UNIVERSITI TUN HUSSEIN ONN MALAYSIA

FINAL EXAMINATION
SEMESTER I
SESSION 2016/2017

TERBUKA

COURSE NAME	:	INTERNAL COMBUSTION ENGINE
COURSE CODE	:	BDE 40603
PROGRAMME	:	BDD
EXAMINATION DATE	:	DECEMBER 2016 / JANUARY 2017
DURATION	:	3 HOURS
INSTRUCTION	:	ANSWER ANY **FIVE (5)** QUESTIONS ONLY

THIS PAPER CONTAINS **SEVEN (7)** PAGES

Q1 (a) Explain the influences of the fuel type in engine design and combustion process.

(3 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 four-cylinder, four-stroke, 1.6-L gasoline engine operates on the Otto cycle with a compression ratio of 10. The air is at 100 kPa and 37°C at the beginning of the compression process, and the maximum pressure in the cycle is 7.5 MPa. The compression and expansion processes may be modeled as polytropic with a polytropic constant of 1.3. Using constant specific heats at 850 K. the air-fuel ratio, defined as the amount of air divided by the amount of fuel intake, is 16. Determine:
- (i) the temperature at the end of the expansion processes;
- (ii) the net work output and the thermal efficiency;
- (iii) the mean effective pressure;
- (iv) the engine speed for a net power output of 50 kW; and
- (v) the specific fuel consumption (g/kWh).

(12 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)

(a) 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 flash point of fuel oil in internal combustion engines.

(3 marks)

(b) Explain and compare Spark Ignition and Compression Ignition engines with respect to

(i) Ignition process; and
(ii) Heat release.

(4 marks)

(c) A blended gasoline comprised 17% by weight of ethanol, 65% of iso-octane and 18% of toluene, with fuel properties as in Table 1. Determine the fuel blended gasoline anti-knock index and the blended gasoline fuel sensitivity to combustion chamber geometry. Discuss your findings with reference to knocking characteristics of the blended fuel.

(13 marks)

Table 1-Propeties of blended gasoline

Fuel	**Motor Octane Number**	**Research Octane Number**	**Percentage (%)**
Ethanol	89	107	17
Iso-octane	100	100	65
Toluene	109	120	18

Q5 (a) Explain an internal combustion engine and how it is differs from an external combustion engine.

(3 marks)

(b) Explain the Research Octane Number and state the procedure of measuring this number.

(3 marks)

(c) A 1300 cm^3, four-stroke cycle, four cylinder compression ignition (C.I) engine, operating at 3000 RPM, produces 50 kW of brake power. The engine volumetric efficiency is 0.93 and with operating air-fuel ratio of 20:1. Calculate:

(i) the required mass air flow rate into the engine (kg/sec);
(ii) brake specific fuel consumption, bsfc (g/kW.hr);
(iii) the mass flow rate of the exhaust gas (kg/hr); and
(iv) brake power output per displacement (kW/litre).

(14 marks)

Q6 (a) **Figure Q6 (a)** shows the influences of turbocharger that increasing the air density in combustion chamber. As seen in Figure Q6 (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.

(4 marks)

(b) **Figure Q6 (b)** 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)

(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.

(3 marks)

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

(3 marks)

(e) 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)

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

(3 marks)

- END OF QUESTION –

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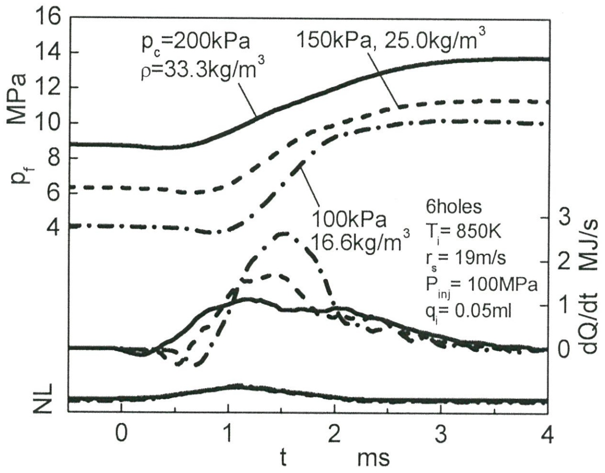

