First Semester Examination
2021/2022 Academic Session

February/March 2022

EMH341 – Applied Thermodynamics

Duration : 3 hours

Please ensure that this examination paper contains **SIX (6)** pages and **FIVE (5)** questions before you begin the examination.

Instructions : Answer **ALL** questions.

Answer all questions in **English** OR **Bahasa Malaysia** OR a combination of both.

Each question must begin from a new page.

Note: Psychrometric Chart and Thermodynamic Properties Tables are given in the eLearn attachment.

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For Q1 – Q3, the values {F1} to {F19} are randomly generated by E-learn.

1. a) Discuss ONE difference by giving an example for the following 3 cases:
(i) carbon neutral effect,
(ii) carbon positive effect and,
(iii) carbon negative effect
on atmosphere under the natural CO_2 cycle.

(30 marks)

b) Consider the ideal gases in insulated rigid vessel (PG in one vessel and Nitrous oxide in the other vessel) with their specifications shown in Figure 1 [b]. PG temperature is {F1}°C while N_2O temperature is {F2}°C. Volume (%) for PG gas composition is as following:

- CH_4 = {F3} %
- CO_2 = {F4} %
- CO = {F5} %
- H_2 = {F6} %
- O_2 = {F7} %
- balance is N_2 %.

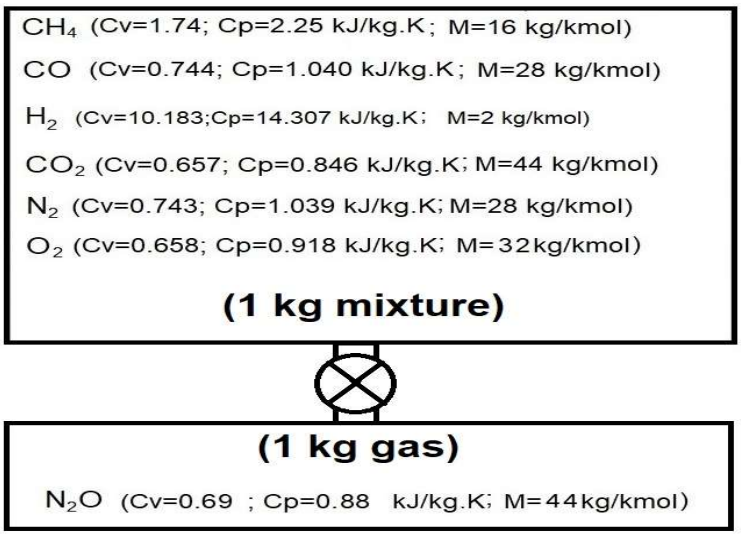

Figure 1(b)

The valve between the two vessels was opened allowing gases to mix and reach steady state. Calculate:

(i) The mass fraction of N_2O, CH_4, CO, H_2, N_2, O_2, CO_2 in final mixture.

(30 marks)

(ii) The total volume.

(10 marks)

(iii) The final pressure and temperature of the mixture.

(30 marks)

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2. a) With the aid of schematic drawing and sketch of the process on psychrometric chart for the cooler, discuss for the following:
   (i) the working principle of air coolers (based on adiabatic humidification).
   (ii) which ambient conditions are optimum for the use of this cooler compared to the ambient conditions where this device is not usable.

(40 marks)

b) The temperature of water flow of {F8} kg/s is reduced from {F9}°C to {F10}°C using cooling tower. Given that atmospheric air enters the tower at {F11}°C and {F12}% relative humidity and leaves the tower saturated at {F13}°C. Calculate:

(i) The required mass flow rate of the make-up water

(ii) The required mass flow rate of air.

(60 marks)

3. a) A burner was designed to run on 1 kg/s methane (CH_4) fuel supply. Producer gas (PG) fuel with composition of CO = {F14}%, H_2 = {F15}%, CH_4 = {F16}% and the balance is N_2% (volume %) was proposed as an alternative fuel.

(i) Write chemical reaction for stoichiometric combustion of PG.

