VERSION-D

TED (10)3043

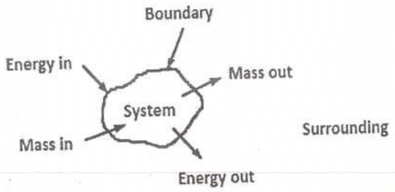
REVISION-10

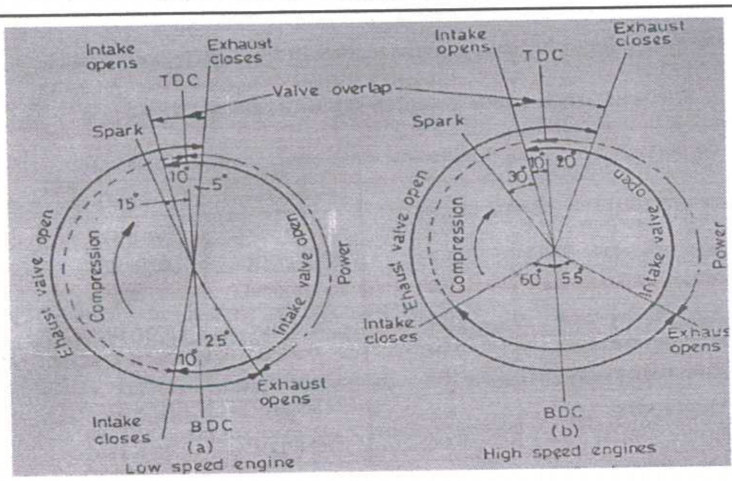
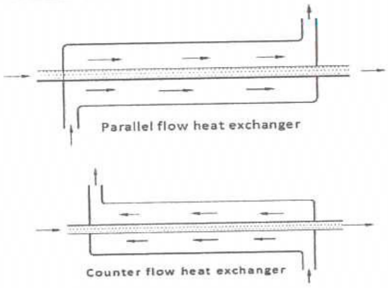
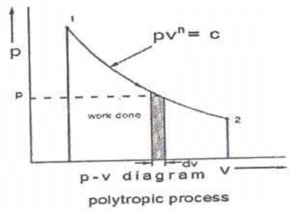
FOURTH SEMESTER DIPLOMA EXAMINATION IN MECHANICAL ENGINEERING

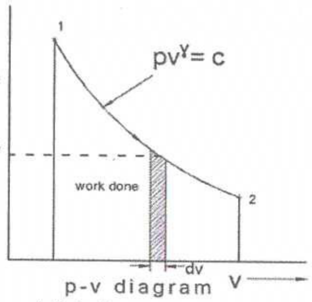
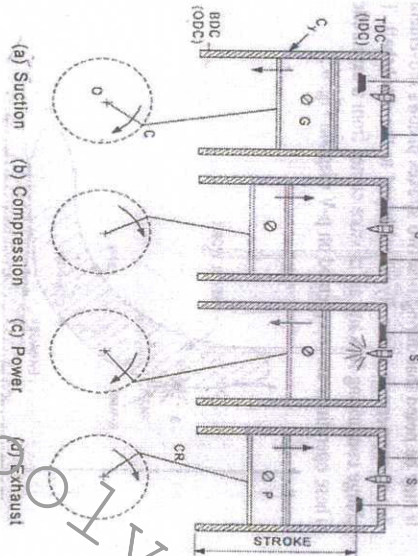
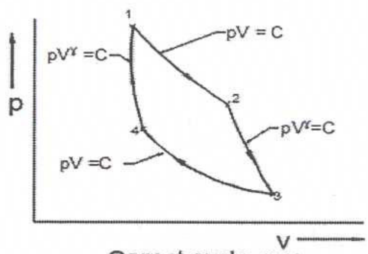
MAX. Marks-100

