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UNIVERSITI TUN HUSSEIN ONN MALAYSIA

FINAL EXAMINATION
SEMESTER II
SESSION 2014/2015

COURSE NAME	:	INTERNAL COMBUSTION ENGINE
COURSE CODE	:	BDE 40603
PROGRAMME	:	4 BDD
EXAMINATION DATE	:	JUNE 2015 / JULY 2015
DURATION	:	3 HOURS
INSTRUCTION	:	ANSWER ANY **FIVE (5)** QUESTIONS ONLY

THIS PAPER CONTAINS SIX (7) PAGES

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Q1 (a) **Figure 1 (a)** shows the influences of turbocharger that increasing the air density in combustion chamber. As seen in Figure 1 (a), it clearly illustrate the histories of combustion pressure p_f and heat release rate dQ/dt together with nozzle needle lift NL against time, t from start of injection. Explain the influences of the changes of ambient density on combustion process.

(5 marks)

(b) Define the following matters with the aid of sketch:

(i) Combustion chamber;
(ii) Displacement volume;
(iii) Cubic capacity;
(iv) Clearance volume; and
(v) Compression ratio.

(5 marks)

(c) A 4.5 liter, 4-cylinder, two-stroke S.I engine is connected to an electrical power generator of 250 volt. At 1800 rpm, the generator produces 55 amps of current with operating efficiency of 86%. Determine:

(i) The power output of the engine (in kW and hp); and
(ii) The engine torque (Nm).

(10 marks)

Q2 (a) State three basic engine designs and sketch their configuration.

(3 marks)

(b) Explain the working principle of four-stroke and two-stroke of internal combustion engine.

(3 marks)

(c) A three-litre engine of six-cylinder is designed to operate on diesel combustion with a four-stroke cycle at 4300 RPM (revolutions per minute). The compression ratio, r_c is 10.5, the length of the connecting rods, r is 14.5 cm, and the engine is square *(B=S)*, *B* = bore, *S* = stroke. At this speed, combustion ends at 20° *TDC* (Top-Dead-Centre). 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*.

(14 marks)

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

(3 marks)

(b) Diesel combustion engines prove more attractive than spark ignition engines with referring to the fuel consumption and thermal efficiency. However, the key element in diesel combustion is the influences fuel-air premixing during the ignition delay on ignition process. Explain and construct the ignition delay period in heat release rate *(dQ/dt)* diagram of diesel engine combustion. Discussion should be focused on the relation between mixture formation and ignition process.

(4 marks)

(c) A 4-cylinder, 2-stroke diesel engine with 11 .5 cm bore and 13.8 cm stroke produces 98 kW of brake power at 2600 rpm. The compression ratio, r_c is 17:1. 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).

(13 marks)

Q4 (a) Explain the phenomena of knock in Spark Ignition (S.I) engine.

(2 marks)

(b) Explain and compare Spark Ignition and Compression Ignition engines with respect to
(i) Ignition process; and
(ii) Heat release.

(3 marks)

(c) 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.

(15 marks)

Q5 (a) **Figure Q5 (a)** shows combustion characteristics with changed ambient pressure and density. Ignition delay τ, which is the amount of heat absorption Q_{ab} during ignition delay period, combustion duration ΔQ_b, total heat release Q_t, and maximum heat release rate $(dQ/dt)_{max}$ are shown as combustion characteristics including NOx emission per injected amount of fuel. Explain the relation influences of ambient density on combustion characteristics especially the NOx production and heat release.

(4 marks)

(b) Explain the following terms with respect to the study of internal combustion engine:

(i) volumetric efficiency;
(ii) brake mean effective pressure *(bmep);*
(iii) thermal efficiency; and
(iv) fuel consumption.

(3 marks)

(c) Describe the main exhaust emissions from the following engine types and suggest the suitable after-treatment system for ;

(i) Spark-ignition engine; and
(ii) Compression-ignition engine.

(4 marks)

(d) Describe the Exhaust Gas Recirculation (EGR) system and explain the oxygen contents in combustion chamber influences from EGR system can reduces the NOx (oxides of nitrogen) emissions.

(4 marks)

(e) Explain the term **dynamometers** and **test facilities** in order to observe the internal combustion engine performance.

