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UNIVERSITI TUN HUSSEIN ONN MALAYSIA

FINAL EXAMINATION
SEMESTER I
SESSION 2022/2023

COURSE NAME	:	AUTOMOTIVE PROPULSIONS
COURSE CODE	:	BDE 41003
PROGRAMME	:	BDD
EXAMINATION DATE	:	FEBRUARY 2023
DURATION	:	3 HOURS
INSTRUCTION	:	1. ANSWER **FIVE (5)** QUESTIONS **ONLY** 2. THIS FINAL EXAMINATION IS CONDUCTED VIA **CLOSED BOOK** 3. STUDENTS ARE **PROHIBITED** TO CONSULT THEIR OWN MATERIAL OR ANY EXTERNAL RESOURCES DURING THE EXAMINATION CONDUCTED VIA CLOSED BOOK

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

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Q1 (a) For a compression ignition (C.I.) engine, the value of volumetric efficiency (V.E.) is proportional to the incoming mass flow rate into the engine. Elaborate the effects from poor V.E. for this type of internal combustion engine.

(4 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);
iii. the mass flow rate (kg/hr) of the exhaust gas; and
iv. brake output per displacement (kW/litre).

(16 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.

(8 marks)

(b) Compression ignition (C.I.) engine operation can be approximated by the ideal Air-Standard Diesel Cycle.

i. Justify the assumptions of isentropic compression stroke and the constant-pressure heat addition process used for this idealised cycle;
ii. Express Diesel Cycle thermal efficiency, based on its temperature values of T_1, T_2, T_3 and T_4.; and
iii. Theorise the suitable method to improve the engine's combustion quality.

(12 marks)

Q3 (a) Elucidate the key challenges related to battery usage for vehicle electrification and outline the current practical strategy to overcome those challenges.

(10 marks)

(b) Individual Lithium-Ion battery cells are packed together to form battery modules, which are 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 an energy density of 500 Wh/L:

i. Calculate the range of outputs for the battery system;
ii. Explain the significance of this range of outputs; and
iii. Outline the potential improvement steps for this battery system.

(10 marks)

Q4 (a) Review the basic functional structure of a hydrogen fuel cell electric vehicle (HFCEV) and elaborate two advantages and disadvantages of deploying HFCEV as a personal transport for intra-city travels.

(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) Referring to the exhaust gas aftertreatment process for an internal combustion engine, describe the roles of diesel particulate filter (DPF) and selective catalytic reduction (SCR) systems for a heavy-duty diesel-fuelled vehicle.

(6 marks)

(b) A dedicated fuel for spark ignition (S.I.) engine has a typical chemical formula of C_8H_{18}. During combustion this fuel will react exothermically with oxygen using this reaction route:

$$\mathbf{C_8H_{18} + O_2 \rightarrow CO_2 + H_2O} \qquad (Eq.\ 1)$$

i. Rewrite Eq. 1 in its chemically balanced form; and
ii. Calculate the ratio between the mass of water and mass of oxygen, assuming a complete combustion process is taken place.

(14 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 QUESTION-

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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:

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

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

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, $\dot{W} = \frac{WN}{n}$ $\quad \dot{W} = 2\pi NT$ $\quad$ 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:

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

where

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

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