 5 \cdot 1.0045 \cdot (1773 - 298) = 5 \cdot 1.0045 \cdot 1475$$

$$\Delta H = 5 \cdot 1481.64 = \boxed{7408.2\,\mathrm{kJ}}$$

(iv) Heat Supplied (Q):
From the **First Law of Thermodynamics**:

$$Q=\Delta U+W$$
$$Q=5291.55+500=5791.55\ \mathrm{kJ}$$

Final Answers (Boxed for exam clarity):
- **(i)** Cv=0.7175 kJ/kg. K Cp=1.0045 kJ/kg
- **(ii)** Change in internal energy, ΔU=5291.55 kJ
- **(iii)** Change in enthalpy, ΔH=7408.2 kJ
- **(iv)** Heat supplied, Q=5791.55 kJ

Q.3 **(a)** State the assumptions made in working of Carnot cycle. Also write down the limitations of Carnot cycle. **03**

Answer:

Assumptions of Carnot Cycle:

1. **All processes are reversible:**
   The Carnot cycle consists of two reversible isothermal and two reversible adiabatic processes.
2. **Working substance is ideal gas:**
   The gas follows the ideal gas laws during all processes.
3. **No friction or losses:**
   The system is free from any mechanical or thermal friction.
4. **Heat transfer takes place isothermally:**
   Heat is added and rejected at constant temperature (during isothermal processes).
5. **Perfect thermal insulation:**
   No heat loss occurs during adiabatic processes due to perfect insulation.
6. **Process is quasi-static:**
   All processes take place infinitely slowly to maintain equilibrium conditions.

Limitations of Carnot Cycle:

1. **Not practical for real engines:**
   The ideal and reversible conditions assumed in the Carnot cycle cannot be achieved in actual machines.
2. **Slow process:**
   Due to quasi-static nature, the cycle takes infinite time to complete one cycle, making it impractical for real power generation.
3. **Isothermal heat transfer is difficult to achieve:**
   Maintaining constant temperature during heat addition and rejection is technically not feasible in real systems.
4. **Ideal gas assumption:**
   Real working fluids like steam or refrigerants do not behave as ideal gases under all conditions.

(b) An engine operation on an air-standard Otto cycle has a compression ratio equal to 7. The conditions at the start of compression are 0.1 MPa and 300 K. The pressure at the end of heat addition is 4 MPa. Determine: (i) thermal efficiency, (ii) net work done per kg of air. Take Cv = 0.718 kJ/kg , and γ = 1.4 **04**

Answer:

Given:

Compression ratio $r = 7$

Initial pressure $P_1 = 0.1\,\mathrm{MPa}$, Temperature $T_1 = 300\,\mathrm{K}$

Maximum pressure (after combustion) $P_3 = 4\,\mathrm{MPa}$

Specific heat at constant volume $C_v = 0.718\,\mathrm{kJ/kg}\text{\cdotp}\mathrm{K}$

Ratio of specific heats $\gamma = 1.4$

(i) Thermal Efficiency of Otto Cycle:

For an ideal Otto cycle, the thermal efficiency is given by:

$$\eta = 1 - \frac{1}{r^{\gamma-1}}$$

Substitute the values:

$$\eta = 1 - \frac{1}{7^{1.4-1}} = 1 - \frac{1}{7^{0.4}}$$

$$7^{0.4} \approx 2.408 \Rightarrow \eta = 1 - \frac{1}{2.408} = 1 - 0.4153 = \boxed{0.5847} \text{ or } \boxed{58.47\%}$$

(ii) Net Work Done per kg of Air:

To find net work done, we must first determine the temperatures at different points in the cycle using **isentropic relations**:

Step 1: Find T2 using isentropic compression:

$$T_2 = T_1 \cdot r^{\gamma-1} = 300 \cdot 7^{0.4} = 300 \cdot 2.408 = \boxed{722.4\,\mathrm{K}}$$

Step 2: Use pressure ratio P3/P2 to find T3:

Since process 2–3 is at constant volume,

$$\frac{T_3}{T_2} = \frac{P_3}{P_2} \Rightarrow T_3 = T_2 \cdot \frac{P_3}{P_2}$$

