Second Semester Examination
2020/2021 Academic Session

July/August 2021

EME 432 – Internal Combustion Engine

Duration: 3 hours

Please check that this examination paper consists of **EIGHT (8)** pages including appendixes before you begin the examination.

Instructions : Answer ALL **SIX (6)** questions.

Answer to each question must begin from a new page.

1. Answer the following question based on the arrangement of your Matric. No.

SET 1 (For students with last digit of Matric Number is ODD):

EGR or Exhaust Gas Recirculation is an efficient method to reduce NOx emissions by reducing the amount of oxygen in the engine cylinder. It works by recirculating a quantity of exhaust gas back to the engine cylinder. Intermixing the recirculated gas with incoming air reduces the amount of available O_2 to the combustion and lowers the peak temperature of combustion. However, the amount of EGR input into Compression-Ignition (CI) engine is limited to approximately 50% only to avoid drawbacks to the engine performance.

(i) Based on your internet search, find a research article that reports the finding of 50% limit of EGR input into CI engine for NOx reduction. Discuss briefly on the modifications which are important to be done on the engine to achieve 50% of EGR input for NOx reduction. Provide source of reference to the answer.

(40 marks)

(ii) Explain what happen to the Naturally Aspirated Diesel engine performance if the EGR input is more than 50%? Select **TWO [2]** performance characteristics of the engine which will be greatly influenced if the EGR input is more than 50%.

(60 marks)

SET 2 (For students with last digit of Matric Number is EVEN):

EGR or Exhaust Gas Recirculation is an efficient method to reduce NOx emissions by reducing the amount of oxygen in the engine cylinder. It works by recirculating a quantity of exhaust gas back to the engine cylinder. Intermixing the recirculated gas with incoming air reduces the amount of available O_2 to the combustion and lowers the peak temperature of combustion. However, the amount of EGR input into Compression-Ignition (CI) engine is limited to approximately 50% only to avoid drawbacks to the engine performance.

(i) Explain if it is possible to increase or to lower the amount of EGR input into CI engine from the cut-off point of 50% by adjusting the compression ratio and retarding the ignition timing?

(40 marks)

(ii) Propose and justify the optimum values of EGR input (in %), compression ratio (by ratio) and ignition timing (by sec. or crank angle) for the best performance of the CI engine that includes NOx reduction. Provide source of reference if the answer provided is based on the external reference.

(60 marks)

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2. The use of biofuel in Compression-Ignition (CI) engine can be realized by modifying few critical components particularly the fuel supply and injection system.

   (i) Discuss **ONE [1]** problem for each component as listed below if biofuel is directly used in the CI engine without any modification to the engine component.

   (a) Fuel pump **(10 marks)**
   (b) Fuel filter **(10 marks)**
   (c) Fuel injector **(20 marks)**

   (ii) Propose **ONE [1]** modification for each component as listed in Q2 (i) which is possible to be done to mitigate the problem and to realize the biofuel's application in the engine. Note: A regular maintenance of the engine component is not part of the modification.

(60 marks)

3. (a) Figure Q3 shows the vehicle speed, acceleration, Air Fuel Ratio (AFR) and air mass flow rate data extracted from a 4-cylinder turbo 2.0L, 5-speed Spark-Ignition passenger car. At time t = 232463 s, the data is as follows:

   - Vehicle speed: 101 km/h
   - Vehicle acceleration: 1.66 m/s^2
   - AFR: 11.14
   - Air mass flowrate: 218.45 g/s

