# UNIVERSITI TUN HUSSEIN ONN MALAYSIA

## FINAL EXAMINATION
## SEMESTER II
## SESSION 2011/2012

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| COURSE NAME | : | INTERNAL COMBUSTION ENGINE |
| COURSE CODE | : | BDE 40603/ BDE 4063 |
| PROGRAMME | : | 4 BDD |
| EXAMINATION DATE | : | JUNE 2012 |
| DURATION | : | 2 ½ HOURS |
| INSTRUCTION | : | ANSWER ANY **FOUR (4)** QUESTIONS ONLY |

THIS PAPER CONTAINS SIX (6) PAGES

**Q1** (a) Define the following matters and sketch their configuration:

(i) Displacement volume;

(ii) Bore;

(iii) Stroke;

(iv) Clearance volume; and

(v) Combustion chamber.

(6 marks)

(b) A two-liter engine of six-cylinder that operates on four-stroke cycle at 3600 RPM (revolutions per minute). The compression ratio, $r_c$ is 11, the length of the connecting rods, r is 15.0 cm, and the engine is square (B=S), B = bore, S = stroke. At this speed, combustion ends at 20° TDC (Top-Dead-Center). Calculate:

(i) Cylinder bore, B and stroke length, S;

(ii) Average piston speed $\overline{U_p}$;

(iii) Clearance volume of one cylinder $V_c$;

(iv) Crank offset $R$;

(v) Piston speed at the end of combustion $U_p$;

(vi) Distance the piston has traveled from TDC at the end of combustion, $x$; and

(vii) Volume in the combustion chamber at the end of combustion $V$.

(19 marks)

**Q2** (a) Describe the four-stroke operating cycle and sketch schematically the position of the piston and valves for each type of stroke.

(7 marks)

(b) In an Otto cycle air at 20°C and 1 bar is compressed adiabatically until the pressure is 10 bar. Heat is added at constant volume until the pressure rises to 50 bar. Calculate the air-standard efficiency, the compression ratio and the mean effective pressure for the cycle. Assume $C_v$=0.717 kJ/kgK, $k=1.4$ and R=8.314 kJ/kmolK.

(18 marks)

**Q3** (a) Explain the importance of achieving stoichimetric combustion, rich combustion and lean combustion.

(5 marks)

(b) A 4-cylinder, 2-stroke diesel engine with 20.2 cm bore and 14.5 cm stroke produces 99 kW of brake power at 2200 rpm. The compression ratio, $r_c$ is 19:1. Calculate:

(i) The engine displacement ($cm^3$);
(ii) Brake mean effective pressure (kPa);
(iii) Engine torque (Nm); and
(iv) Clearance volume of one cylinder ($cm^3$).

(20 marks)

**Q4** (a) Explain and sketch the ignition delay period in heat release rate *(dQ/dt)* diagram of diesel engine combustion and discuss based on the relation between mixture formation and ignition process.

(8 marks)

(b) Light diesel ($C_{12}H_{22}$) used for compression ignition engine reacts exothermically with 30% excess air from the surroundings.

(i) Write the chemically balanced equation of the fuel reaction with air;
(ii) Calculate the mass of water that will be produced , assuming complete combustion process has taken place;
(iii) Calculate the air to fuel ratio and the corresponding fuel to air ratio; and
(iv) Determine the equivalence ratio value.

Given; The molecular weight values of Carbon (C), Hydrogen ($H_2$), Nitrogen ($N_2$) and Oxygen ($O_2$) are 12.01, 2.02, 28.01 and 32.00, respectively.

(17 marks)

**Q5** (a) What is Premixed Charge Compression Ignition (PCCI) combustion as shown in Figure 5.0(a) (introduced by Toyota) and how it is improve the combustion process in order to reduce the exhaust emissions.

(5 marks)

(b) What is the *Zeldovich mechanism* and discuss the relation between temperature and NOx-production in diesel combustion.

(5 marks)

(c) Describe the Exhaust Gas Recirculation (EGR) system and explain how EGR reduces the NOx (oxides of nitrogen) emissions.

(5 marks)

(d) List five reasons that influence the hydrocarbons (HC) emissions in the exhaust of an automobile.