We must first find P_2 using isentropic relation:

$$\frac{P_2}{P_1} = r^{\gamma} = 7^{1.4} \approx 18.38 \Rightarrow P_2 = 0.1 \cdot 18.38 = \boxed{1.838\,\mathrm{MP}}$$

Now find T_3:

$$T_3 = 722.4 \cdot \frac{4}{1.838} = 722.4 \cdot 2.176 = \boxed{1572.3\,\mathrm{K}}$$

Step 3: Find T4 using isentropic expansion:

$$\frac{T_4}{T_3} = \left(\frac{1}{r}\right)^{\gamma-1} \Rightarrow T_4 = T_3 \cdot r^{-(\gamma-1)} = 1572.3 \cdot \frac{1}{2.408} = \boxed{652.9\,\mathrm{K}}$$

Now calculate Net Work Done per kg of air:

Wnet=Cv·[(T3−T4) −(T2−T1)]

Wnet=0.718·[(1572.3−652.9) −(722.4−300)] =0.718·[919.4−422.4]

=0.718·497.0

Wnet=356.65 kJ/kgW

Final Answers:

- **(i)** Thermal Efficiency = 58.47%
- **(ii)** Net Work Done = 356.65 kJ/kg

(c) Derive equation for air standard efficiency of diesel cycle. **07**

Answer:
Introduction:
The **Diesel cycle** is the ideal cycle for compression ignition (CI) engines. It consists of **two adiabatic**, **one constant pressure**, and **one constant volume** process.

Processes in Diesel Cycle:

1. **1–2**: Isentropic compression
2. **2–3**: Constant pressure heat addition
3. **3–4**: Isentropic expansion
4. **4–1**: Constant volume heat rejection

Assumptions (Air-Standard Assumptions):

- Working fluid is **ideal gas (air)**.
- All processes are **reversible**.
- Specific heats are **constant**.
- Combustion is replaced by equivalent **heat addition**.

Let:

- r=V1/V2 = **compression ratio**
- rc=V3/V2 = **cut-off ratio**
- γ=Cp/Cv = **ratio of specific heats**

Step 1: Efficiency Definition

η=1−Qout/Qin

Step 2: Heat Added (Constant Pressure 2–3)

Qin=Cp(T3−T2)

Step 3: Heat Rejected (Constant Volume 4–1)

Q out = Cv (T4−T1)

Step 4: Efficiency Expression

$$\eta = 1 - \frac{C_v(T_4 - T_1)}{C_p(T_3 - T_2)} = 1 - \frac{T_4 - T_1}{\gamma(T_3 - T_2)}$$

Now express all temperatures in terms of T1 using isentropic relations.

Step 5: Use Isentropic Relations

From **Process 1–2** (Isentropic Compression):

$$T_2 = T_1 \cdot r^{\gamma-1}$$

From **Process 2–3** (Constant Pressure Heat Addition):

$$T_3 = T_2 \cdot r_c = T_1 \cdot r^{\gamma-1} \cdot r_c$$

From **Process 3–4** (Isentropic Expansion):

$$T_4 = T_3 \cdot \left(\frac{1}{r_c}\right)^{\gamma} = T_1 \cdot r^{\gamma-1} \cdot r_c \cdot \left(\frac{1}{r_c}\right)^{\gamma} = T_1 \cdot r^{\gamma-1} \cdot r_c^{1}$$

Step 6: Substitute in Efficiency Expression

$$\eta = 1 - \frac{T_4 - T_1}{\gamma(T_3 - T_2)}$$

Now substitute the values of T_2, T_3, T_4:

$$\eta = 1 - \frac{T_1\left(r^{\gamma-1} \cdot r_c^{1-\gamma} - 1\right)}{\gamma \cdot T_1\left(r^{\gamma-1}(r_c - 1)\right)}$$

Cancel T_1 from numerator and denominator:

$$\eta = 1 - \frac{r^{\gamma-1} \cdot r_c^{1-\gamma} - 1}{\gamma \cdot r^{\gamma-1}(r_c - 1)}$$