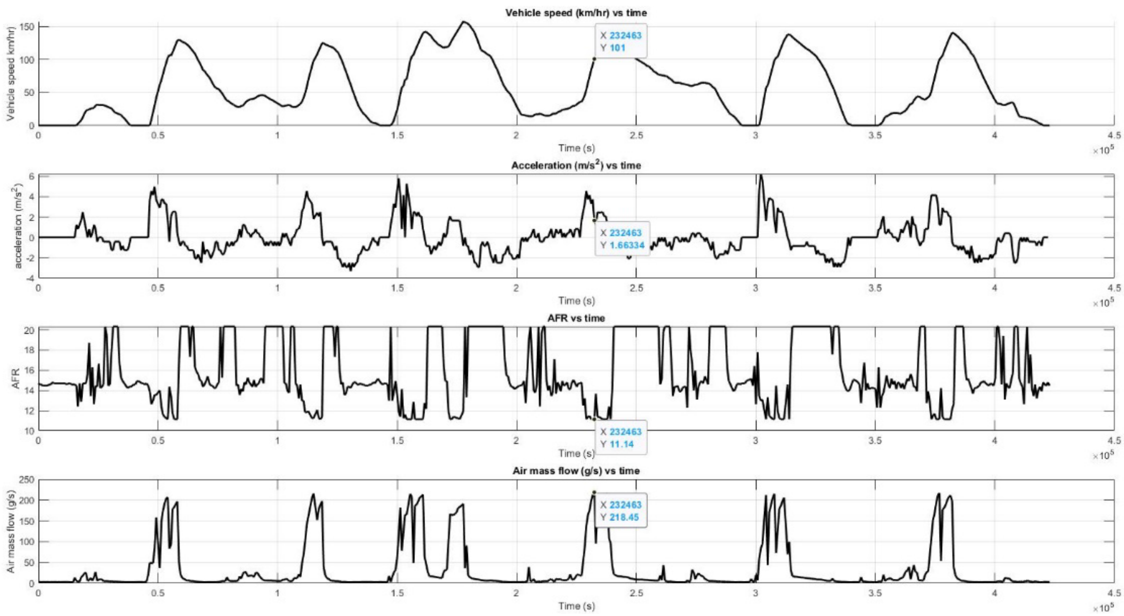

Figure Q3

(i) Determine the mass flow of fuel (g/s) at t = 232463 s.

(30 marks)

(ii) How does the Air Fuel Ratio (AFR) change with the power demand? Give specific example of data from Figure Q3.

(20 marks)

(b) A 1200 cc two-cylinder four stroke engines running on wide open throttle (WOT) at a speed of 2500 RPM and consumes 65 g petrol (C_8H_{18}) per minute. The fuel used has lower heating value (Q_{lhv}) of 44.4 MJ/kg. The volumetric efficiency is 85% and density of air is 1.2 kg/m^3. The engine compression ratio is 8.5 and its efficiencies are as follows: $\eta_m = 0.8$, $\eta_c = 0.94$

Molar mass: N = 14 g/mol, O = 16 g/mol, H = 1 g/mol, C= 12 g/mol

Relevant formulas:

$$\text{Brake Power} = \eta_m (0.8\, \eta_{otto}) \eta_c\, \eta_v\, \rho_{air}\, V_d \frac{N}{n} Q_{lhv} \frac{1}{AFR}$$

$$\eta_{otto} = 1 - \left(\frac{1}{CR}\right)^{\Upsilon-1}$$

$$\Upsilon = 1.3$$

Determine:

(i) The engine AFR and equivalence ratio for the combustion.

(25 marks)

(ii) Indicated power (in kW) of the engine running at the condition mentioned.

(25marks)

4. (a) (i) Draw and compare **TWO (2)** electric hybrid architectures. Other than cost, provide **ONE (1)** advantage and **ONE (1)** disadvantage for each architecture.

(5 marks)

(ii) Distinguish **THREE (3)** major differences between spark ignition engine and compression ignition engine.

(5 marks)

(b) You are an engineer in a car manufacturing company that has a base naturally aspirated spark-ignition engine with compression ratio of 8 and operate at inlet pressure of 1 atm. You are given two options to increase the power of the engine:

- Option 1: Increase the compression ratio (CR) from 8 to 11.
- Option 2: Increase the intake manifold absolute pressure from 1 atm to 2.5 atm by using turbocharges.

The fuel used has lower heating value (Q_{lhv}) of 44.4 MJ/kg. The intake manifold temperature is 303.15 K, and the air density is 1.2 kg/m^3.
$M_{fuel}/M_{total} = 0.06$, $C_v = 946$ J/kg/K, $\Upsilon = 1.3$

Relevant formulas:

$Q = M_f Q_{lhv} = M_{Total} Cv\ (T_{final} - T_{initial})$

$PV^{\Upsilon} = \text{Constant}$

$PV = nRT$

$$\eta_{otto} = 1 - \left(\frac{1}{CR}\right)^{\Upsilon - 1}$$

1atm = 101,325 Pa

(i) Calculate the compression pressure and temperature of the engine from both options.

(25 marks)

(ii) Calculate the maximum Otto cycle pressure of the engine from both options.

(25 marks)

(iii) Calculate the Otto cycle efficiency of the engine from both options.

(20 marks)

(iv) Which option would you choose to increase the power output of the base engine? Discuss the risk(s) with the option you chose.