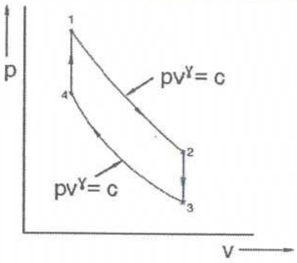
THERMAL ENGINEERING

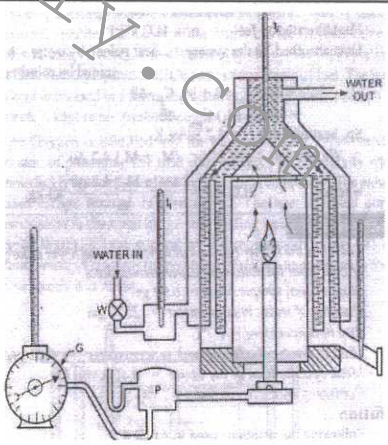
scoring indicator

Q. no.		PART - A	Split scor	Total score
I	1	Open system is one in which, the system permits the transfer of mass and energy across the boundary of the system 	2	
	2	Zeroth law of thermodynamics states that if two systems 'A' and 'B' are in thermal equilibrium with each other and 'B' in thermal equlibrium seperatly with a third system 'C', then 'A' and 'C' will be in thermal equilibrium with each other. Zero0th law is the basis for temperature measurement.	2	
	3	Air standard efficiency is defined as the ratio of available heat energy for doing external work to the heat supplied during the cycle.	2	
	4	When the heat carried away by the product of combustion is not recovered and the steam formed during combustion is not condensed, then the amount of heat obtained per kg of fuel burned is called lover calorific value (LCV)	2	
	5	1) leakage past the piston, 2) Very high speed of the compressor, 3) Obstruction or resistance in the inlet valve. 4) Over heating of air due to contact with the cylinder walls, 5) Inertia of air in the suction pipe.	any two points- 2marks	10
		PART - B		
II	1	Relation between gas constant and two specific heats of a gas (Relation between R, Cp and Cv) Case 1- Let one Kg of gas at initial condition P1, V1, T1 be heated at constant pressure. Energy equation for the process Q = ΔU + W Work done W = P(v2 – v1) N-M Q = Cp (T2 – T1) (since gas is heated at constant pressure) ΔU = Q – W = Cp (T2 – T1) – P(v2 – v1) Case 2-If the same one Kg of gas is heated at constant volume through the same temperature range, T1 to T2, there is no external work done during the process. There for ΔU = Cv(T2 – T1) N-M Since the gas is heated through the same temperature change, internal energy change is same for both the case. Equating the equation 1 and 2 $C_p(T_2-T_1) - P(v_2-v_1) = C_v(T_2-T_1)$ $C_p(T_2-T_1) - C_v(T_2-T_1) = P(v_2-v_1)$ $C_p(T_2-T_1) - C_v(T_2-T_1) = R(T_2-T_1)$ (Since. $Pv_2=RT_2$, and $P_1v_1 = RT_1$) Dividing both sides with T2 – T1 we will get R = $C_p - C_v$.	6	6
II	2	Given. $V = 6\,m^3$ $m = 26\,kg$ $n = 25$ $t = 15^\circ C = 288K$ $R = \frac{8314}{25} = 332.6\,J/kgK = 0.3326\,kJ/kgK$ $PV = mRT$ $\therefore P = \frac{26 \times 332.6 \times 288}{6 \times 10^2} = 4.15\,bar$	3 + 3	6

<table>
<tr><td>II</td><td>3</td><td>Given. Compression Ratio. $r = 16$, Cut off Ratio. $\rho = 2.5$, $\gamma = 1.4$.
Air Standard η $= 1 - \frac{1}{16^{0.4}}\left[\frac{2.5^{1.4}-1}{1.4(2.5-1)}\right]$ $\quad\Big|\quad \eta = 1 - \frac{1}{r^{\gamma-1}}\left[\frac{\rho^{\gamma}-1}{\gamma(\rho-1)}\right]$
$= 1 - \frac{1}{3.03} \times \frac{2.61}{2.1} = \underline{\underline{59\%}}$</td><td>6</td><td>6</td></tr>
<tr><td>II</td><td>4</td><td>
</td><td>Any one of the figure</td><td>6</td></tr>
<tr><td>II</td><td>5</td><td>1) It should have low ignition point, 2) High calorific value, 3) It shouls burn freely with high efficiency, 4) It should not produce any harmfull effect, 5) It should not produce any foul smell, 6) It should produce least quantity of smoke, 7) Can be easily storable and can transport easily.</td><td>at least 4 points.</td><td>6</td></tr>
<tr><td>II</td><td>6</td><td><u>Parallel flow heat exchangers.</u> In this type of heat exchangers hot and cold fluid flows in the same direction. The hot and cold fluid enters on the same side and leaves at the other side.
<u>Counter flo heat exchangers</u>. In this type of heat exchangers hot and cold fluid flows in the opposite direction. The flow arrangement is shown in figure.