✅ **Final Expression:**

$$\boxed{\eta = 1 - \frac{r_c^{1-\gamma} - \frac{1}{r^{\gamma-1}}}{\gamma(r_c - 1)}}$$

or simplified:

$$\boxed{\eta = 1 - \frac{1}{r^{\gamma-1}} \cdot \frac{r_c^{\gamma} - 1}{\gamma(r_c - 1)}}$$

Conclusion:

The air-standard efficiency of the Diesel cycle depends on:

- Compression ratio r,
- Cut-off ratio rc, and

- Specific heat ratio γ

Higher compression ratio and lower cut-off ratio result in higher efficiency.

OR

Q.3 **(a)** Give difference between SI and CI engines. **03**

Answer:
Difference between SI and CI Engines:

S.No.	**SI Engine (Spark Ignition Engine)**	**CI Engine (Compression Ignition Engine)**
1.	Ignition is done using a **spark plug**.	Ignition is done by **compression of air**, no spark plug is used.
2.	Works on the **Otto cycle**.	Works on the **Diesel cycle**.
3.	**Petrol** or gasoline is used as fuel.	**Diesel** is used as fuel.
4.	Compression ratio is **low** (6:1 to 10:1).	Compression ratio is **high** (14:1 to 22:1).
5.	Thermal efficiency is **lower**.	Thermal efficiency is **higher**.
6.	Used in **light vehicles** like cars, bikes.	Used in **heavy vehicles** like trucks, buses.

Conclusion:
The **SI engine** uses external ignition and lighter fuels, while the **CI engine** relies on high compression to ignite heavier fuel. Each is suited to different types of vehicles and performance requirements.

(b) The following data were noted for a 4-cylinder, 4-stroke engine: **04**
Diameter = 101 mm, stroke = 114 mm, engine speed = 1600 rpm, fuel consumption = 0.204 kg/min, heating value of fuel = 41,800 kJ/kg, difference in either side of the brake pulley = 378 N, brake pulley radius = 3.35 m. Assume mechanical efficiency = 83%.
Calculate: (i) brake thermal efficiency, (ii) indicated thermal efficiency, (iii) fuel consumption per brake power.

Answer:
Step-by-Step Solution:

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1. Brake Power (BP):
Brake power is calculated using the formula:

$$BP = 2\pi r\, NF/60$$

Where:
- $r = 3.35$ m
- $N = 1600$ rpm
- $F = 378$ N

$$BP = \frac{2 \cdot \pi \cdot 3.35 \cdot 1600 \cdot 378}{60}$$

$$BP = \frac{12751550.27}{60} = \boxed{212525.8\,\mathrm{W}} = \boxed{212.53\,\mathrm{kW}}$$

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2. Heat Supplied by Fuel (Q_{in}):

$$Qin = \dot{m}\ f \cdot CV = 0.0034 \cdot 41800 = 142.12\ \mathrm{kW}$$

(Note: Since BP > Qin, recheck unit conversion: Fuel consumption = 0.204 kg/min = **0.0034 kg/s**, CV = 41,800 kJ/kg, so power input is correctly calculated.)

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3. Brake Thermal Efficiency (η_{bth}):

$$\eta_{bth} = \frac{BP}{Q_{\mathrm{in}}} = \frac{212.53}{142.12} = \boxed{1.495}$$

🔴 **This is not possible.** Brake thermal efficiency **cannot be more than 100%.**
Let's revisit the **brake power calculation**, suspecting an issue with pulley radius.

🔄 **Correct Brake Power Calculation:**
Pulley radius is **too large** at 3.35 m (realistic values are around 0.335 m). Let's **assume a typo**, and take:

$$r = 0.335\ \mathrm{m}$$

Now,

$$BP = \frac{2 \cdot \pi \cdot 0.335 \cdot 1600 \cdot 378}{60} = \frac{1275135.6}{60} = \boxed{21252.26\,\mathrm{W}} = \boxed{21.25\,\mathrm{kW}}$$

✅ Now this is realistic.

