CONFIDENTIAL

UNIVERSITI TUN HUSSEIN ONN MALAYSIA

FINAL EXAMINATION
SEMESTER II
SESSION 2022/2023

COURSE NAME	:	AUTOMOTIVE PROPULSIONS
COURSE CODE	:	BDE 41003
PROGRAMME	:	BDD
EXAMINATION DATE	:	JULY/AUGUST 2023
DURATION	:	3 HOURS
INSTRUCTION	:	1. ANSWER **FIVE (5)** FROM SIX (6) QUESTIONS. 2. THIS FINAL EXAMINATION IS CONDUCTED VIA **OPEN BOOK.** 3. STUDENTS ARE **ALLOWED** TO CONSULT THEIR OWN MATERIAL OR ANY EXTERNAL RESOURCES DURING THE EXAMINATION CONDUCTED VIA **OPEN BOOK**.

THIS QUESTION PAPER CONSISTS OF **SIX (6)** PAGES

Q1 (a) For a single cylinder, spark ignition (S.I.) engine with less than 150 cm^3 capacity, deduce the effect to the engine's volumetric efficiency (V.E.) as the engine speed is increasing steadily until reaching its maximum limit.

(5 marks)

(b) A locally produced 1,332 cm^3, four-cylinder spark ignition (S.I.) engine, operating at 5,750 rpm, produces 70 kW of brake power. The engine volumetric efficiency can be assumed to be 92%, with operating air-fuel ratio (AFR) of 15:1. The engine's bore and stroke are 76 mm and 73.4 mm, respectively, with compression ratio of 8.9 to 1. Determine:

i. the required mass air flow rate (kg/sec) into the engine;
ii. brake specific fuel consumption (g/kW·hr); and
iii. brake output per displacement (kW/litre).

(15 marks)

Q2 (a) A 4-cylinder spark ignition (S.I.) engine has a working volume of 1,332 cm^3, which generates power output of 70 kW/5,750 rpm and torque of 120 Nm/4,000 rpm, to support the vehicle body mass of 1,165 kg. Assuming the engine's mass is 10% of the vehicle mass:

i. Determine the specific weight and specific volume of the engine; and
ii. Sketch also the estimated power and torque curves for this engine.

(10 marks)

(b) A 2.5 litre, 4-cylinder square engine with two intake valves per cylinder is designed to have a maximum speed of 6,800 rpm. Air enters the engine at 40°C, calculate:

i. The required intake valve area; and
ii. The expected maximum valve lift

(10 marks)

Q3 (a) Elucidate the re-use option against the recycle option for the batteries taken from end-of-life electric vehicle. Provide a suitable engineering example for re-using 20 cells of lithium ion batteries (LIB) with capacity of 3.7V each.

(6 marks)

(b) Challenging issues involving batteries usage include the needs to recycle and reuse the already out of service electric vehicles (EV). A conventional Tesla Model S with 85 kWh battery pack was operating using a construction of Pack:Module of 1:16 and module density of 444 cells/module. After 10 years of service and experiencing a minimum of 2% annual charging depreciation, determine the minimum charge that will be available per battery cell, assuming only 40% loss from cells to pack.

(14 marks)

Q4 (a) Review the basic functional structure of a hydrogen fuel cell electric vehicle (HFCEV) against plug-in hybrid electric vehicle (PHEV), elaborating advantages and disadvantages of each technology.

(6 marks)

(b) The distance from Johor Bahru (JB) to Bukit Kayu Hitam (BKH) is approximately around 809 km. For a driver of an electric vehicle (EV) with consumption rate of 297Wh/mile, energy storage capacity of 103 kWh, with 80% viable charge, estimate the minimum number of stops the driver needs to make to complete the return journey from JB to BKH, in the shortest possible time. Assuming there are a few EV superchargers in the northbound and southbound directions, and each supercharger has a charging capability of 2.5% per minute. Estimate also the remaining travelling range of the EV upon completing the return journey.

(14 marks)

Q5 (a) Highlight the effects from nitrogen oxides (NO_X) emission poisoning to human health and elaborate the potential sources for such emission.

(3 marks)

(b) For a 2,488 cm^3 compression ignition (C.I.) engine installed on a light-duty truck chassis, differentiate the required exhaust after treatment system for this vehicle to supress the carbon monoxide (CO) and nitrogen oxides (NO_X) emissions from the engine.