(20 marks)

(ii) Calculate the required air/fuel ratio for PG combustion in stoichiometric condition compared to methane combustion.

(10 marks)

(iii) If the PG flow rate was fixed at 1 kg/s, compare the output heat from the burner (based on LHV) when using PG compared to the original fuel (methane). Take LHV to be 120 MJ/kg for H_2, 10 MJ/kg for CO, and 50 MJ/kg for CH_4.

(10 marks)

(iv) Discuss the effect of the A/F ratio and heating value of PG on the combustion completion compared to the original fuel (methane) and put your recommendation to overcome the combustion difficulty.

(10 marks)

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b) The volumetric analysis of combustion exhaust (dry basis) are {F17}% CO_2, {F18}% CO, {F19}% O_2 and the balance is N_2 %.

(i) Calculate chemical formula of the fuel (CxHy).

(20 marks)

(ii) Compare the theoretical air to the actual air used in combustion.

(20 marks)

(iii) Discuss why CO is present in exhaust along with excess O_2.

(10 marks)

EITHER 4 (a) OR 4 (b)

4. a) (i) The brake thermal efficiency of spark ignition and compression ignition engines is considerably lower compared with the theoretical thermal efficiency of an Otto and diesel cycle. Discuss **FOUR** factors that contribute to these phenomena and provide the estimated percentage loss of each factor.

(40 marks)

(ii) A performance curve for a four-stroke, naturally aspirated direct injection engine is shown in Figure 4. Figure 4 (a) shows the mean piston speed (m/s) against the specific fuel consumption (kg/MJ) and brake mean effective pressure (bar) and Figure 4(b) shows the mean piston speed against the specific power (MW/m^2). The engine produces 240 kW at a corresponding maximum torque of 1200 Nm. The calorific value of the fuel is 44200 kJ/kg. By choosing the appropriate values of bmep and mean piston speed, calculate the

(a) stroke
(b) number of engine cylinders
(c) corresponding engine speed
(d) brake thermal efficiency

Sketch the trend of brake power (W) and torque output (Nm) against the engine speed (rev/min). You are only required to sketch the trend and you are not required to plot in the graph paper.

(**Hint**: The specific power is defined as the ratio between the power and the total piston area)

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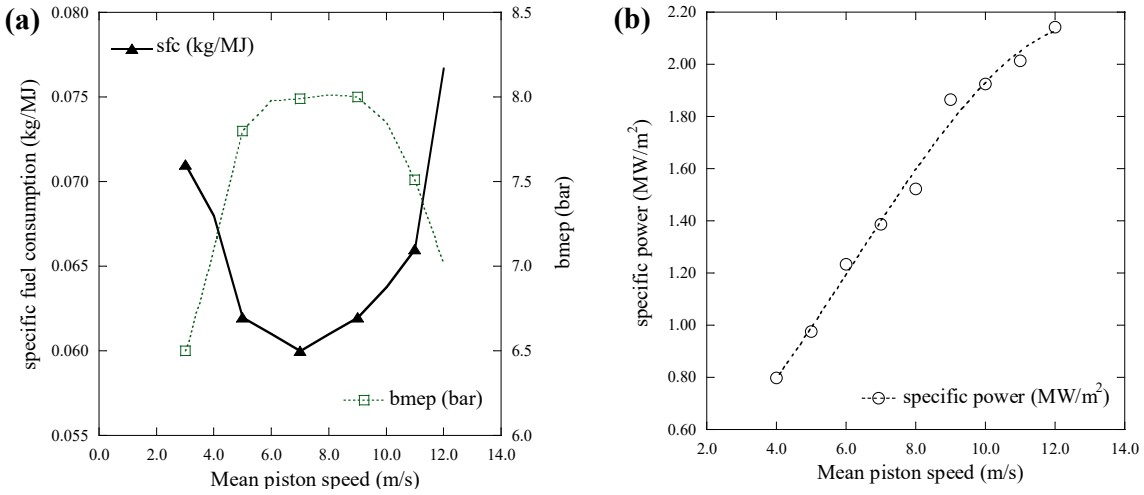

Figure 4

(60 marks)

b) (i) Elaborate on the importance of brake specific air consumption. What does it indicate?