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4. Brake Thermal Efficiency (Revised):

$$Q_{\mathrm{in}} = 0.0034 \cdot 41800 = \boxed{142.12\,\mathrm{kW}}$$

$$\eta_{bth} = \frac{21.25}{142.12} = \boxed{0.1495} = \boxed{14.95\%}$$

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5. Indicated Power (IP):

$$\eta_{mech} = \frac{BP}{IP} \Rightarrow IP = \frac{BP}{\eta_{mech}} = \frac{21.25}{0.83} = \boxed{25.6\,\mathrm{kW}}$$

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6. Indicated Thermal Efficiency (η_{ith}):

$$\eta_{ith} = \frac{IP}{Q_{\mathrm{in}}} = \frac{25.6}{142.12} = \boxed{0.18} = \boxed{18.02\%}$$

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7. Fuel Consumption per Brake Power (Specific Fuel Consumption):

$$\text{BSFC} = \frac{\dot{m}_f}{\text{BP}} = \frac{0.0034}{21.25} = \boxed{0.00016\,\text{kg/s}\backslash\text{cdotpkW}} = 0.00016 \cdot 3600 = \boxed{0.576\,\text{kg/kWh}}$$

✅ **Final Answers:**

- **(i) Brake thermal efficiency** = 14.95%
- **(ii) Indicated thermal efficiency** = 18.02%
- **(iii) Fuel consumption per brake power** = 0.576 kg/kW

(c) Explain with neat sketch four stoke diesel engine. **07**

Answer:
Introduction:
A **four-stroke diesel engine** is an internal combustion engine in which the **cycle is completed in four strokes of the piston** (two revolutions of the crankshaft). It operates on the **Diesel cycle** and uses **compression ignition** to burn fuel.

Neat Labeled Sketch:

Working of Four-Stroke Diesel Engine:

1. **Suction Stroke:**
   - **Inlet valve opens**, exhaust valve remains closed.
   - Piston moves from **Top Dead Center (TDC) to Bottom Dead Center (BDC)**.
   - **Only air** is drawn into the cylinder.
   - No fuel is injected at this stage.
2. **Compression Stroke:**
   - Both valves are **closed**.
   - Piston moves from **BDC to TDC**.
   - Air is **highly compressed**, and its temperature rises significantly (up to ~600–700°C).
3. **Power Stroke (Expansion):**
   - At the end of compression, **fuel is injected** into the hot compressed air.
   - Fuel auto-ignites due to **high temperature** (compression ignition).
   - Rapid combustion causes **high pressure**, pushing the piston from **TDC to BDC**.
   - This is the **only stroke that produces power**.
4. **Exhaust Stroke:**
   - **Exhaust valve opens**, inlet valve remains closed.
   - Piston moves from **BDC to TDC**, pushing burnt gases out of the cylinder.
   - Cycle repeats.

Conclusion:
In a **four-stroke diesel engine**, the cycle is completed in **four strokes**: suction, compression, power, and exhaust. It is widely used in **heavy-duty applications** such as trucks, buses, generators, and marine engines due to its **fuel efficiency and durability**.

Q.4 **(a)** What is priming? Why is it required in centrifugal pump? **03**

Answer:
Priming (Definition):
Priming is the process of **filling the suction pipe, casing, and a portion of the delivery pipe of a centrifugal pump with liquid (usually water)** before starting the pump. This ensures that **no air pockets** remain inside the pump.

Why Priming is Required:

1. A **centrifugal pump cannot handle air** because it operates on the principle of **centrifugal force**.
2. If air is present in the pump casing or suction pipe, the **impeller cannot generate sufficient pressure** to lift the liquid.
3. **Without priming**, the pump will **run dry**, leading to **no discharge**, **vibration**, or even **damage to internal components**.
4. Therefore, priming is essential to ensure the **initial suction head** and to allow **continuous flow** of the liquid.

✅ **Conclusion:**
Priming is a **necessary step** before operating a centrifugal pump to **remove air** and **allow proper liquid flow** through the pump. Without it, the pump **fails to function** effectively.

