UNIVERSITY OF ZAMBIA
SCHOOL OF ENGINEERING
DEPARTMENT OF MECHANICAL ENGINEERING

MID YEAR FINAL EXAMINATIONS FOR THE 2016 ACADEMIC YEAR

MEC 3401: THERMODYNAMICS

TIME ALLOWED: THREE (3) HOURS   **CLOSED BOOK**

INSTRUCTIONS

1. Answer a **TOTAL OF FIVE (5)** questions.

2. Answer:

   TWO (2) Questions from Section A.

   THREE (3) Questions from Section B.

3. If any of **Questions 3, and 7** is / are attempted, it / they should be tied together and submitted as a **separate booklet.**

4. If any of **Questions 1, 2, 4, 5 and 6,** is / are attempted, it / they should be tied together and submitted as a **separate booklet.**

5. ALL Questions carry 20 Marks

6. **THERMODYNAMIC STEAM TABLES ARE ALLOWED.**

7. Draw neat sketches and graphs where necessary and clearly state any assumptions made.

Question One ✓

(a) What do you understand by the following terms:

    (i)   Throttling
    (ii) Wet steam
    (iii) Dry steam
    (iv) Dryness fraction

(b) A rotary compressor provides compressed air at a rate of *1.6kg/s*. The air enters the inlet of the compressor with a velocity of *80m/s* and specific volume of *0.9m³/kg* and exits at the outlet with a velocity of *46m/s* and specific volume of *0.4m³/kg*. During its passage through the compressor, the air experiences an increase in specific enthalpy of *118kJ/kg* and a heat transfer loss of *22kJ/kg*. Determine:

    (i)   The inlet and exit areas of the compressor.
    (ii) The power required to drive the compressor.
    (iii) What type of system would you regard the given arrangement and why?

[4+16 =20 Marks]

Question Two

(a) Briefly explain using neat sketches, the *four basic circuits* of a steam plant.

(b) Explain with relevant sketches, the working principle of a *"reheat"* cycle for a team plant.

(c) Give two advantages of the *"reheat"* cycle.

[10+8+2 = 20 Marks]

Question Three ✓

(a) Discuss the purpose of undertaking energy conversion.

(b) Discuss the conventional and renewable energy sources under energy conversion.

(c) What are the challenges associated with the use of thermal power plants and nuclear power plants.

[4+8+8 = 20 Marks]

Question Four ✓

(a) Briefly explain the significance of the *Otto* cycle.

(b) Provide a sketch of the *PV* and *TS* diagrams for the *Otto* cycle.

(c) A Carnot cycle involves the circulation of *1 kg* of air. The initial pressure and temperature of the air are *1.73MN/m²* and *300°C* respectively. From these initial conditions, the air is expanded isothermally to three times its initial volume and then further expanded adiabatically to six times its initial volume. The cycle is then completed by an isothermal compression followed by an adiabatic compression. Provide sketches of the *PV* and *TS* diagrams for the cycle and determine:

- (i) The parameters of state for each state point of the cycle. *(Tabulate your results)*
- (ii) The thermal efficiency of the cycle
- (iii) The work done per cycle
- (iv) The work ratio

Take R = 0.29kJ/kgK ; γ = 1.4)

[4+16 = 20 Marks]

Question Five ↲

The following readings were recorded at 2 minute intervals during a laboratory session, using the Combined Separating and Throttling Calorimeter, to determine the dryness fraction of steam flowing through a steam main.

M	m	Before Throttling		After Throttling	
(ml)	(ml)	Pressure (bar)	Temperature (°C)	Pressure (bar)	Temperature (°C)
116	38	7.7	45	14	110
112	36	7.7	52	8	110
105	24	7.4	54	8	110

- Atmospheric pressure = *658mmHg*
- Density of mercury = *13,600kg/m³*
- Density of water = *1000kg/m³*
- M = Mass of condensate from throttling calorimeter
- m = Mass of suspended water separated in the separator

(a) Derive the expression for dryness fraction for the combined Separating and Throttling Calorimeter.