</td><td>Fig' 3 marks Explenation 3marks.</td><td>6</td></tr>
<tr><td>II</td><td>7</td><td>Air compressors are classified as follows :
<table>
<tr><th></th><th>Criterion</th><th>Name of Compressor</th></tr>
<tr><td>1.</td><td>Design</td><td>Reciprocating
Rotary</td></tr>
<tr><td>2.</td><td>Operation</td><td>Single acting
Double acting</td></tr>
<tr><td>3.</td><td>Number of cylinders</td><td>Single cylinder
Multi-cylinder</td></tr>
<tr><td>4.</td><td>Number of stages</td><td>Single-stage
Multi-stage</td></tr>
<tr><td>5.</td><td>Pressure limit</td><td>Low pressure
Medium pressure
High pressure</td></tr>
<tr><td>6.</td><td>Method of cooling</td><td>Air cooled
Water cooled</td></tr>
<tr><td>7.</td><td>Installation</td><td>Portable
Fixed</td></tr>
</table></td><td>4 x 1.5</td><td>6</td></tr>
<tr><td>III</td><td>a)</td><td>For Polytropic Process $pv^n = P_1V_1^n$, $P = P_1V_1^n \times \frac{1}{v^n}$
Expansion Work $W_{1-2} = \int_1^2 p\,dv = P_1V_1^n \int_1^2 \frac{1}{v^n}\,dv$
$P_1V_1^n\left[\frac{v^{-n+1}}{-n+1}\right]_1^2 = \frac{P_1V_1^n}{-n+1}\left[V_2^{-n+1} - V_1^{-n+1}\right]$
$\frac{P_2V_2^n \times V_2^{-n+1} - P_1V_1^n \times V_1^{-n+1}}{-n+1} = \frac{P_2V_2 - P_1V_1}{-n+1}$
or $\underline{\underline{\frac{P_1V_1 - P_2V_2}{n-1}}}$ Work done during Polytropic Process.

</td><td>figure 3 marks and explenation</td><td></td></tr>
<tr><td></td><td>b)</td><td>Given. $m = 1kg$, $P_1 = 700\ kN/m^2$, $P_2 = P_1$, $V_1 = 0.28\ m^3$, $V_2 = 1.68\ m^3$
$R = 0.28\ kJ/kg\,K$, $C_p = 1.005\ kJ/kg\,K$
i) Work done $\quad W = P[V_2 - V_1] = 700[1.68 - 0.28] = \underline{980\ kJ}$
ii) Change in Internal energy $\Delta U = mC_v(T_2 - T_1)$
$C_v = 1.005 - 0.28 = 0.725\ kJ/kg\,K$.
$P_1V_1 = mRT_1$, $\therefore T_1 = \frac{700 \times 0.28}{1 \times 0.28} = 700\ K$.
lly $T_2 = \frac{700 \times 1.68}{1 \times 0.28} = 4200\ K$.
$\Delta U = 1 \times 0.725(4200 - 700) = \underline{2537.5}\ kJ$</td><td>4 + 4</td><td>15</td></tr>
</table>

