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Apr-25

DIPLOMA EXAMINATION IN ENGINEERING/TECHNOLOGY/MANAGEMENT/ COMMERCIAL PRACTICE – APRIL-2025

P-12

4021

THERMAL ENGINEERING

PART–A

1	Open system	1	1
2	An extensive property is a property of a system that depends on the amount of matter present in the system. It changes when the system size or mass changes. eg: Volume, mass , Enthalpy, Entropy, Heat Capacity etc.	1	1
3	The air standard efficiency of the Otto cycle is given by the expression, $\eta_{\text{otto}} = 1 - \frac{1}{r^{\gamma-1}}$ ☐ r = Compression ratio (V1/V2) ☐ γ= Ratio of specific heats (Cp/Cv)	1	1
4	Brake Power (BP) is the actual power delivered by an engine at the output shaft, after overcoming internal friction and other losses. It is the usable power available for performing work. BP=2πNT/60	1	1
5	Valve timing.	1	1
6	Superheating.	1	1
7	Watt per meter-Kelvin (W/m·K)	1	1
8	E= σT^4 • E = Radiant energy emitted per unit area (W/m²) • σ = Stefan-Boltzmann constant • T = Absolute temperature of the surface (K)	1	1
9	A grey body is a material or object that does not absorb or emit radiation perfectly like a black body, but instead has an emissivity (ε) that is less than 1 and constant for all wavelengths.	1	1

PART B

1	$\delta Q = dU + PdV$ $For\ ideal\ gas:\ dU = C_v dT\ (\ U\ as\ function\ T\ and\ V)$ $\rightarrow\ \delta Q = C_v dT + PdV$ $with\ dV = \left(\frac{\partial V}{\partial T}\right)_P dT$ $\rightarrow\ \delta Q = C_v dT + P\left(\frac{\partial V}{\partial T}\right)_P dT$ $\rightarrow \frac{\delta Q}{dT} = C_v + P\left(\frac{\partial V}{\partial T}\right)_P$ $\left(\frac{\delta Q}{dT}\right)_P = C_p; V = \frac{nRT}{P}$ $\rightarrow C_p = C_v + nR$	1 1 1	3
2	Joule's Law states that the heat produced in a conductor due to the flow of electric current is directly proportional to the square of the current, the resistance of the conductor, and the time for which current flows $H = I^2Rt$ H = Heat generated (Joules) I= Electric current (Amperes) R= Resistance of the conductor (Ohms) t = Time for which current flows (Seconds)	2 1	3

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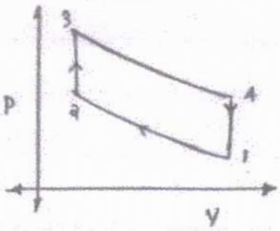

process 1-2 : Isentropic compression.
process 2-3 : constant volume heat addition.
process 3-4 : Isentropic expansion.
process 4-1 : constant volume heat rejection.
$$\eta_{otto} = 1 - \frac{\text{Heat rejected } (Q_r)}{\text{Heat supplied } (Q_s)}$$
$$Q_s = mC_v(T_3 - T_2)$$
$$Q_r = mC_v(T_4 - T_1)$$
$$\eta_{otto} = 1 - \frac{mC_v(T_4 - T_1)}{mC_v(T_3 - T_2)}$$
$$\eta_{otto} = 1 - \frac{T_4 - T_1}{T_3 - T_2}$$
$$\eta_{otto} = 1 - \frac{T_1(r^{\gamma-1} - 1)}{T_3(1 - r^{1-\gamma})}$$
$$\eta_{otto} = 1 - \frac{1}{r^{\gamma-1}}$$
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Parameter	2-Stroke Petrol Engine	4-Stroke Petrol Engine
Power Stroke per Revolution	1 power stroke per revolution of the crankshaft	1 power stroke per 2 revolutions of the crankshaft
Efficiency	Lower efficiency due to incomplete combustion	Higher efficiency due to complete combustion
Power Output	Higher power output for the same engine size due to more power strokes	Lower power output compared to a 2-stroke engine of the same size
Fuel Consumption	Higher due to fuel wastage and incomplete combustion	Lower due to better fuel utilization
Cost	Generally cheaper to manufacture	More expensive due to complex design
Applications	Used in motorcycles, chainsaws, boats, and lawnmowers	Used in cars, bikes, and generators where efficiency matters