(b) Explain with P-V diagram need of multi staging in reciprocating air compressor. **04**

Answer:
Introduction:
In a **single-stage reciprocating air compressor**, when air is compressed from **atmospheric pressure to high pressure** in one stroke, it results in:

- Excessive work input
- High temperature rise
- Poor volumetric efficiency
- Risk of mechanical failure due to heat

To overcome these limitations, **multi-stage compression** is used.

Need for Multi-Staging in Air Compressor:

1. **Reduces Work Input:**
   - Dividing the compression process into multiple stages with **intercooling** between stages reduces the total work required for compression.
2. **Temperature Control:**
   - With intercooling between stages, **temperature of air is lowered** before entering the next stage. This reduces thermal stresses on parts and improves efficiency.
3. **Improves Volumetric Efficiency:**
   - Cooler air entering each stage occupies **less volume**, improving the volumetric efficiency of the compressor.
4. **Reduces Load on Components:**
   - By dividing pressure increase into smaller steps, the load on piston, cylinder, and valves is **reduced**, enhancing mechanical reliability.
5. **Enables Higher Final Pressures:**

- Multi-staging is **essential** when **very high delivery pressures** are required, which is not practical in single-stage systems.

P–V Diagram of Multi-Stage Compression:

(c) Explain with neat sketch working of Babcock and Wilcox boiler. **07**

Answer:
Introduction:
A **Babcock and Wilcox boiler** is a **water-tube, horizontal, externally fired, natural circulation** type boiler. It is widely used in **thermal power plants** for generating steam at **high pressure and capacity**.

Neat Labeled Sketch:

Construction Details:

- **Steam Drum**: Positioned at the top; stores steam and water mixture.
- **Water Tubes**: Connected to the steam drum; inclined to assist natural circulation.
- **Mud Drum**: Located at the bottom to collect sediments and impurities.
- **Furnace**: Located below the water tubes, where coal is burned.
- **Baffles**: Direct the flow of hot gases across the water tubes multiple times.
- **Chimney**: Expels flue gases into the atmosphere.
- **Superheater**: Used to further heat the saturated steam.

Working Principle:

1. **Fuel burning** occurs on the **grate** in the furnace, producing **hot gases**.
2. These hot gases pass over the **water tubes** and transfer heat to the water inside.
3. **Water circulates naturally** from the drum to the tubes due to density differences (convection).
4. Heat from gases converts water into **steam**, which rises back to the steam drum.
5. **Baffles** guide the hot gases over the tubes multiple times to increase efficiency.
6. The **saturated steam** may pass through the **superheater** before being sent to the turbine or engine.
7. Finally, **flue gases exit through the chimney**.

Advantages:

- High steam generation rate (up to 20,000 kg/hr).
- Operates at pressures up to 40 bar.
- Good heat transfer due to large heating surface area.
- Easy maintenance and cleaning.

Conclusion:
The **Babcock and Wilcox boiler** is one of the most efficient water-tube boilers, suitable for **high-pressure applications** in modern thermal power plants due to its **excellent circulation, high capacity**, and **reliability**.

OR

Q.4 (a) Define boiler. Also mention at least five essential requirements of a good boiler. **03**

Answer:
Definition of Boiler:
A **boiler** is a **closed vessel** in which water is converted into steam by **applying heat** generated from the combustion of fuel. The steam produced is used for **power generation, heating, or industrial purposes**.

Essential Requirements of a Good Boiler:

1. **Efficient Heat Transfer:**
   A good boiler should ensure **rapid and efficient transmission of heat** from the combustion gases to the water.
2. **Minimum Fuel Consumption:**
   It should consume **less fuel** to generate maximum steam output.
3. **Quick Starting:**
   The boiler should **start quickly** and reach the desired pressure and temperature in minimum time.
4. **Safety in Operation:**
   It must be equipped with **safety valves, water level indicators**, and other necessary fittings to ensure safe operation.
5. **Simple Construction and Maintenance:**
   The design should allow for **easy cleaning, inspection, and repair**.
6. **Durability:**
   Made from **high-quality materials** to ensure long life under high pressure and temperature conditions.
7. **Low Cost of Installation:**
   Should be economical to install and operate.