(20 marks)

5. Recently, one of our national car makers has launched their very first-ever B-segment sport utility vehicle (SUV) and as shown in Table Q5 is the engine specifications of the vehicle for two different models.

Table Q5

	Variant	
Parameter	**1.5T Standard**	**1.5 TGDI Flagship**
Engine Type	3 Cylinders In-line, 12 valves DOHC, Turbocharged	3 Cylinders In-line, 12 valves DOHC, Turbocharged
Displacement (cc)	1477	1477
Compression Ratio	10.1:1	10.5:1
Max. Power (kW/rpm)	110/5500	130/5500
Max. Torque (Nm/rpm)	226/ 1500-4000	255/ 1500-4000
Fuel System	Multi Point Fuel Injection (MPFI)	Direct Injection (DI)

By referring to the information given in Table Q5, please answer for the following questions:

(i) Explain how does the type of fuel system affect the maximum torque and maximum power? Which one is more efficient and why?

(40 marks)

(ii) The DI engine has more power than the MPFI engine. Based on this statement, discuss briefly on the advantages of DI over the MPFI engine.

(40 marks)

(iii) There are now engines that use compound injection technology (combination of both MPFI and DI) as their fuel system, do you think it is efficient and cost effective? Justify your answer.

(20 marks)

6. (a) Using the information given in Figure Q6a and Q6b, explain the changes in conversion efficiency seen for all three pollutants when the A/F value is:

(i) greater than the window for optimum conversion.

(35 marks)

(ii) less than the window for optimum conversion.

(35 marks)

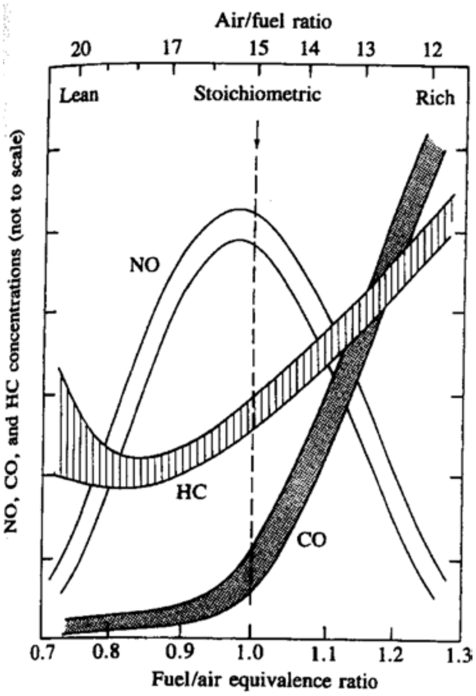

Figure Q6a

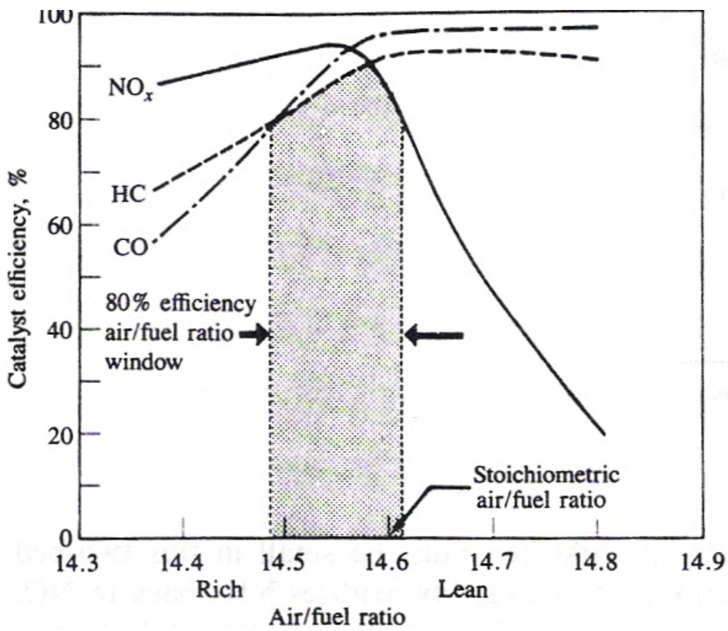

Figure Q6b

(b) When a three-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

(15 marks)

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

(5 marks)

(iii) Engine torque (T) at 4500 rpm

(5 marks)

(iv) Engine specific volume (S_V)

(5 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)

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