Second Semester Examination
2023/2024 Academic Session

July / August 2024

EME 432 – Internal Combustion Engine
(Enjin Pembakaran Dalam)

Duration: 3 hours
(Masa: 3 Jam)

Please check that this examination paper consists of SIX (6) pages of printed material before you begin the examination.

[Sila pastikan bahawa kertas peperiksaan ini mengandungi ENAM (6) muka surat yang bercetak sebelum anda memulakan peperiksaan ini.]

Instructions: Answer ALL **FOUR (4)** questions.

*[**Arahan**: Jawab **EMPAT (4)** soalan]*

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1. (a) Explain abnormal combustion in Diesel engine, and how it is influenced by the ignition delay (ID) period, fuel injection timing and cetane number of Diesel fuel (fuel ignition quality).

(30 marks)

(b) The spark plug is fired at 18°bTDC in spark-ignition, petrol engine running at 1800 rpm. It takes 8° of engine rotation to start combustion and get into flame propagation mode. Flame termination occurs at 12°aTDC. Bore diameter is 8.4cm with the central spark plug. The flame front can be approximated as a sphere moving out from the spark plug.

Calculate:

(i) The rotational angle during flame propagation in crank angle degree (CAD).

(10 marks)

(ii) The time of flame propagation, t (second).

(10 marks)

(iii) The maximum flame travel, D_{max} (meter).

(10 marks)

(iv) The effective flame front speed during flame propagation, V_f (m/s).

(10 marks)

(c) The engine in Q1(b) is now run at 3000 rpm. As speed is increased in this engine, greater turbulence and swirl increase the flame front speed at a rate such that $V_{f\,(increase)} = 0.85\left(\frac{N_{increase}}{N_{initial}}\right)V_f$ where N is the engine speed. Flame development after spark plug firing still takes 8°of engine rotation.

Calculate how much ignition timing must be advanced in CAD such that the flame termination again occurs at 12°aTDC.

(30 marks)

2. (a) Explain the impact of high and low hydrogen to carbon atoms ratio (H/C) to the burning velocity, quality of fuel combustion and emissions.

(20 marks)

(b) A 120cc single-cylinder, four stroke engine run Wide Open Throttle (WOT) at 4500 rpm and consumes 22g gasoline (C_8H_{18}) per minute.

Given:

$$\eta_v = \frac{M_a}{\rho_a V_d (N/n)}$$

Where ρ_a is air density (1.2 kg/m^3), V_d is displacement volume, *N* is engine speed, and *n* is number of revolutions per cycle. Assume the volumetric efficiency, η_v = 90%.

Calculate:

(i) The fuel hydrogen to carbon atoms ratio (H/C).

(10 marks)

(ii) The actual air-fuel ratio (AFR_{actual})

(10 marks)

(iii) The equivalence ratio (Φ) by assuming the stoichiometric air-fuel ratio, AFR_{stoich} = 14.7.

(10 marks)

(c) The following (dry) emission data are measured using a gas analyzer from a loaded engine using C_8H_{15} as a fuel:

CO_2	12.5%
CO	3.5%
O_2	1%
HC	200 ppm

Calculate:

(i) The stoichiometric air-fuel ratio (AFR_{stoich})

(20 marks)

(ii) The actual air-fuel ratio (AFR_{actual})

(20 marks)

(iii) The equivalence ratio (Φ)

(10 marks)

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3. (a) When a four-cylinder, four-stroke cycle, SI engine operating at 4500 rpm is connected to an eddy current dynamometer, 80 kW of power is dissipated by the dynamometer. The engine had a total displacement volume of 2.4 liters and a mechanical efficiency of 82% at 4500 rpm. Because of heat and mechanical losses, the dynamometer has an efficiency of 93%.