✅ **Conclusion:**
A good boiler is one that provides **efficient steam generation** with **safe, economical, and durable operation** under working conditions.

(b) Give comparison between reciprocating and centrifugal pump. **04**

Answer:
Comparison between Reciprocating and Centrifugal Pump:

S.No.	**Reciprocating Pump**	**Centrifugal Pump**
1.	Positive displacement pump	Dynamic (non-positive displacement) pump
2.	Delivers a **fixed amount** of fluid with each stroke	Delivers **variable discharge** depending on speed and head

3.	Operates with **piston or plunger** moving back and forth	Operates with **rotating impeller**
4.	Suitable for **high pressure, low flow** applications	Suitable for **high flow, low pressure** applications
5.	Requires **priming** only in case of suction lift	Requires **priming before every start**
6.	Generally used for **small discharge at high head**	Used for **large discharge at moderate head**
7.	More complex, **higher maintenance** required	Simple in construction, **low maintenance**
8.	Pulsating flow	Continuous and smooth flow

✅ **Conclusion:**
The **reciprocating pump** is ideal for precise, high-pressure applications, whereas the **centrifugal pump** is more efficient for large-scale fluid transport in **domestic, agricultural, and industrial systems**.

(c) What do you mean by mounting and accessories? Enlist different boiler mountings and accessories with their functions. **07**

Answer:
Definition:

🔹 **Boiler Mountings:**
Boiler mountings are the **essential safety devices and fittings** that are **mounted on the boiler** to ensure **safe and efficient operation**. These are **legally required** for a boiler to operate.

🔹 **Boiler Accessories:**
Boiler accessories are the **auxiliary parts** that help in **improving the efficiency and performance** of the boiler but are **not essential** for its basic operation.

✅ **Boiler Mountings (with Functions):**

S. No.	Mounting	Function
1.	**Water Level Indicator**	Shows the level of water inside the boiler drum.
2.	**Pressure Gauge**	Measures steam pressure inside the boiler.
3.	**Safety Valve**	Releases steam automatically when pressure exceeds the safe limit to prevent explosion.
4.	**Steam Stop Valve**	Controls the flow of steam from the boiler to the steam pipe.
5.	**Feed Check Valve**	Allows water to enter the boiler and prevents its backflow.
6.	**Blow-off Cock**	Removes mud, impurities, and sediments from the bottom of the boiler.
7.	**Fusible Plug**	Melts and extinguishes fire in the furnace when water level is dangerously low.

✅ **Boiler Accessories (with Functions):**

S. No.	Accessory	Function
1.	**Economizer**	Heats feedwater using flue gases, increasing efficiency.
2.	**Air Preheater**	Increases the temperature of air before it enters the furnace.
3.	**Superheater**	Converts saturated steam into dry and superheated steam.
4.	**Injector**	Forces feedwater into the boiler using steam pressure.
5.	**Steam Separator**	Removes water particles from steam to improve quality.

Conclusion:

- **Mountings** are essential for the **safe operation** of the boiler.
- **Accessories** are used to **improve efficiency** and **performance**.
- A good boiler must be equipped with all **necessary mountings** and may include suitable **accessories** for economical operation.

Q.5 **(a)** Define the terms: Refrigeration, Refrigeration effect and Coefficient of Performance. **03**

Answer:

1. Refrigeration:

Refrigeration is the **process of removing heat** from a substance or space to **maintain it at a temperature lower** than the surrounding temperature.
It involves **transfer of heat** from a low-temperature body to a high-temperature body using **external work**.

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2. Refrigeration Effect:

Refrigeration effect is the **amount of heat removed** (in kJ or kcal) from the space or substance to be cooled in a refrigeration cycle.
It represents the **cooling capacity** of the system.

- **Unit**: kJ or TR (Tonne of Refrigeration)
- **1 TR = 210 kJ/min = 3.5 kW**

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3. Coefficient of Performance (COP):

The **Coefficient of Performance (COP)** is the ratio of the **refrigeration effect produced** to the **work input** required to produce that effect.

$$\text{COP} = \frac{\text{Refrigeration Effect (Q_L)}}{\text{Work Input (W)}}$$

- For refrigerators, COP is usually **greater than 1**.
- **Higher COP** means **better efficiency**.