(b) Use the expression derived in Part (a) to determine the dryness fraction in the steam main

[4+16 = 20 Marks]

Question Six

(a) Briefly explain the refrigeration cycle using neat sketches of the *T-S* and *P-h* diagrams and show how the refrigeration effect may be increased.

(b) A simple heat pump using *Freon – 12* is used for heating up a room. It consists of an evaporator, compressor, condenser and a throttle regulator. The heat pump works between pressure limits of *0.567 MN/m²* and *1.084 MN/m²*. At the beginning of compression, the *Freon – 12* is assumed dry saturated and after compression, it has a temperature of *60°C*. At the end of the condensation process, the refrigerant is liquid but not under – cooled. If the heat transfer required from the condenser unit is *90 MJ/h*, assuming the specific heat capacity of the superheated vapour to be constant, determine:

    (i)   The mass flow rate of the *Freon – 12* in kg/h assuming no energy loss.
    (ii)   The dryness fraction of the *Freon – 12* at entry to the evaporator.
    (iii)   The power of the driving motor assuming that only *73%* of the power of the driving motor is available in the *Freon – 12*.
    (iv)   The ratio of the heat transferred from the condenser to the power required to drive the motor in the same time.

$$[5+2+13 = 20 \text{ Marks}]$$

Question Seven

(a) A gaseous fuel n-Butane (C_4H_{10}), reacts under stoichiometric conditions in a gas turbine to form products of combustion, which are used to propel an electric generator.

    (i)   Draw the ideal cycle for this operation.
    (ii)   Determine the threshold amount of air required for complete combustion.
    (iii)   Determine the amount of products of combustion by volume.

(b) The fuel n-Butane (C_4H_{10}) again is allowed to react with *200%* theoretical air.

    (i)   Determine the theoretical equation for this reaction, products and combustion.
    (ii)   Determine the excess air coefficient for this reaction.

$$[14+6 = 20 \text{ Marks}]$$

End of MEC 3401 – Thermodynamics I Mid Year Final Examination, May 2017.

Prepared By:
Prof. F.D. Yamba and Mr. S.S. Virdy

MID YEAR FINAL EXAMINATIONS FOR THE 2016 ACADEMIC YEAR

MEC 3401: THERMODYNAMICS

TIME ALLOWED: THREE (3) HOURS   CLOSED BOOK

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Question One

(a) What do you understand by the following terms:

   (i) Throttling
   (ii) Wet steam
   (iii) Dry steam
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(b) A rotary compressor provides compressed air at a rate of $1.6kg/s$. The air enters the inlet of the compressor with a velocity of $80m/s$ and specific volume of $0.9m^3/kg$ and exits at the outlet with a velocity of $46m/s$ and specific volume of $0.4m^3/kg$. During its passage through the compressor, the air experiences an increase in specific enthalpy of $118kJ/kg$ and a heat transfer loss of $22kJ/kg$. Determine:

   (i) The inlet and exit areas of the compressor.
   (ii) The power required to drive the compressor.
   (iii) What type of system would you regard the given arrangement and why?

[4+16 =20 Marks]

Question Two

(a) Briefly explain using neat sketches, the *four basic circuits* of a steam plant.

(b) Explain with relevant sketches, the working principle of a *"reheat"* cycle for a team plant.

(c) Give two advantages of the *"reheat"* cycle.

[10+8+2 = 20 Marks]

Question Three

(a) Discuss the purpose of undertaking energy conversion.

(b) Discuss the conventional and renewable energy sources under energy conversion.

(c) What are the challenges associated with the use of thermal power plants and nuclear power plants.

[4+8+8 = 20 Marks]

Question Four

(a)   Briefly explain the significance of the *Otto* cycle.

(b)   Provide a sketch of the *PV* and *TS* diagrams for the *Otto* cycle.

