Name : Enrolment No:	UPES

UNIVERSITY OF PETROLEUM AND ENERGY STUDIES
End Semester Examination, May 2018

Course : I C Engines
Semester : IV **Course Code : ADEG 227**
Program : B. Tech – Automotive Design Engineering **Max. pages : Eleven**
Time : 03 hrs. **Max. Marks : 100**

Instructions:

- **Assume suitable data if missing**
- Draw neat diagrams wherever required
- Give suitable examples in support of your answer
- Be precise in your answer
- Write the Roll No. on the Question Paper also.
- Other than the Roll No. don't write anything on the Question Paper
- Make use of Annexure I & II

SECTION A

S. No.	All Questions are Compulsory	Marks	CO
Q 1	a. Explain the importance of arranging the multi valves in a given cylinder	02	CO1
	b. The air requirement of a petrol engine during starting compared to theoretical air required for complete combustion is	02	CO2
	c. In the electronic unit injector (EUI) both ______________ and ______________ are integrated in one unit	02	CO3
	d. Two main classifications of CRFI are______________ and ________________	02	CO3
	e. ________________ valve controls the start and end of injection in CRFI system	02	CO3
	f. Determine the Quantity of fuel to be injected per cycle per cylinder for a 6 cylinder, 4 stroke diesel engine having bsfc of 245 gm/kw-hr and developing 89 kW at 2500 rpm.	04	CO3
	g. Typical length to diameter ratio of diesel engine injector is in the range of ______________ for a proper atomized spray	02	CO4
	h. The other name of the Pre-mixed combustion is ___________________	02	CO4
	i. Mention the number of factors affect the fuel atomization and droplet size in diesel sprays	02	CO4
	Total Marks	**20**	

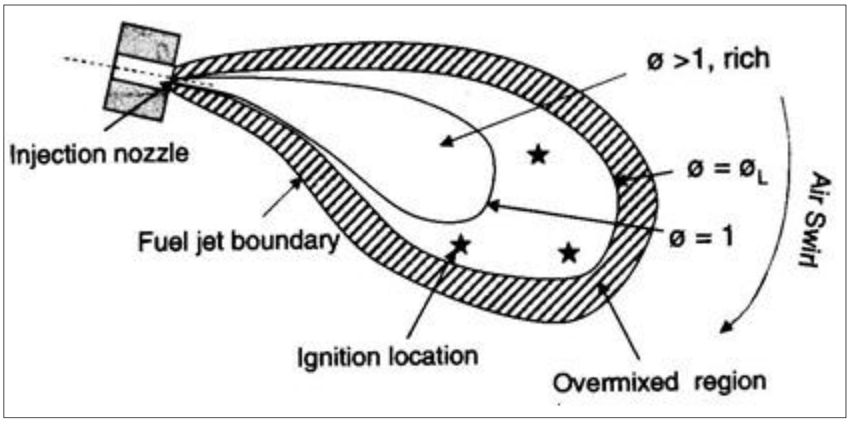
<table>
<tr><td colspan="4">SECTION B</td></tr>
<tr><td>S. No</td><td>All Questions are Compulsory</td><td>Marks</td><td>CO</td></tr>
<tr><td>Q 2</td><td>Analyze the HC emissions from combustion of hydrocarbon fuel under overmixing mode, from the following Figure 1


Figure 1. HC Emission formation in Compression Ignition engines from the fuel spray along with Swirl</td><td>08</td><td>CO4</td></tr>
<tr><td>Q 3</td><td>A Simple jet Carburetor is required to supply 5 kg of air and 0.5 kg of fuel/min. The fuel specific gravity is 0.75, The air is initially at 1 bar and 300 K. Calculate the throat diameter choke for a flow velocity of 100 m/s. Velocity coefficient is 0.8. If the pressure drop across the fuel metering orifice is 0.8 of that of choke, Calculate orifice diameter assuming coefficient of discharge is 0.6 and $\gamma = 1.4$</td><td>08</td><td>CO3</td></tr>
<tr><td>Q 4</td><td>In detail explain the design of Fins in order to optimize heat transfer of Air cooled engine shown in Figure 2.