✅ **Example Summary:**

Term	Meaning
Refrigeration	Heat removal to maintain lower temperature

Refrigeration Effect	Amount of heat extracted (cooling effect)
COP	Efficiency ratio = Cooling produced / Work input

(b) Write down comparison between Belt, Chain and Gear drive. **04**

Answer:
Comparison between Belt, Chain, and Gear Drives:

S. No.	**Belt Drive**	**Chain Drive**	**Gear Drive**
1.	Uses **flexible belt** over pulleys.	Uses **linked chains** over sprockets.	Uses **meshing gears** for power transmission.
2.	**Slips** may occur.	No slip, but **some elongation** over time.	**No slip**, provides exact velocity ratio.
3.	Suitable for **long-distance** power transmission.	Suitable for **moderate-distance** transmission.	Suitable for **short-distance** and **high torque** transmission.
4.	Can transmit **moderate power** at **high speed**.	Can transmit **more power** than belts.	Can transmit **very high power** and torque.
5.	**Quiet** and smooth operation.	Slightly noisy due to metal contact.	**Noisy** at high speeds.
6.	**Low cost**, simple maintenance.	**Moderate cost** and maintenance.	**High cost**, requires precise alignment.

✅ **Conclusion:**

- **Belt drives** are economical and suitable for flexible power transmission.
- **Chain drives** are more efficient with less slip.
- **Gear drives** are best where **exact speed ratio and high torque** are required.

(c) Explain with neat sketch vapour compression refrigeration system. **07**

Answer:
Introduction:
The **Vapour Compression Refrigeration System (VCRS)** is the **most widely used refrigeration system**, commonly found in **refrigerators, air conditioners, and cold storage systems**. It works on the principle of **removing heat from a low-temperature region and rejecting it at a higher temperature** using a refrigerant.

✅ **Main Components of VCRS:**

1. **Compressor**
   - Compresses low-pressure refrigerant vapour into high-pressure,

high-temperature vapour.

2. **Condenser**
   - Condenses the high-pressure vapour into liquid by **rejecting heat** to the surroundings.
3. **Expansion Valve (Throttle Valve)**
   - Reduces the pressure and temperature of the liquid refrigerant before it enters the evaporator.
4. **Evaporator**
   - Absorbs heat from the refrigerated space and converts low-pressure liquid refrigerant into vapour.

✅ **Neat Labeled Sketch:**

Working of Vapour Compression Cycle:

1. **Compression:**
   - The **low-pressure vapour** refrigerant from the evaporator enters the **compressor**, where it is compressed to **high pressure and temperature**.
2. **Condensation:**
   - The **high-pressure vapour** enters the **condenser**, where it releases heat to the surroundings and condenses into **high-pressure liquid**.
3. **Expansion:**
   - The **high-pressure liquid** then passes through the **expansion valve**, which reduces its pressure and temperature, converting it into a **low-pressure, low-temperature mixture**.
4. **Evaporation:**
   - The cold refrigerant enters the **evaporator**, where it absorbs heat from the space to be cooled and **evaporates** into low-pressure vapour.
   - This vapour is then sent back to the **compressor**, and the cycle repeats.

✅ **Conclusion:**

The **vapour compression refrigeration system** is a **closed-loop system** that efficiently removes heat from a low-temperature space and is widely used due to its **high efficiency**, **compact design**, and **reliable performance**.

OR

Q.5 **(a)** Define air conditioning. Also give the classification of air conditioning system. **03**

Answer:

Definition of Air Conditioning:

Air conditioning is the process of **treating air** in order to **control simultaneously** its:

- **Temperature**
- **Humidity**
- **Purity**
- **Air motion (circulation)**

It is done to provide **comfort for human beings** or to meet the **requirement of a specific process**.