Calculate:

(i) Brake power (BP), Indicated power (IP) and Friction power (FP) in kW

(20 marks)

(ii) Brake mean effective pressure (BMEP) in kPa

(10 marks)

(iii) Engine torque (T) at 4500 rpm

(10 marks)

(v) Engine specific volume (S_V)

(10 marks)

Where:

- η_{dyno} *= [power recorded by dynamometer] / [actual power from engine]*
- $P = 2\pi NT$
- $S_V = V_d / BP$
  where S_V *is engine specific volume (L/kW) and* V_d *is total displacement volume (L)*

(b) A diesel truck achieves fuel efficiency of 6 kilometers per liter of diesel fuel, priced at RM 2.11 per liter. Compressed Natural Gas (CNG) is available at RM 1.00 per liter equivalent. Upon converting the diesel truck to a "dual fuel" configuration, it can substitute an average of 75% CNG for diesel (i.e., 25% diesel and 75% CNG usage). The conversion cost amounts to RM 20,000. Assuming an annual mileage of 50,000 kilometers, the following data as shown in **Table 3** will be utilized for calculations:

Table 3

Fuel type	**Diesel**	**CNG**
Cost	RM 2.11/ liter	RM 1.00/ liter equivalent
Fuel economy	6 km/L	-
Density	850 g/liter	800 g/m^3 at STP
Composition	C_8H_{18}	CH_4

(i) Calculate the Return of Investment (ROI) time (years) of the system conversion.

(30 marks)

(ii) Evaluate the technological feasibility based on the calculated ROI.

(20 marks)

4. (a) Recently, one of the imported car makers has launched their latest car model and as shown in **Table 4 (a)** is the powertrain and engine specifications of the vehicle for two different models.

Table 4 (a)

	Variant	
Parameter	**Civic 1.5L RS**	**Civic e:HEV 2.0L RS**
Engine Type	4 Cylinder, 16 Valve, DOHC VTEC TURBO	4 Cylinder, 16 Valve, DOHC (Atkinson Cycle)
Displacement (cc)	1,498	1,993
Compression Ratio	10.6:1	13.5:1
Max. Power (kW/rpm)	134 @ 6,000	*Engine:* 105 @ 6,000 *Motor:* 135 @ 5,000-6,000
Max. Torque (Nm/rpm)	240 @ 1,700-4,500	*Engine:* 189 @ 4,500 *Motor:* 315 @ 0 - 2,000
Fuel System	Electronic Fuel Injection (PGM-FI)	Direct Fuel Injection
Fuel Consumption (L/100km)	6.3	4.0

By referring to the information given in Table 4 (a), please answer for the following questions:

(i) Examine the impact of turbocharging on maximum torque and maximum power. Discuss the future of internal combustion engines and how the downsizing strategy contributes to carbon reduction.

(30 marks)

(ii) Despite the e:HEV variant having a larger volumetric displacement compared to the RS variant, its fuel consumption is superior. Discuss how hybridization contributes to this improvement.

(10 marks)

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(b) An SI engine is running at a stoichiometric air/fuel ratio and has the following engine-out emissions numbers as shown in **Table 4 (b)**:

Table 4 (b)

Gas type	Emission number	Catalyst efficiency, %
HC	650 ppm	95
CO	1.5%	95
NOx	1000 ppm	92
CO_2	13.3%	-
O_2	1.7%	-

A three-way catalyst, as shown in **Figure 4**, is used to convert these engine-out emissions into less toxic pollutants.

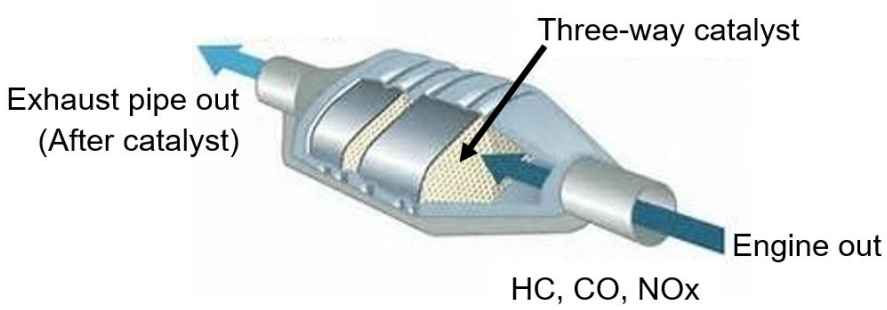

Figure 4

(i) Calculate the emissions numbers at exhaust pipe-out (post-catalyst) for the same pollutants, consider the catalyst operates with the efficiency provided in **Table 4 (b)**.

(40 marks)

(ii) By providing **TWO (2)** key factors, analyze the reasons behind the recent surge in catalytic converter thefts.

(20 marks)

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