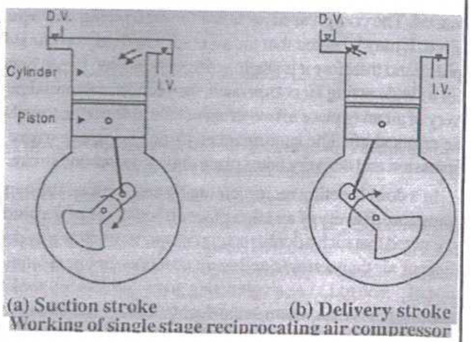
IV	a)	For a Small change in 1kg of gas during Adiabatic process. $dQ = du + Pdv$ Since $dQ=0$ for Adiabatic Process. $0 = C_v dT + Pdv = C_v dT + RT\frac{1}{v}dv \div T$ $= C_v \frac{dT}{T} + R\frac{1}{v}dv$ Integrating $C = C_v \ln T + R \ln V$ $\div C_v$ $C_1 = \ln T + \frac{R}{C_v}\ln V = \ln T + (\gamma-1)\ln V$ $= \ln T + \ln V^{(\gamma-1)} = C_1 \therefore TV^{\gamma-1} = C_2$ $= \frac{PV}{R} \times V^{\gamma-1} = C_2$ or $PV \times V^{\gamma-1} = RC_2$ i.e. $PV^{\gamma} = C$ or $PV^{\gamma} = P_1V_1^{\gamma} = \text{Constant}$. $PV = RT$ $P = RT/V$. $R = C_p - C_v \div C_v$ $\frac{R}{C_v} = \gamma - 1$ $T = \frac{PV}{R}$  p-v diagram Adiabatic process	diagram 2 +derivation5	
IV	b)	Given. $V_1 = 0.15 m^3$, $T_1 = 20°c = 293K$, $P_1 = 1.1$ bar $= 1.1 \times 10^2\ KN/m^2$ $P_2 = 20$ bar $= 20 \times 10^2\ KN/m^2$, $\gamma = 1.4$ i. Final Volume $\frac{V_2}{V_1} = \left(\frac{P_1}{P_2}\right)^{1/\gamma}$ $V_2 = \left(\frac{1.1}{20}\right)^{1/1.4} \times 0.15 = 0.0189\ m^3$ ii. Final Temperature $\frac{T_1}{T_2} = \left(\frac{P_1}{P_2}\right)^{\frac{\gamma-1}{\gamma}} \therefore T_2 = \frac{293}{(1.1/20)^{0.4/1.4}} = 671\ K$ iii. Work done $= \frac{1}{\gamma-1}\left[P_2V_2 - P_1V_1\right] = \frac{1}{0.4}\left[20\times10^2\times0.0189 - 1.1\times10^2\times0.15\right]$ $= 53.25\ KJ$	2 + 2 + 4	15
V	a)	The following four strokes are are caried out in a four stroke petrol engine. 1) Suction stroke- During Suction stroke petrol air mixsture is drawn in to the cylinder. 2) Compression stroke- during compressio9n stroke both valves are closed and as the piston moves from the bottom dead centre to the top dead centre the fuel air mixture is compressed to high pressure and temperature. 3) Expansion stroke- Just before the exopansion stroke the spark plug is activated and the air fuel mixture is ignited. The pressure inside the cylider increasses pushes downward. during expansion stroke external work is done. 4) Exhaust stroke- At the end of expansion stroke exhaust valve is opened and as the piston moves from BDC to TDC the burned gases are ehausted.  	Fig : 4 marks, explenation3marks.	
V	b)	Data Given $\frac{V_4}{V_1} = 5$, $V_1 = 0.3\ m^3$ $T_1 = 550 K$, $P_1 = 21$ bar i) Minimum temperature in the cycle $\frac{T_1}{T_4} = \left(\frac{V_4}{V_1}\right)^{\gamma-1}$ $T_4 = \frac{550}{(5)^{0.4}} = 289\ K$ ii) Thermal efficiency $= \frac{550-289}{550} = 47.45\%$  Carnot cycle p-v diagram	4 + 4	15

<table>
<tr><td>VI</td><td>a)</td><td>$\eta_{otto\,cycle} = \dfrac{\text{Heat Supplied} - \text{Heat Rejected}}{\text{Heat Supplied}}$
Heat Supplied $= mC_v(T_1 - T_4)$
Heat rejected $= mC_v(T_2 - T_3)$
$\eta = \dfrac{mC_v(T_1 - T_4) - mC_v(T_2 - T_3)}{mC_v(T_1 - T_4)}$
$= (T_1 - T_4) - (T_2 - T_3) / T_1 - T_4$.
For Isentropic Process 1-2 — $T_2/T_1 = \left(\frac{V_1}{V_2}\right)^{\gamma-1}$
For Isentropic Process 3-4 — $T_3/T_4 = \left(\frac{V_4}{V_3}\right)^{\gamma-1}$
Since $V_1 = V_4$, $V_2 = V_3$ $T_2/T_1 = T_3/T_4$ i.e. $\frac{T_4}{T_1} = \frac{T_3}{T_2}$
$\eta = \dfrac{T_1(1 - T_4/T_1) - T_2(1 - T_3/T_2)}{T_1(1 - T_4/T_1)}$
$\therefore \eta = \dfrac{T_1 - T_2}{T_1}$ ||ly $\eta = \dfrac{T_4 - T_3}{T_4}$