📘 *As per ASHRAE (American Society of Heating, Refrigerating and Air Conditioning Engineers):*
"Air conditioning is the process of treating air to control its temperature, humidity, cleanliness, and distribution to meet the comfort of occupants or the needs of a process."

✅ **Classification of Air Conditioning Systems:**
Air conditioning systems can be classified into the following types:
1. **Based on Purpose:**
   - **Comfort Air Conditioning** (used in homes, offices, etc.)
   - **Industrial Air Conditioning** (used in factories, labs, etc.)
2. **Based on Season:**
   - **Winter Air Conditioning System**
   - **Summer Air Conditioning System**
   - **Year-round Air Conditioning System**
3. **Based on Arrangement:**
   - **Central Air Conditioning System**
   - **Unitary or Room Air Conditioning System**

✅ **Conclusion:**
Air conditioning is essential in modern living and industrial processes. Its classification helps in selecting the appropriate system for different applications like **residential, commercial, or industrial environments**.

(b) Explain with a neat sketch working of internal expanding shoe brake. **04**

Answer:
Introduction:
An **internal expanding shoe brake** is a type of **drum brake** in which the **brake shoes expand outward** and press against the **inner surface of a rotating drum** to produce braking action. It is commonly used in **automobiles, motorcycles**, and **light vehicles**.

✅ **Neat Labeled Sketch:**

Labeling includes: Brake drum, brake shoes, return springs, actuating cam or lever, friction lining.

✅ **Construction:**
- **Brake Drum:** Attached to the rotating wheel.
- **Brake Shoes:** Two curved metal pieces with **friction lining**, mounted inside the drum.
- **Actuating Mechanism:** Usually a **cam** or **hydraulic piston** that pushes the shoes outward.
- **Return Springs:** Pull the shoes back when braking force is released.

✅ **Working Principle:**
1. When the brake is applied, the **actuating cam rotates** or **hydraulic piston pushes**, forcing the **brake shoes outward**.
2. The **friction lining** on the shoes presses against the **inner surface of the**

drum.
3. Due to **friction**, the rotating drum slows down or stops, thereby braking the wheel.
4. When the brake is released, the **return springs** pull the shoes back to their original position, clearing the drum surface.

✅ **Applications:**

- Used in **automobiles** (rear wheels), **bicycles**, and **light commercial vehicles**.

✅ **Conclusion:**

The **internal expanding shoe brake** is a reliable and widely used braking mechanism that operates using **frictional resistance** between expanding shoes and the rotating drum. It provides effective braking in compact and economical design.

(c) What do you mean by the word 'Friction clutches'? Explain with neat sketch working of a centrifugal clutch. **07**

Answer:

Definition of Friction Clutch:

A **friction clutch** is a mechanical device used to **connect and disconnect power transmission** from the engine to the gearbox or driven shaft. It works on the principle of **friction** developed between **driving and driven surfaces** when they are brought in contact.

It allows **smooth engagement** of power, particularly useful in automobiles and machines.

✅ **Centrifugal Clutch – Neat Labeled Sketch:**

Working of Centrifugal Clutch:

1. The **central hub** is connected to the engine shaft (input), and the **outer drum** is connected to the output shaft.
2. When the engine speed is **low**, the clutch shoes are held inward by **springs** or **gravity**, and **no contact** occurs with the drum—**no power is transmitted**.
3. As the engine speed **increases**, **centrifugal force** causes the shoes to **move outward**.
4. At a certain speed, the shoes **come in contact with the inner surface of the drum**, and due to **friction**, the **rotational motion is transferred** to the drum (output shaft).
5. The clutch **automatically engages** at a certain speed and **disengages** when the speed falls below the threshold.

✅ **Applications:**

- Used in **scooters**, **mopeds**, **go-karts**, **lawn mowers**, and **automatic machines** where **gradual engagement** is required.

✅ **Advantages:**

- **Automatic engagement and disengagement** based on speed.
- **Smooth operation**, no sudden jerks.
- No external control required.

✅ **Conclusion:**

A **centrifugal clutch** is a type of **friction clutch** that operates automatically using **centrifugal force**. It is ideal for applications where **speed-sensitive automatic control** of power transmission is needed.

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