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5	The **heat balance test** is based on the **First Law of Thermodynamics**, which states that energy cannot be created or destroyed, only transferred or transformed. The principle of the test is: Heat Supplied=Useful Work Output+Heat Losses Qin=W+Qloss	2 1	3
6	Lower temperature = 27°C = 27+273=300 K Higher temperature = 377°C = 377+273=650 K $\eta\text{Carnot} = 1 - \frac{300}{650}$ =53.8 %	1 2	3
7	Using steam tables, we extract the values: At P_1 = 48.263 bar, T_1= 359.99 h_1(specific enthalpy) = 3131.8kJ / kg s_1(specific entropy) = 6.8132kJ /Kg-K At P_2= 9.65 bar, s_2 =s_1= 6.8132 kJ / kg -K: Interpolating from the steam table for isentropic conditions, h_2= 2784.6kJ / kg Δh= h_2-h_1= 2784.6−3131.8 =−347.2 kJ/kg	1 1 1	3
8	Absorptivity (α) is the fraction of incident radiation that a material absorbs at a given wavelength. It is a dimensionless quantity and ranges from 0 to 1 Emissivity is the ratio of the radiation emitted by a surface to the radiation emitted by a black body at the same temperature. It indicates how efficiently a surface emits thermal radiation. Reflectivity is the fraction of incident radiation that is reflected by a surface rather than being absorbed or transmitted	1 1 1	3

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<tr><th>Free Convection</th><th>Forced Convection</th></tr>
<tr><td>Heat transfer due to natural fluid movement caused by density differences.</td><td>Heat transfer due to external forces like fans, pumps, or blowers.</td></tr>
<tr><td>Buoyancy forces due to temperature differences.</td><td>Mechanical forces (external source) create fluid motion.</td></tr>
<tr><td>- Heat rising from a hot surface.
- Cooling of a hot metal plate in air.
- Warm air rising from a heater.</td><td>- Heat exchangers with fans/pumps.
- Cooling in car radiators.
- Air conditioning systems.</td></tr>
<tr><td>Uncontrolled, depends on temperature differences</td><td>Controlled, depends on external power source.</td></tr>
<tr><td>Heat Transfer Rate Generally lower, as it depends on natural circulation</td><td>Generally higher, due to forced fluid movement.</td></tr>
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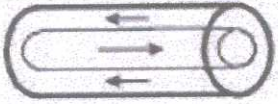

Counter flow heat exchanger

In a counter flow heat exchanger, hot and cold fluids enter the exchanger from opposite ends. As they move through the exchanger, heat is transferred from the hotter fluid to the cooler fluid.

Working Process:

- One fluid (hot) enters from one end, while the other fluid (cold) enters from the opposite end.
- They move in opposite directions through separate channels.
- Heat is transferred continuously along the length of the exchanger.
- The temperature difference between the fluids remains relatively high throughout the process, improving efficiency.
- The cold fluid progressively heats up as it moves along the exchanger.
- The hot fluid progressively cools down.
- The maximum possible heat exchange occurs due to the maintained temperature gradient.
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PART C

III	(a) System: A system is a specific quantity of matter or a region in space selected for analysis in thermodynamics. It is separated from the rest of the environment by a boundary, which can be real or imaginary	2	7
	(b) Surroundings: The surroundings refer to everything outside the system's boundary that can interact with the system by exchanging energy or matter.	2	
	(c) Universe: The universe in thermodynamics is the sum of the system and its surroundings.	1	
	(d) State: The state of a system is defined by its properties (such as pressure, temperature, and volume) at a specific moment	1	
	(e) Properties: Properties are measurable characteristics of a system that describe its state.	1	
	OR		
IV	An **adiabatic process** is a thermodynamic process in which **no heat transfer** occurs between the system and its surroundings.	2	7
	For adiabatic process, $pv^{\gamma} = \text{constant}$ workdone $w = \int p \cdot dv$ $p = \frac{c}{v^{\gamma}}$ $w = \int_{v_1}^{v_2} \frac{c}{v^{\gamma}} \cdot dv$ Since $v = p_1 v_1^{\gamma} = p_2 v_2^{\gamma}$ $w = \int_{v_1}^{v_2} p_1 v_1^{\gamma} \cdot v^{-\gamma} \cdot dv$ $w = \frac{p_1 v_1 - p_2 v_2}{\gamma - 1}$ For ideal gas $pv = nRT$ $w = \frac{nR(T_1 - T_2)}{\gamma - 1}$ where w = workdone, P_1, V_1, T_1 are initial pressure, volume, temperature $\gamma = \frac{C_p}{C_v}$ (adiabatic index)	5	