FIGURE Q6 (a)

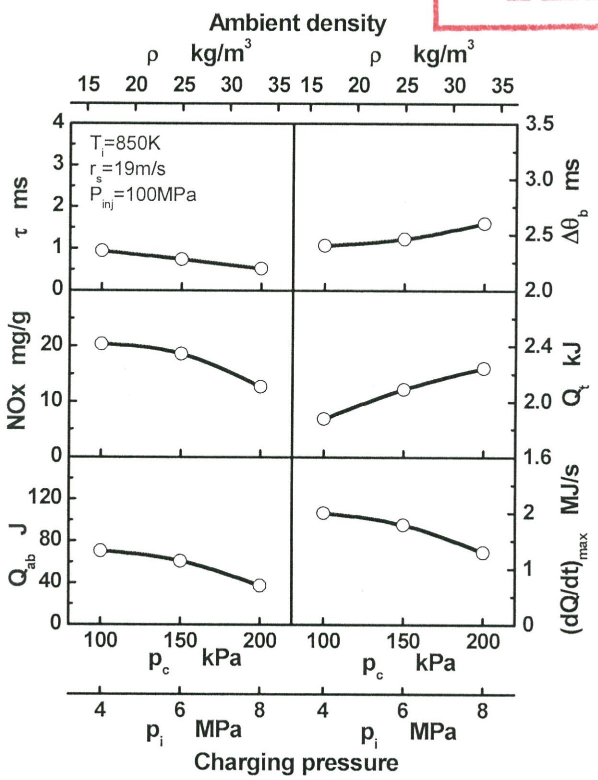

FIGURE Q6 (b)

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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 :

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

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TABLE A-2 PROPERTIES OF FUELS

Fuel		Molecular Weight	Heating Value HHV (kJ/kg)	Heating Value LHV (kJ/kg)	Stoichiometric $(AF)_s$	Stoichiometric $(FA)_s$	Octane Number MON	Octane Number RON	Heat of Vaporization (kJ/kg)	Cetane Number
gasoline	C_8H_{15}	111	47300	43000	14.6	0.068	80–91	92–99	307	
light diesel	$C_{12.3}H_{22.2}$	170	44800	42500	14.5	0.069			270	40–55
heavy diesel	$C_{14.6}H_{24.8}$	200	43800	41400	14.5	0.069			230	35–50
isooctane	C_8H_{18}	114	47810	44300	15.1	0.066	100	100	290	
methanol	CH_3OH	32	22540	20050	6.5	0.155	92	106	1147	
ethanol	C_2H_5OH	46	29710	26950	9.0	0.111	89	107	873	
methane	CH_4	16	55260	49770	17.2	0.058	120	120	509	
propane	C_3H_8	44	50180	46190	15.7	0.064	97	112	426	
nitromethane	CH_3NO_2	61	12000	10920	1.7	0.588			623	
heptane	C_7H_{16}	100	48070	44560	15.2	0.066	0	0	316	
cetane	$C_{16}H_{34}$	226	47280	43980	15.0	0.066			292	100
heptamethylnonane	$C_{12}H_{34}$	178			15.9	0.063				15
α-methylnaphthalene	$C_{11}H_{10}$	142			13.1	0.076				0
carbon monoxide	CO	28	10100	10100	2.5	0.405				
coal (carbon)	C	12	33800	33800	11.5	0.087				
butene-1	C_4H_8	56	48210	45040	14.8	0.068	80	99	390	
triptane	C_7H_{16}	100	47950	44440	15.2	0.066	101	112	288	
isodecane	$C_{10}H_{22}$	142	47590	44220	15.1	0.066	92	113		
toluene	C_7H_8	92	42500	40600	13.5	0.074	109	120	412	
hydrogen	H_2	2	141800	120000	34.5	0.029		90		

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