(2 marks)

(f) Explain the operation of catalytic converters and how are they helpful in reducing HC, Carbon Monoxide (CO) and NOx emissions. Sketch the catalytic converters configuration.

(3 marks)

Q6 (a) Explain the ***Zeldovich mechanism*** and discuss the effects of mixture formation and ignition process that influences the Soot-NOx Trade-off in diesel combustion.

(3 marks)

(b) The main issue in diesel engine using natural gas as an alternative fuel is ignitibility process. Based on this reason, explain natural gas as alternative fuel for internal combustion (IC) engines bringing out their merits and demerits.

(3 marks)

(c) A spark-ignition engines working on ideal Otto cycle, pressure and temperature at the beginning of compression are 25°C and 1 bar, respectively. During the compression process, the air at is compressed adiabatically until the pressure is 15 bar. Heat is added at constant volume until the pressure rises to 45 bars. 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.

(14 marks)

- END OF QUESTION –

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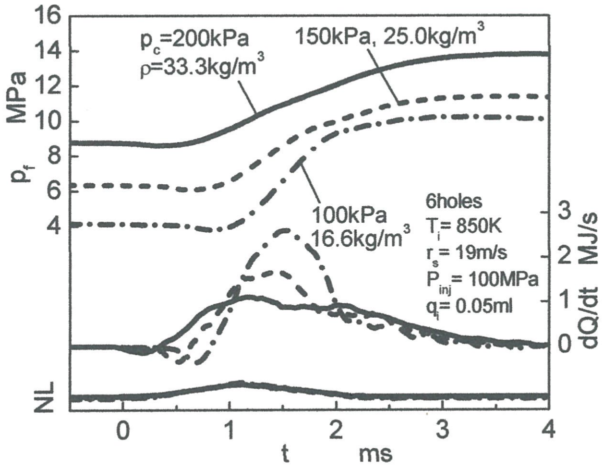

FIGURE Q1 (a)

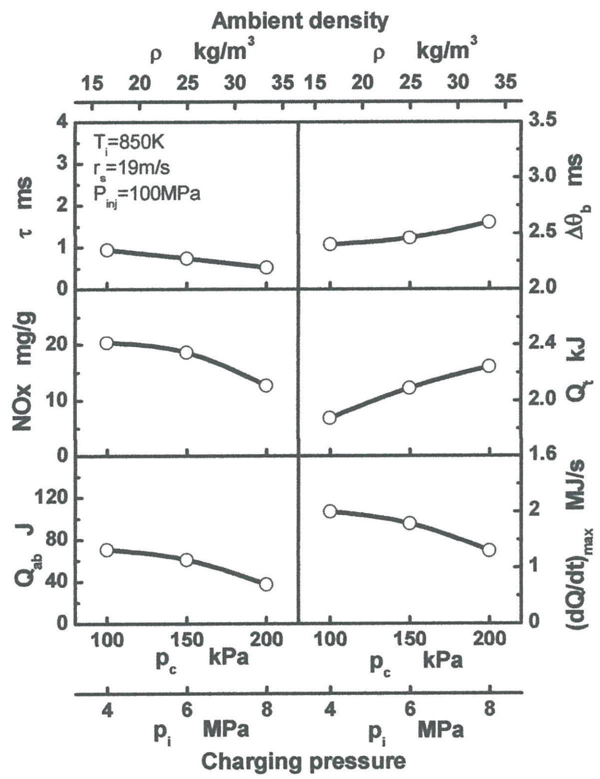

FIGURE Q5 (a)

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Power output motor (watt) = Power output engine (watt) = volts x amps

Piston speed, $\overline{U_P} = 2SN$ ambient density (air), $\rho_a = 1.181 kg/m^3$

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

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

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

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

Where a = crankshaft offset, r = connecting rod length and θ = 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, θ : $\frac{V}{V_c} = 1 + \frac{1}{2}(r_c - 1)\left[R + 1 - \cos\theta - \sqrt{R^2 - \sin^2\theta}\right]$

Vc = clearance volume, R = r/a

For an engine with N_c cylinders, displacement volume , N_d :

$V_d = V_{BDC} - V_{TDC}$ $V_d = N_c\left(\frac{\pi}{4}\right)B^2 S$ 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 $sfc = \frac{\dot{m}_f}{\dot{W}}$