Otto cycle p-v diagram</td><td>fig-2, derivation 5</td><td></td></tr>
<tr><td>VI</td><td>b)</td><td>Given. $T_3 = 316\,K$, $T_4 = 596\,K$
① $\eta_{otto\,cycle} = \dfrac{T_4 - T_3}{T_4} = \dfrac{596-316}{596}$
$= 47\%$
② Compression Ratio r:
$\eta_{otto} = 1 - \dfrac{1}{r^{\gamma-1}}$ =
$\dfrac{1}{r^{0.4}} = 1 - 0.47$ $\therefore r = 4.89$.</td><td>4 + 4</td><td>15</td></tr>
<tr><td>VII</td><td>a)</td><td>i) <u>Indicated mean effective pressure</u>- The pressure developed inside the engine cylinder varies during the power stroke. The average pressure is calculated from the p-V diagram. This average pressure is called mean effective pressure.
ii) <u>Indicated power</u> - It is the actual power developed inside the engine cylinder during a cycle. It is calculated from the actual mean effective pressure obtained from the indicator diagram. iii) <u>Brake power</u> - It is the actual power or usefull power available at the out put shaft for doing external work. It is always less than the indicated power .</td><td>3+2+2</td><td></td></tr>
<tr><td>VII</td><td>b)</td><td>Given $m_f = 6\,kg/h$, $C_v = 30000\,kJ/kg$
$BP = 20\,kW$, $\eta_m = 80\% = 0.8$
i) Indicated Power $IP = \dfrac{BP}{\eta_m} = \dfrac{20}{0.8} = 25\,kW$
Indicated thermal efficiency $= \dfrac{IP \times 3600}{m_f \times C}$
$= \dfrac{25 \times 3600}{6 \times 30000} = 0.5 = 50\%$
ii Brake thermal efficiency $= \dfrac{BP \times 3600}{m_f \times C} = \dfrac{20 \times 3600}{6 \times 30000}$
$= 0.4 = 40\%$
iii) Specific fuel Consumption $= \dfrac{M_f}{BP} = \dfrac{6}{20} = 0.3\,kg/kWh$</td><td>3 + 3 + 2</td><td>15</td></tr>
<tr><td>VIII</td><td>a)</td><td>Junkers calorimeter is used to find HCV of liquid and gaseous fuels. It consists of a cylindrical combustion chamber surrounded by waterjacket which absorbs heat of combustion. The metered quantity of fuel and air burn to form combustion products. They rise through inner central portionand then flows through tubes surrounded by circulating water and finally leaves the apparatus. Cooling water enters at the bottomand moves upwardsand leaves at the top. HCV is given by the equation 4.2M x dt/V_0 KJ/M^3 where M is the mass of water collected, dt = temperature change of inlet and outlet water, V0 = volume of gas burned at STP

</td><td>Fig 3, explenation 4</td><td></td></tr>
<tr><td>VIII</td><td>b)</td><td>Given. $C = 80\% = 0.8\,kg$, $H_2 = 12\% = 0.12\,kg$, $O_2 = 6\% = 0.06\,kg$
$S = 2\% = 0.02\,kg$.
i) Theoretical Air supply Per kg of fuel $= \dfrac{100}{23}\left[\left(\frac{8}{3}C + 8H_2 + S\right) - O_2\right]kg$
$= \dfrac{100}{23}\left[\left(\frac{8}{3} \times 0.8 + 8 \times 0.12 + 0.02\right) - 0.06\right] kg$.
$= 13.27\,kg$. Ans.
ii) mass of Product of Combustion.
$= \dfrac{11}{3}C + 9H_2 + 2S = \dfrac{11}{3}0.8 + 9 \times 0.12 + 2 \times 0.02$
$= 4.053\,kg$.</td><td>4 + 4</td><td>15</td></tr>
</table>

IX a)

A single stage single acting reciprocating compressor in its simplest form consists of a piston, cylinder, crank shaft connecting rod, inlet and outlet valve. The reciprocating compressor receives work from a prime mover, so that the crank shaft can rotate. As piston starts moving from the TDC to BDc suction starts. Inlet valve opens due to fall in pressure inside the cylinder. Further movement of piston from BDC to TDC, compresses the air traped in the cylinder. as the pressure increases inlet valve closes. As the pressure increases above the reservoir tank pressure the discharge valve opens and the compressed air is delivered to the receiver.