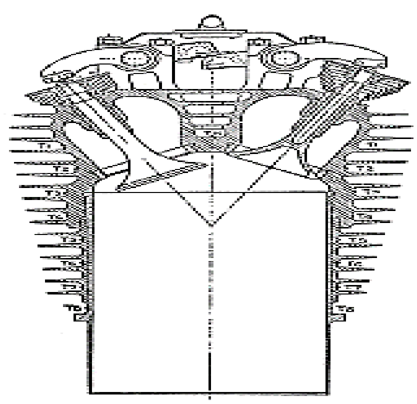
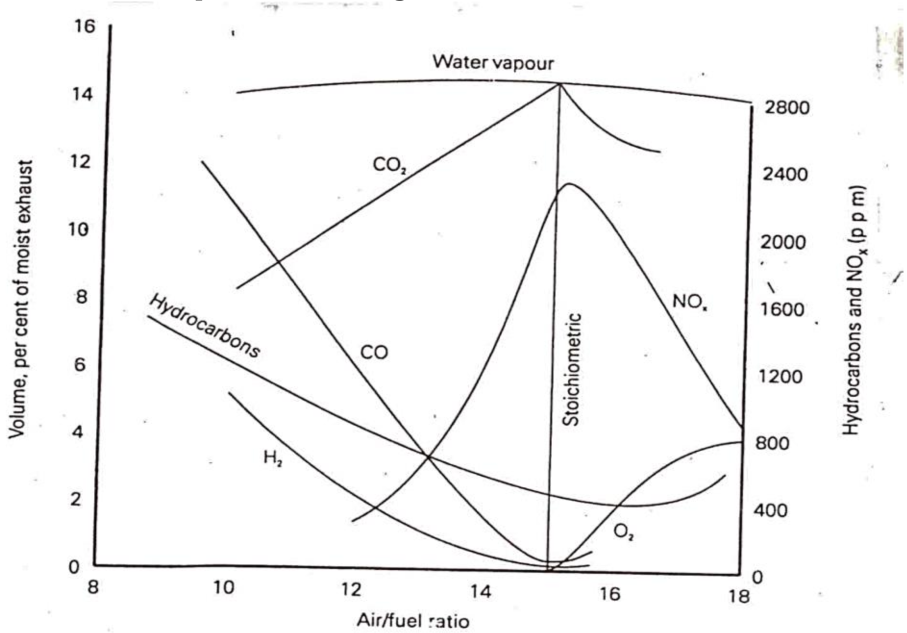
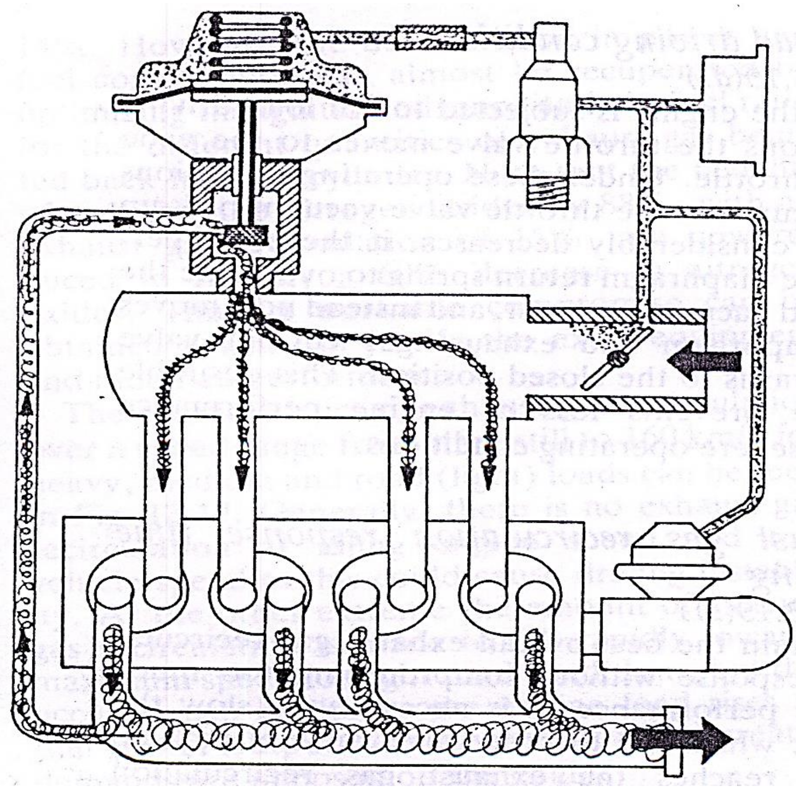



Figure 2 Fins arrangement of an air cooled engine</td><td>08</td><td>CO5</td></tr>
</table>