(40 marks)

(ii) A performance curve for a four-stroke compression ignition engine is shown in Figure 4. Figure 4 (a) shows the engine speed (rev/min) against the brake power (kW) and brake mean effective pressure (bar) and Figure 4 (b) shows the engine speed against the specific fuel consumption (kg/MJ). The calorific value of the fuel is 44000 kJ/kg. Using the performance data shown in Figure 4, calculate:

(a) engine displacement
(b) minimum and maximum torque output
(c) engine stroke
(d) the number of engine cylinders

Verify your answer in (d) with a suitable value of piston diameter.

Plot the trend of torque output (Nm) and brake thermal efficiency against the engine speed (rev/min).

(**Hint:** for both (c) and (d), assume an appropriate value of maximum mean piston speed)

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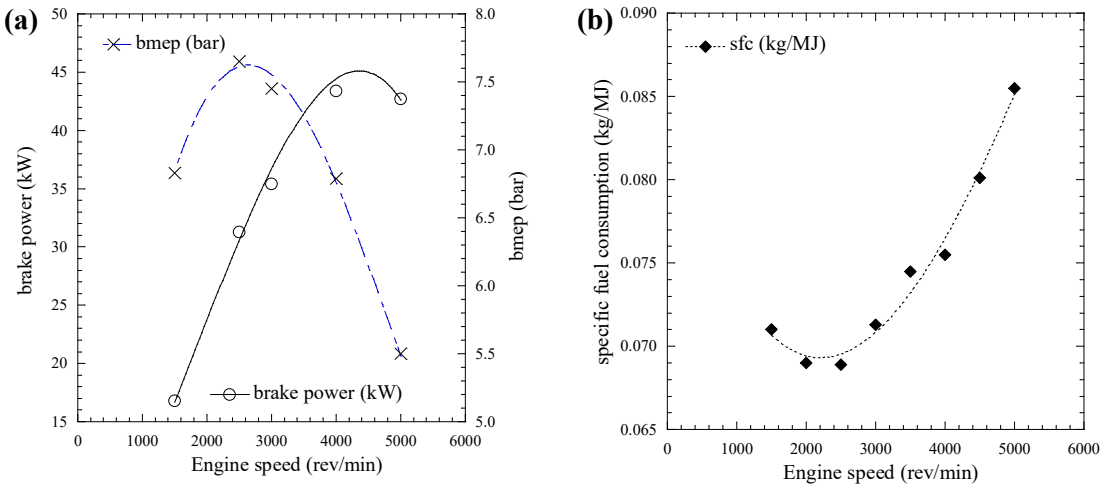

Figure 4

(60 marks)

5. (a) Single stage compression at very high pressure is highly ineffective compared with multistage compression. Discuss **TWO (2)** difficulties in single stage compression at very high pressure and the solutions which are practically applied to multistage compression.

(40 marks)

OR

(a) Discuss **TWO (2)** reasons why a typical p-V diagram for an actual compression process is fundamentally different compared with the corresponding theoretical diagram?

(40 marks)

**Yellow highlighted parameters are subject to change.*

(b) A single acting two stage compressor draws in free air and compresses it to 8.5 bar. The compressor runs at 600 rev/min. The atmospheric conditions are 1.013 bar and 15 °C. The intermediate pressure is 3 bar and the intercooler cools the air back to 30 °C. The polytropic index for all compressions and expansions is 1.28. Due to the effect of warming from the cylinder walls, the induction pressure and temperature at the start of the low pressure compression stroke is 0.96 bar and 25 °C, respectively. The clearance volume for each stage is 4% of the swept volume of that stage. The diameter of the low pressure cylinder is 300 mm and the stroke for both low and high pressure cylinders is 160 mm. Calculate:

(i) the free air delivery, FAD
(ii) the volumetric efficiency of the low pressure stage
(iii) the diameter of the high pressure cylinder

(60 marks)

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