(a) Suction stroke (b) Delivery stroke
Working of single stage reciprocating air compressor

Fig-3 marks, explanation in brief 4 marks.

IX b)

Given. $V_1 = 7.5\ m^3/min$, $P_1 = 1 bar = 1\times10^5\ N/m^2$, $T_1 = 30^\circ c = 303 K$

$P_2 = 5\ bar = 5\times10^5\ N/m^2$ $n = 1.3$.

i) temperature of Air delivered T_2 = temperature of Air delivered.

$$\frac{T_2}{T_1} = \left(\frac{P_2}{P_1}\right)^{\frac{n-1}{n}} = \left(\frac{5}{1}\right)^{\frac{1.3-1}{1.3}} = 1.45$$

$$T_2 = 1.45\times303 = 439.3\ K.$$

ii) Shaft Power required to drive the Compressor

Indicated Power/work done by the Compressor $W = \frac{n}{n-1} P_1V_1\left[(P_2/P_1)^{\frac{n-1}{n}} - 1\right]$

$$= \frac{1.3}{1.3-1}\ 1\times10^5\times7.5\left[(5/1)^{\frac{1.3-1}{1.3}} - 1\right] = 1462.5\ KJ/min$$

Shaft Power required $= \frac{\text{work done by the Compressor}}{\text{Mechanical efficiency}}$

$$= \frac{1462.5}{0.8} = 1827.5\ KJ/min$$

$= \underline{30.46 KW}$. Ans.

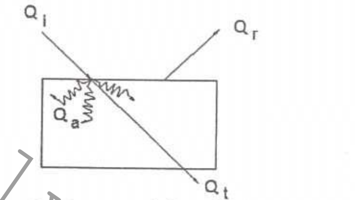
4 + 4

15

X a)

Absorptivity, Rflectivity and Transmissivity

If a thermal radiation fall on a body, a part of the thermal radiation is absorbed by the body, a part of the thermal radiation is reflected by the body and a part of the thermal radiation is transmitted by the body.



absorption, reflection, transmission of incident radiation

7

15

Let Q_i be the incident total radiation energy fall on the body

Q_a be the part of this radiation absorbed by the body

Q_r be the part of the radiation reflected by the body

Q_t be the part of the radiation transmitted by the body

Then $Q_i = Q_a + Q_r + Q_t$

Dividing both sides by Q_i $\quad \frac{Qa}{Qi} + \frac{Qr}{Qi} + \frac{Qt}{Qi} = 1$

$\frac{Qa}{Qi}$ Is the fraction of incident radiation absorbed by the body, called absorptivity 'α'

$\frac{Qr}{Qi}$ Is the fraction of radiation reflected by the body called reflectivity 'ρ'

$\frac{Qt}{Qi}$ Is the fraction of radiation Transmitted by the body called Transmissivity 'τ'

X b)

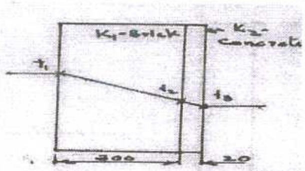
Given $l_1 = 300 mm = 0.3 m.$

$l_2 = 20\ mm = 0.02 m$

$t_1 = 30^\circ c$ $t_3 = 5^\circ c$

Area $= 10\times3 = 30 m^2$

$K_1 = 0.7$, $K_2 = 0.9\ w/m k$



i) Heat transfer $Q = \frac{t_1 - t_3}{L_1/K_1A + \frac{L_2}{K_2A}}$.

$$= 30-5 \Big/ \left[\frac{0.3}{0.7\times30} + \frac{0.02}{0.9\times30}\right] = \frac{25}{0.0143 + 7.4\times10^{-4}}$$

$= \underline{1662 W}$. Ans.

ii) Inter face temperature T_2

$$Q = \frac{T_1 - T_2}{L_1/K_1A} = 1662 = \frac{30 - T_2}{0.0143}$$

$\therefore T_2 = 30 - 0.0143\times1662 = \underline{6.23^\circ C}$.

4 + 4