Q 5	A multi hole diesel injector at an injection pressure of 65 Mpa injects fuel in air at 6.0 MPa. The Nozzle hole diameter is 0.2 mm. Using the following data and single hole of the injector calculate kinematic viscosity in m^2/sec of fuel for the calculated Sauter Mean diameter using El-Kotb equation is 18.9 μm. Density of air = 25 kg/m^3 Density of liquid fuel = 850 kg/m^3 Surface tension of liquid fuel = 0.03 N/m Coefficient of discharge = 0.5 Volume of fuel injected per cycle = 12 x 10^{-9} m^3 Injection time difference = 1.5 x 10^{-3} Dynamic viscosity of air = 4.084 x 10^{-5} kg/m.s Initial Fuel jet velocity = 255 m/s **OR** Fuel is injected from a diesel injector in air at 57.4 bar and 800 K. The injector has following data: Type of Injector = 5 hole Nozzle Nozzle hole diameter = 0.2 mm Discharge coefficient = 0.7 Fuel delivery = 62.5 mm^3/stroke Injection duration = 1.2 x 10^{-3} Sec. Fuel density = 850 kg/m^3 Find the spray break-up time, break-up length and spray penetration with no swirl If the Injector nozzle used in the above problem, injects fuel in an engine operating at 2000 rpm and the swirl ratio is 4. Find the spray penetration and compare to injection in quiescent air.	**08**	**CO4**

Q 6	A Six cylinder, four stroke gasoline engine with a bore of 125 mm and a stroke of 190 mm under test was supplied with petrol composition C= 82% and H_2 = 18% by mass. The dry exhaust composition by volume was CO_2= 11.19%. O_2 =3.61%, and N_2 =85.2%. Determine the mass of air supplied per kg of gasoline, the percentage excess air and the volume of mixture per kg of gasoline, at 17^0 C and 1 bar which were the conditions for the mixture entering the cylinder during the test. Also determine the volumetric efficiency of the engine based on intake conditions when the mass of gasoline used per hour was 31.3 kg and the engine speed was 1500 rpm. The petrol is completely evaporated before entering the cylinder and the effect of its volume on the volumetric efficiency should be included. Take the density of gasoline vapour as 3.35 times that of air at the same temperature and pressure. 1 kg of air at ^{0}C and 1.013 bar occupies 0.773 m^3. Air contains 23% O_2 by mass. OR	**08**	**CO2**
Q 7	A six cylinder natural gas engine is to develop 110 kW at 1600 rpm. The fuel is to be used having heating value of 10287 Kcal/kg and its percentage composition by mass is C=86.2% and H_2=13.5%. The absolute volumetric efficiency is 78% and indicated thermal efficiency is 38%, mechanical efficiency is 80%. Air consumption is 110% in excess of that required for theoretically correct combustion. (1) Estimate the volumetric composition of dry exhaust gas (2) Determine the bore and stroke of the engine, taking the stroke to bore ratio of 1.5 to 1 The volume of 1 kg air is 0.72 m^3. O_2 in air is 23.1% by mass and 20.8% by volume.		
	Total Marks	**40**	

SECTION-C			
Q 8	a. Differentiate the Diurnal emissions with Hot Soak Emissions of SI Engine	**03**	**CO6**
	b. In detail explain the SHED test procedure evolved to test gasoline engines as per US norms	**04**	**CO6**
	c. For the following Figure 3, explain the reasons for their existence at Stoichiometric Air-fuel ratio. Need not to re-produce the Figure 3 in Answer sheet.  **Figure 3 Relation between Exhaust emissions and Air-fuel ratio of a gasoline engine**	**06**	**CO6**
	d. Explain the process of Soot, HC and NOx formation in Diesel engines	**07**	**CO6**
	OR		
Q 9	a. Analyze the NO formation in all three stages like: Thermal NO, Fuel NO and Prompt NO. And also explain chemical reactions proposed by Zeldovich	**07**	**CO6**
	b. Analyze the NO formation in DI and as well as IDI engines and discuss the EGR to control the NOx from diesel engines from Figure 4	**08**	**CO6**

	 **Figure 4 Exhaust Gas Recirculation**		
	c. Analyze the five main sources of HC emissions formation in diesel engines	**05**	**CO6**
	And		
Q 10	In detail characterize the diesel engine combustion process with reference to following a. P-θ diagram for DI and IDI engines b. Differential Heat Release Rate c. Integral Heat Release Rate d. Ignition delay for diesel and vegetable oils e. Influence of Injection timing on combustion of viscous fuels f. Parameters affecting the fuel atomization g. Parameters affecting the fuel vaporization	**14**	**CO4**
	h. Influence of Spray angle on BSHC and PM i. Influence of swirl on BSFC and BSNOx j. Influence of Compression Ration on BSFC, BSNOx, BSHC and PM	**06**	**CO6**
	Total Marks	**40**	

Annexure -I

Empirical Calculations from Literature:

SMD = $2.33 \times 10^3 \, (\Delta P)^{-0.135} \, (\rho_a)^{0.121} (V_f)^{0.131}$ – by Hiroyasu and Kadota in 1974

SMD = $3.08 \times 10^6 \, (\Delta P)^{-0.54} \, (\upsilon_l)^{0.385} (\sigma_l \; x \; \rho_a)^{0.737} \, (\rho_a)^{0.06}$ - by El-Kotb in 1982

For Low injection pressures and injection Velocities by Hiroyasu, Arai and Tabati in 1989

$$SMD = 4.12 \, Re_{jl}^{0.12} \, We_{jl}^{-0.75} \left[\frac{\mu_l}{\mu_a}\right]^{0.54} \left[\frac{\rho_l}{\rho_a}\right]^{0.18} d_n$$

For high injection pressures and velocities

$$SMD = 0.38 \, Re_{jl}^{0.25} \, We_{jl}^{-0.32} \left[\frac{\mu_l}{\mu_a}\right]^{0.37} \left[\frac{\rho_l}{\rho_a}\right]^{-0.47} d_n$$

where	a	-	air
	l	-	liquid fuel
	jl	-	liquid fuel jet

The correlations given by Hiroyasu et al., for spray penetration in quiescent air are as

For $t < t_b$

$$S = 0.551 \left[\frac{\Delta P}{\rho_l}\right]^{1/2} t$$

For $t > t_b$

$$S = 2.95 \left\{\left[\frac{\Delta P}{\rho_a}\right]^{1/2} d_n \; t\right\}^{1/2}$$

Where $t_b = 28.65\, d_n \ \rho_l \left[\frac{1}{\rho_a\, \Delta P}\right]^{1/2}$

And spray break up length is equal to spray penetration at $t = t_b$

$$S_b = S_{t=tb} = 15.8\, d_n \left[\frac{\rho_l}{\rho_a}\right]^{1/2}$$

Spray penetration in presence of swirl, S_s is empirically related with swirl by

$$\frac{S_S}{S} = \frac{1}{\frac{1+(2\Pi Ns\, S)}{U_{jl}}}$$

Supporting Calculations

Calculation of Total Working Fluid

M_t = moles of total working fluid

M_a = moles of air present

M_f = moles of fuel

M_{fc} = moles of fresh charge = $M_a + M_f$

M_{res} = moles of residual gases

$M_a = \alpha M_o$ ($M_{o=}$ kg mole of air/kg of fuel)

$M_t = M_a + M_f + M_{res}$

$= \alpha M_o + {}^1/M_f + \mu . M_{fc}$ ($\mu = M_{res}/ M_{fc}$)

$= (\alpha M_o + {}^1/M_f) + (\alpha M_o + {}^1/M_f) \mu$

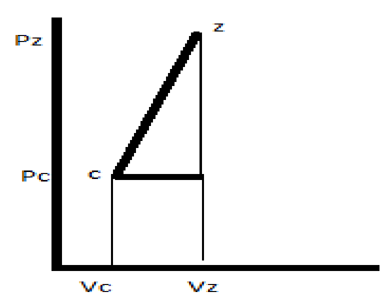
$= (\alpha M_o + {}^1/M_f) (1 + \mu)$

Calculation of Combustion Equation

W=JH

J=A=427 kgf.m/kcal

According to the first law



$Q_{c-z} = U_z - U_c + Al_{cz}$

$U_z = M_z.C_{vmz}.T_z = \beta M_c .mC_{vmz}.T_z$ -------------------(1) $M_z = \beta M_c$ (β=coeff of molar change)

$U_c = M_c.mC_{vmc}.T_c$ -------------------(2)

$Al_{cz}= [(P_z-P_c)/2] * (V_z-V_c)$ -------------------(3) Area of triangle = ½ b.H

$=^1/_2[P_zV_z-P_zV_c\ ^-{}_+ P_cV_z+P_cV_c]$

$=^1/_2[848M_zT_z- P_z V_z/\rho\ ^-{}_+ P_cV_c\rho\ _+848M_cT_c]$ (ratio of preliminary expansion, $\rho= V_z/V_c$,)

$=^1/_2[848M_zT_z-848M_zT_z/\rho\ ^-{}_+848M_cT_c\rho\ _+848M_cT_c]$

$=^1/_2848[M_zT_z(1-1/\rho)\ ^-{}_+ M_cT_c (\rho-1)]$

$l_{cz} =^{848}/_{2x427}[\beta\ M_zT_z(1-1/\rho)- M_cT_c (\rho-1)]$

$=0.99[\beta\ M_zT_z(1-1/\rho)- M_cT_c (\rho-1)]$

$Q_{cz} = \zeta Q_l'B$

$= \beta M_c.mC_{vmz}.T_z - M_c.mC_{vmc}.T_c + 0.99[\beta\ M_zT_z(1-1/\rho) - M_cT_c (\rho-1)]$