V	$T2=T1\times(V2/V1)=470\times0.2/0.1=940$ K $\Delta T=T2-T1=940-470=470$ K $m=(0.8\times0.10)/(.287*470)=0.000593$ kg $\Delta U=(0.000593)\times(0.718)\times(470)=0.201$ kJ	**Eqns: 3** **substitution :4**	7
	OR		
VI	For a **constant volume** process, the heat supplied to the gas is entirely used to increase its internal energy $\delta Q=dU+\delta W$ $\delta W=PdV$ Since volume is constant ($dV=0$) $\delta W=0$ $\delta Q=dU+0$ $\delta Q=dU$ The heat supplied at constant volume is given by $Q=mCv\Delta T$ Similarly, the change in internal energy is $\Delta U=mCv\Delta T$ Thus, $Q=\Delta U$ Where δQ = heat supplied to the system, dU = change in internal energy, δW = work done by the system.		7
VII	$T1=377+273=650$ K $T2=37+273=310$ K $Q=290$ kJ $\eta=1-(T2/T1)$ $\eta=1-(310/650)$ $\eta=52.31\%$ Heat Rejected to the Sink $Q=290\times(1-0.5231)=138.3$ kJ $W=290-138.3=151.7$ kJ	**Eqns: 3** **substitution :4**	7
	OR		
VIII	when one cylinder of a multi-cylinder engine is cut off (by stopping fuel supply or disabling the spark plug), the total brake power of the engine decreases. The difference in power before and after cutting off the cylinder represents the **indicated power (IP)** of that cylinder.	4	7
	The **indicated power (IP) of the disabled cylinder** is calculated as: IP cylinder=BP−BP′ BP′ (reduced brake power) IPtotal=∑IP each cylinder FP=IPtotal−BP	3	

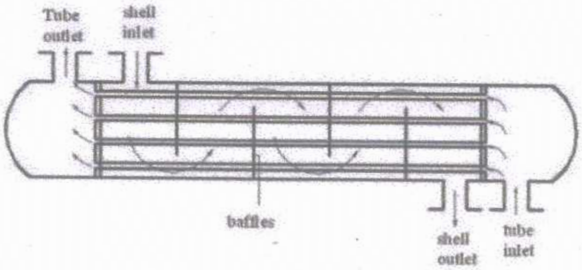
IX	☐ **Saturation Temperature (T_s):** The temperature at which water boils and transforms into steam at a given pressure. • At 10 bar, the saturation temperature is approximately **179.9°C**.	2	7
	☐ **Specific Enthalpy of Saturated Liquid (h_l):** The heat content per unit mass of water at the saturation temperature, before it starts to vaporize. • At 10 bar, the specific enthalpy of the saturated liquid is approximately **762.81 kJ/kg**.	2	
	☐ **Specific Enthalpy of Dry Saturated Steam (h_s):** The heat content per unit mass of steam at the saturation temperature, after complete vaporization. • At 10 bar, the specific enthalpy of dry saturated steam is approximately **2,778.11 kJ/kg**.	3	
	OR		
X	Unlike an impulse turbine, where steam expands in stationary nozzles, in a reaction turbine, steam expands gradually in both the fixed and moving blades.	2	
	• **Steam Expansion in Fixed Blades:** • High-pressure steam enters the **fixed blades (stators)**, which are shaped like nozzles. • The steam expands and **gains velocity**, directing it towards the **moving blades (rotors)**.	3	
	• **Steam Expansion in Moving Blades:** • The **moving blades** also act like small nozzles, where further **expansion of steam** occurs. • This creates a **reaction force** on the blades, which produces rotation.		7
	• **Continuous Energy Conversion:** • As steam moves through multiple **stages** of fixed and moving blades, energy is continuously extracted. • The turbine shaft rotates, converting **thermal energy into mechanical energy**.		
	Key Characteristics of a Reaction Steam Turbine: • **Pressure drops gradually** across both fixed and moving blades.	2	

	• Steam **accelerates in the fixed blades** and **further expands in the moving blades**. • Suitable for **high-power applications** like power plants. • Requires **more stages** than impulse turbines due to gradual expansion. • Needs **steam sealing** (Labyrinth glands) to prevent leakage.		
XI	**Boiler mountings** are **safety and control devices** installed on a boiler to ensure **safe and efficient operation**. They help in monitoring and controlling steam pressure, water level, and other critical parameters ☐ **Safety Valve**: Automatically releases excess steam when the pressure exceeds a safe limit to prevent boiler explosion. ☐ **Water Level Indicator**: Shows the water level inside the boiler to prevent dry running and overheating. ☐ **Pressure Gauge**: Measures and displays the steam pressure inside the boiler. ☐ **Blow-off Valve**: Removes sediments and impurities from the boiler by draining water at intervals.	3 4	7
	OR		
XII	1. Higher Efficiency: • Water tube boilers have better heat transfer efficiency as water flows through tubes surrounded by hot gases, ensuring rapid heat absorption. 2. Higher Pressure Handling Capacity: • They can operate at higher pressures (above 100 bar), making them ideal for power plants and industrial applications. 3. Faster Steam Generation: • Due to the large heating surface area, water tube boilers generate steam faster than fire tube boilers. 4. Lightweight and Compact Design: • They are lighter and more compact for the same power output, making them ideal for ships and power plants. 5. Safer Operation: • Water tube boilers are less prone to explosion because water is contained in small tubes rather than a large drum, reducing stored energy.	7	7

