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UNIVERSITI TUN HUSSEIN ONN MALAYSIA

FINAL EXAMINATION
SEMESTER II
SESSION 2021/2022

COURSE NAME	:	AUTOMOTIVE PROPULSIONS
COURSE CODE	:	BDE 41003
PROGRAMME	:	BDD
EXAMINATION DATE	:	JULY 2022
DURATION	:	3 HOURS
INSTRUCTION	:	1. ANSWER **FIVE (5)** QUESTIONS **ONLY** 2. THIS FINAL EXAMINATION IS AN **ONLINE** ASSESSMENT AND CONDUCTED VIA **OPEN BOOK**

THIS QUESTION PAPER CONSISTS OF **SEVEN (7)** PRINTED PAGES

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Q1 (a) A spark ignition (S.I.) engine that is operating with poor volumetric efficiency is susceptible to poor torque output. Evaluate this statement and elaborate the necessary steps to improve the engine's volumetric efficiency.

(7 marks)

(b) A 1500 cm^3, four-stroke cycle, four-cylinder compression ignition (C.I.) engine, operating at 3200 RPM, produces 48 kW of brake power. The engine volumetric efficiency is 0.92 and with operating air-fuel ratio of 21:1. Calculate:

i. the required mass air flow rate (kg/sec) into the engine;

ii. brake specific fuel consumption (g/kW·hr); and

iii. the mass flow rate (kg/hr) of the exhaust gas.

(13 marks)

Q2 (a) Using appropriate sketches, describe the main components of a battery electric vehicles (BEV) powertrain system and their functions.

(6 marks)

(b) Elaborate the main challenges for rapid adoption of battery electric vehicles (BEV) and propose the related mitigation steps

(6 marks)

(c) Individual Lithium-Ion battery cells are packed together to form battery modules, which then arranged in a housing structure as the final battery complete system. This arrangement involves different mechanical housing, thermal management, and electrical settings. For cylindrical type cells that have efficiency rates between 48.4% to 67.2%, and if the cells contain energy density of 500 Wh/L, calculate the range of outputs for the battery system. Explain the significance of this output.

(8 marks)

Q3 (a) Referring to the exhaust gas aftertreatment process for a 2998 cc compression ignition (C.I.) engine, differentiate the roles of a lean NO_X trap (LNT) and diesel particulate filter (DPF). Calculate the theoretical requirements for the aftertreatment devices.

(10 marks)

(b) A dedicated fuel for compression ignition (C.I.) engines can be approximated to have a chemical formula of $C_{12}H_{22}$. Determine the approximate ratio between the mass of oxygen to mass of water, assuming this fuel will react exothermically with oxygen using this reaction route:

$$\mathbf{C_{12}H_{22} + O_2 \rightarrow CO_2 + H_2O} \quad \textit{(Equation 1)}$$

(10 marks)

Q4 (a) Elaborate the functionalities of a hydrogen fuel cell electric vehicle (HFCEV) main components and analyse the disadvantages of such propulsion system.

(10 marks)

(b) A local municipal council proposes hydrogen fuel cell electric vehicle (HFCEV) to replace taxis, which are normally powered by conventional 1.3-litre spark ignition (S.I.) engines, as a step towards reducing air pollution in the city. Outline the suitable system and characterise quantitatively this HFCEV. Describe also the related technical and infrastructure necessary for operating HFCEV as intra-city people carriers.

(10 marks)

Q5 (a) Differentiate the advantages and disadvantages of using chassis dynamometer against a hydraulic engine dynamometer.

(6 marks)

(b) A V6, 3-litre research engine operates on a 4-stroke cycle at 3600 RPM. The compression ratio is 9.49 and the connecting rod length is 17.1 cm. Its bore is equivalent with the stroke. At the given engine speed, the combustion terminates at 20 °C after-top-dead-centre (aTDC). Calculate the average piston speed and the clearance volume of each cylinder.

(7 marks)

(c) 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.

(7 marks)

Q6 During a combustion process inside a spark ignition (S.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 percentage of fuel that does not get burned due to being trapped in the surface boundary layer. Provide your assumptions and justifications.

(20 marks)

END OF QUESTIONS

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The distance between the crank axis and wrist pin axis or piston position 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, measured from the centerline and it is zero when the piston is at TDC

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

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

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

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,

$$\dot{W} = \frac{WN}{n} \qquad \dot{W} = 2\pi NT$$

N = engine speed

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

Instantaneous volume, V at any crank angle, θ:

$$\frac{V}{V_c} = 1 + \frac{1}{2}(r_c - 1)\left[R + 1 - \cos\theta - \sqrt{R^2 - \sin^2\theta}\right]$$

V_c = clearance volume, 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

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

For a generator, power output is the product of voltage and current.

Average piston speed is U_p=2SN

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

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

where

$$R = {r}/{a}$$

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, $l_{max} < \frac{d_v}{4}$

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Compound/Element	Molecular weight	Compound/Element	Molecular weight
Air	28.966	Nitric Oxide, NO	30.006
Carbon Dioxide, CO_2	44.010	Nitrogen, N_2	28.0134
Carbon Monoxide, CO	28.011	Nitrous Oxide, N_2O	44.0133
Isooctane, C_8H_{18}	114.230	Nitrogen dioxide, NO_2	46.0065
Methane, CH_4	16.040	Oxygen, O_2	31.9998
Hydrogen, H_2	2.016	Water Vapor - Steam, H_2O	18.0200
Gasoline, C_8H_{15}	111.000	Light diesel, $C_{12.3}H_{22.2}$	170.000
		Heavy diesel, $C_{14.6}H_{24.8}$	200.000