Take out common terms of T_c & T_z

$\zeta Q_l'B/M_c = \beta[mC_{vmz}+ 0.99(1-1/\rho)]\ T_z – [mC_{vmc}+0.99(\rho-1)]\ T_c$

for, $mC_{vmz}=a+^1/_2b.T_z$ (correlation for sp. heat)

$\zeta Q_l'B/M_c =\beta[a+^1/_2b.T_z + 0.99(1-1/\rho)]\ T_z – [mC_{vmc}+0.99(\rho-1)]\ T_c$

where $M_c/B = (\alpha M_o+1/M_f) (1+\mu)$

$=\beta_o[a+0.99(1-1/\rho)]T_z + \beta/2\ b\ T_z^2 – [\zeta Q_l'B/M_c +\{ mC_{vmc}+0.99(\rho-1)\}]\ T_c$

$0 = AT_Z^2+BT_z+C$

Gas equation at the end of compression and combustion.

$P_cV_c= M_cT_c$----------------(1)

$P_zV_z= M_zT_z$-----------------(2)

Divide 2 by 1

$P_zV_z/ P_cV_c= M_zT_z/ M_cT_c$ as $V_z/V_c= \rho$ and $M_z/M_c=\beta$

$P_z\rho/P_c= \beta T_z/T_c$

$P_z= \beta/\rho.T_z/T_c. P_c$

Calculation of Expansion Process

$\Delta Qzb = \Delta Uzb + ALzb$ and for temp. the eq. is $T_b = T_z * 1/\delta^{ne-1}$

a) = b) + c) … eq (1)

a) $\Delta Q_{zb} = Q_L.B - Q_L.B.\zeta z - Q_L.B\, W_e$
$= Q_L.B\,(1-\zeta z-W_e)$, kcal/cycle
W_e = relative heat losses
$W_e = 0.05$ to 0.1

b) $\Delta U_{zb} = mC_{vmb}.M_z.T_b - mC_{vmz}.M_z.T_z$

Where; $M_z = (\alpha M_o + 1/m_f).B.(1+\mu)\,\beta$
For fuel qty to be very small as compared to air it can be approximated as;
$M_z = \alpha M_o B(1+\mu)\,\beta$

c) $AL_{zb} = WD = {}^{Vz}\int_{Vb} P.\, dv$ ….. (2)

$P_z V_z^{\,ne} = C = P_b V_b^{\,ne}$ or $P = [\, C/ V^{ne} \,]$ substitute P in eq (2)

$WD = {}^{Vz}\int_{Vb} [\, C/ V^{ne} \,]\, dv = C\, {}^{Vz}\int_{Vb} V^{-ne}\, dv = C\ {}^{Vz}{}_{Vb} [\, V^{-ne+1} / -ne+1 \,]$

$= C\ [\, \{Vb^{-ne+1} - Vz^{-ne+1}\} / \{-ne+1\} \,]$ substitute $C = P_z V_z^{\,ne}$

$= [P_z V_z^{\,ne} / \{-ne+1\}]\,[\, Vb^{-ne+1} - Vz^{-ne+1} \,]$

$= [P_z V_z^{\,ne} . Vz^{-ne+1} / \{-ne+1\}]\,[\, (Vb/Vz)^{-ne+1} - 1 \,]$ substitute $Vb / Vz = \delta$

$= [P_z V_z / 1 - ne\,]\ [\, (\delta^{ne-1} - 1 \,]$

therefore
$AL_{zb} = [P_zV_z/n_e-1][1-(V_z/V_b)^{ne-1}]$ Substituting $V_z/V_b = \delta$ and $P_zV_z = 848\, M_z.T_z$
$AL_{zb} = [(1/427)848 * M_z.T_z/n_e-1][1- \delta^{ne-1}]$

Substitute a), b) and c) in above Eq. (1)

$Q_L.(1-\zeta z-W_e)/\alpha M_o(1+\mu)\beta + mC_{vmz}Tz = mC_{vmb}.T_b + 1.985T_z/(n_e-1)*(1-1/\delta^{ne-1})$

The expansion process calculation (Temp. and Press.) can be done with above Temp. eq. and press eq. as below

$T_b = T_z * 1/\delta^{ne-1}$

$P_b = P_z * 1/ \delta^{ne}$

***