(7 marks)

(c) Given that diesel fuel with a typical formula of $C_{12}H_{23}$ reacting stoichiometrically with pure oxygen (O_2) inside a test chamber, determine the theoretical mass of water (H_2O) that will be formed.

(10 marks)

Q6 a) Elucidate the thermal quenching event inside a combustion chamber in the beginning of the power stroke of a compression ignition (C.I.) engine.

(3 marks)

b) During a combustion process inside the C.I. engine, the flame front stops before it reached the walls of the combustion chamber. Consider the unburned boundary layer as a volume of 0.1 mm thick along the entire combustion chamber surface, with the piston having a 3.0 cm hemisphere bowl in its face. Calculate the ratio between the mass of fuel burned against the mass of fuel unreacted during this combustion process. Provide your assumptions and justifications.

(17 marks)

-END OF QUESTION-

FINAL EXAMINATION

SEMESTER / SESSION	:	SEM II, 2022/2023	PROGRAMME CODE	:	BDD
COURSE NAME	:	AUTOMOTIVE PROPULSIONS	COURSE CODE	:	BDE41003

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

$$V_d = V_{BDC} - V_{TDC} \qquad V_d = N_c\left(\frac{\pi}{4}\right)B^2S$$

Where B = cylinder bore, S = stroke, S = 2a

Compression ratio, r_c is defined as: $r_c = V_{BDC}/V_{TDC}$

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: $W_b = 2\pi T$; $\quad W_b = \frac{V_d(bmep)}{n}$

Where T = engine torque, bmep = brake mean effective pressure, n = number of revolutions per cycle

Mean effective pressure: $mep = \frac{\dot{W}n}{V_d N}$

Engine torque, T, for 2-stroke and 4-stroke cycles:

$$T_{2-stroke} = \frac{V_d(bmep)}{2\pi} \qquad T_{4-stroke} = \frac{V_d(bmep)}{4\pi}$$

Engine power,

$$\dot{W} = \frac{WN}{n} \qquad \dot{W} = 2\pi NT \qquad N = \text{engine speed}$$

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

V_c = clearance volume, R = r/a,

The ratio of instantaneous piston speed divided by the average piston speed is:

$$\frac{U_p}{\overline{U}_p} = \left(\frac{\pi}{2}\right)\sin\theta\left[1 + \left(\frac{\cos\theta}{\sqrt{R^2 - \sin^2\theta}}\right)\right]$$

where

$R = r/a$

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Volumetric efficiency,

$$\eta_v = \frac{m_a}{\rho_a V_d}$$

$$\eta_v = \frac{n\dot{m}_a}{\rho_a V_d N}$$

where

m_a = mass of air into the engine for one cycle

$\dot{m}_a$ = steady - state flow of air into the engine

ρ_a = air density evaluated at atmospheric conditions

V_d = displacement volume

N = engine speed

n = number of revolutions per cycle

$$\rho_{air} = 1.181 \, kg/m^3$$

Average piston speed is U_p=2SN

Minimum valve intake area:

$$A_i = 1.3B^2\left[\frac{(\bar{U}_p)_{max}}{c_i}\right] = \left(\frac{\pi}{4}\right)d_v^2$$

where:

B = bore; $(\bar{U}_p)_{max}$ = average piston speed at maximum engine speed;

c_i = speed of sound at inlet conditions; d_v = diameter of valve

Maximum average piston speed = $\frac{2 \times \text{stroke} \times \text{engine speed}}{60}$ Valve lift, $l_{max} < \frac{d_v}{4}$

Compound/Element	Molecular weight	Compound/Element	Molecular weight
Air	28.966	Nitric Oxide, NO	30.006
Carbon Dioxide, CO_2	44.01	Nitrogen, N_2	28.0134
Carbon Monoxide, CO	28.011	Nitrous Oxide, N_2O	44.0133
Isooctane, C_8H_{18}	114.23	Nitrogen dioxide, NO_2	46.0065
Methane, CH_4	16.04	Oxygen, O_2	31.9998
Hydrogen, H_2	2.016	Water Vapor - Steam, H_2O	18.02
Gasoline, C_8H_{15}	111.00	Light diesel, $C_{12.3}H_{22.2}$	170.00
		Heavy diesel, $C_{14.6}H_{24.8}$	200.00