	6. Better Control Over Steam Production: • These boilers allow better control of steam temperature and pressure, making them suitable for applications requiring superheated steam. 7. Ability to Handle High Loads and Fluctuations: • They can quickly adjust to load variations, making them ideal for power plants where steam demand fluctuates.		
XIII	3. Shell and tube heat exchanger Construction: 1. Shell – A large cylindrical container that holds the second fluid and allows heat exchange. 2. Tubes (Tube Bundle) – A set of tubes placed inside the shell through which one of the fluids flows. 3. Tube Sheets – Plates that hold the tubes in place at both ends. 4. Baffles – Plates inside the shell that direct the fluid flow and improve heat transfer efficiency. 5. Inlet & Outlet Ports – Separate openings for hot and cold fluids to enter and exit. ☐ Fluid Flow Arrangement • One fluid (hot) enters the tubes through the hot fluid inlet. • The other fluid (cold) enters the shell through the cold fluid inlet and surrounds the tubes. ☐ Heat Transfer Process • Heat is transferred from the hot fluid inside the tubes to the cold fluid in the shell through the tube walls. • The baffles direct the cold fluid to move in a controlled manner, ensuring maximum heat exchange. ☐ Exit of Fluids • The now-cooled hot fluid exits through the hot fluid outlet.	4 3	7

- The cold fluid, after absorbing heat, exits through the cold fluid outlet.

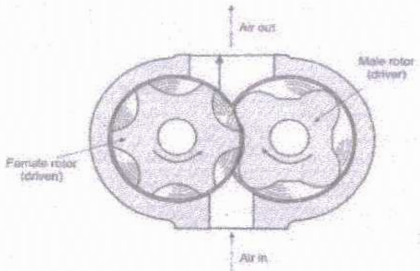
XIV



OR

1. Screw Compressor (Rotary Screw Compressor)

- A **rotary screw compressor** uses **two helical screws (rotors)** rotating in opposite directions inside a casing.
- The air enters through the **inlet valve** and gets trapped between the screw lobes.
- As the screws rotate, the air moves along the length of the rotors, getting **compressed due to decreasing volume**.
- The compressed air exits through the **discharge valve** at high pressure.



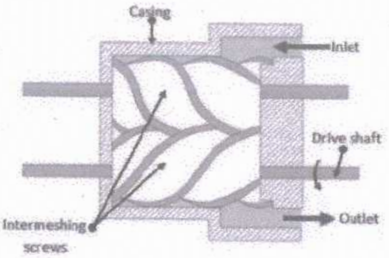


Figure :4
Explanation :3

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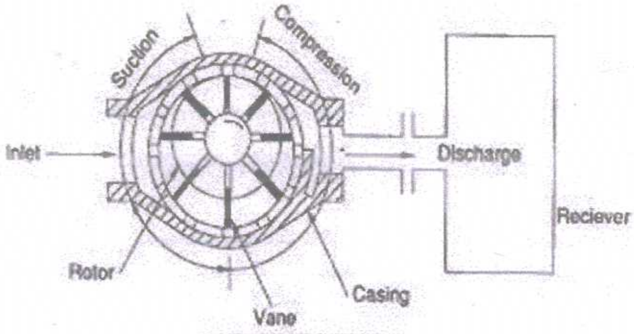
✓Continuous and smooth operation with minimal pulsations.
✓ High efficiency and suitable for high-volume air supply.
✓ Used in industrial applications like manufacturing, power plants, and HVAC systems.

2. Vane Compressor (Rotary Vane Compressor)



Vane Compressor

- A rotary vane compressor consists of a cylindrical rotor with sliding vanes inside a stator.
- As the rotor spins, the vanes move outward due to centrifugal force and create air pockets.
- These pockets reduce in size as they move toward the discharge side, compressing the air.
- The compressed air exits through the discharge port.

Key Features:

✓ Simple design with fewer moving parts.
✓ Suitable for medium-pressure applications like automotive and small industrial uses.
✓ Provides consistent and reliable airflow.