(5 marks)

(e) What are catalytic converters and how are they helpful in reducing HC, Carbon Monoxide (CO) and NOx emissions.

(5 marks)

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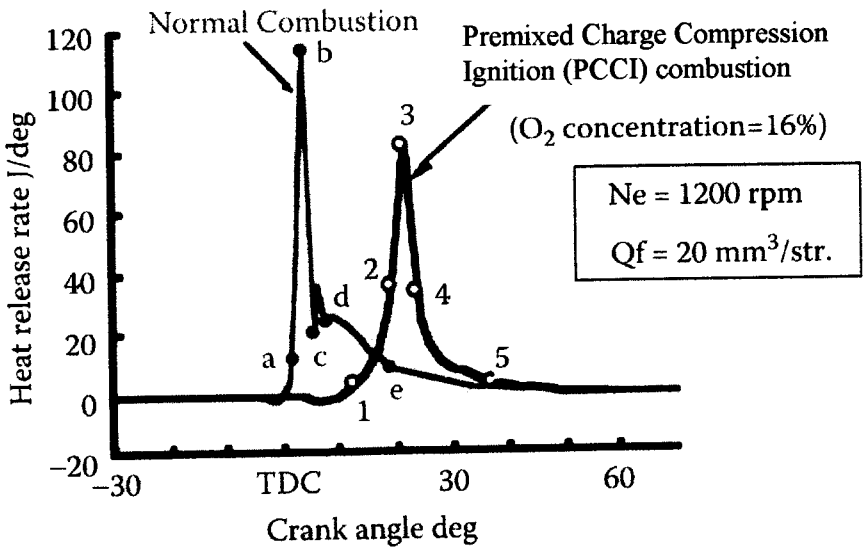


**Figure Q5 (a)**

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Piston speed, $\overline{U_P} = 2SN$

Compression ratio, $r_c$ is defined as : $r_c = V_{BDC} / V_{TDC}$, $r_c = (V_d + V_c) / V_c$

Instantaneous piston speed; $\frac{U_p}{\overline{U_p}} = \left(\frac{\pi}{2}\right)\sin\theta\left[1 + \left(\frac{\cos\theta}{\sqrt{R^2 - \sin^2\theta}}\right)\right]$, $R = r/a$, $a = S/2$

Piston position or the distance between the crank axis and wrist pin axis or piston is given by, s:

$$s = a\cos\theta + \sqrt{r^2 - \sin^2\theta}$$

Where a = crankshaft offset, r = connecting rod length and $\theta$ = crank angle, measure from the centerline and it is zero when the piston is at TDC

Distance from TDC , $x = r + a - s$

Instantaneous volume, V at any crank angle, $\theta$ : $\frac{V}{V_c} = 1 + \frac{1}{2}(r_c - 1)\left[R + 1 - \cos\theta - \sqrt{R^2 - \sin^2\theta}\right]$

Vc = clearance volume, R = r/a

For an engine with $N_c$ cylinders, displacement volume , $V_d$ :

$V_d = V_{BDC} - V_{TDC}$ $V_d = N_c\left(\frac{\pi}{4}\right)B^2S$ Where B = cylinder bore, S = stroke, S=2a

The cylinder volume at any crank angle is given by: $V = V_c + \left(\frac{\pi B^2}{4}\right)(r + a - s)$, Where $V_c$ = clearance volume

Brake work of one revolution, $W_b$ : $W_b = 2\pi T$; $W_b = \frac{V_d(bmep)}{n}$, Where T = engine torque, bmep = brake mean effective pressure, n = number of revolutions percycle

Mean effective pressure; $mep = \frac{Wn}{V_d N}$

Engine torque, T, for 2-stroke and 4-stroke cycles: $T_{2-stroke} = \frac{V_d(bmep)}{2\pi}$ $T_{4-stroke} = \frac{V_d(bmep)}{4\pi}$

Engine power, $\dot{W} = \frac{WN}{n}$ , $\dot{W} = 2\pi NT$ , N = engine speed

Specific fuel consumption $sfc = \frac{\dot{m}_f}{\dot{W}}$