(c)   A Carnot cycle involves the circulation of *1 kg* of air. The initial pressure and temperature of the air are *1.73MN/m²* and *300°C* respectively. From these initial conditions, the air is expanded isothermally to three times its initial volume and then further expanded adiabatically to six times its initial volume. The cycle is then completed by an isothermal compression followed by an adiabatic compression. Provide sketches of the *PV* and *TS* diagrams for the cycle and determine:

(i)   The parameters of state for each state point of the cycle. *(Tabulate your results)*
(ii)   The thermal efficiency of the cycle
(iii)   The work done per cycle
(iv)   The work ratio

Take R = 0.29kJ/kgK ; γ = 1.4)   O   *[4+16 = 20 Marks]*

Question Five

The following readings were recorded at 2 minute intervals during a laboratory session, using the Combined Separating and Throttling Calorimeter, to determine the dryness fraction of steam flowing through a steam main.

M	m	Before Throttling		After Throttling	
		Pressure	Temperature (°C)	Pressure (bar)	Temperature (°C)
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112	36	7.7	54	8	110
105	24	7.4			

- Atmospheric pressure   =   *658mmHg*
- Density of mercury   =   *13,600kg/m³*
- Density of water   =   *1000kg/m³*
- M = Mass of condensate from throttling calorimeter
- m = Mass of suspended water separated in the separator

(a)   Derive the expression for dryness fraction for the combined Separating and Throttling Calorimeter.

(b)   Use the expression derived in Part (a) to determine the dryness fraction in the steam main
                                                                                    [4+16 = 20 Marks]

_____ 3

Question Six

(a) Briefly explain the refrigeration cycle using neat sketches of the *T-S* and *P-h* diagrams and show how the refrigeration effect may be increased.

(b) A simple heat pump using *Freon – 12* is used for heating up a room. It consists of an evaporator, compressor, condenser and a throttle regulator. The heat pump works between pressure limits of *0.567 MN/m²* and *1.084 MN/m²*. At the beginning of compression, the *Freon – 12* is assumed dry saturated and after compression, it has a temperature of *60°C*. At the end of the condensation process, the refrigerant is liquid but not under – cooled. If the heat transfer required from the condenser unit is *90 MJ/h*, assuming the specific heat capacity of the superheated vapour to be constant, determine:

(i)   The mass flow rate of the *Freon – 12* in kg/h assuming no energy loss.
(ii)   The dryness fraction of the *Freon – 12* at entry to the evaporator.
(iii)   The power of the driving motor assuming that only *73%* of the power of the driving motor is available in the *Freon – 12*.
(iv)   The ratio of the heat transferred from the condenser to the power required to drive the motor in the same time.

[5+2+13 = 20 Marks]

Question Seven

(a) A gaseous fuel *n-Butane (C₄H₁₀)*, reacts under stoichiometric conditions in a gas turbine to form products of combustion, which are used to propel an electric generator.

(i)   Draw the ideal cycle for this operation.
(ii)   Determine the threshold amount of air required for complete combustion.
(iii)   Determine the amount of products of combustion by volume.

(b) The fuel *n-Butane (C₄H₁₀)* again is allowed to react with *200%* theoretical air.

(i)   Determine the theoretical equation for this reaction, products and combustion.
(ii)   Determine the excess air coefficient for this reaction.

[14+6 = 20 Marks]

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End of MEC 3401 – Thermodynamics I Mid Year Final Examination, May 2017.

Prepared By:
Prof. F.D. Yamba and Mr. S.S. Virdy

4

UNIVERSITY OF ZAMBIA
SCHOOL OF ENGINEERING
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MID YEAR EXAMINATIONS FOR THE 2014 ACADEMIC YEAR

MEC 3401: THERMODYNAMICS

TIME ALLOWED: THREE (3) HOURS

CLOSED BOOK

INSTRUCTIONS

1. Answer a **TOTAL OF FIVE (5)** questions.

2. Answer:

   TWO (2) Questions from Section A.

   THREE (3) Questions from Section B.

3. If any of **Questions 3, and 7** is / are attempted, it / they should be tied together and submitted as a **separate booklet.**

4. If any of **Questions 1, 2, 4, 5 and 6,** is / are attempted, it / they should be tied together and submitted as a **separate booklet.**

5. ALL Questions carry **20 Marks**

6. **THERMODYNAMIC STEAM TABLES ARE ALLOWED.**

7. Draw neat sketches and graphs where necessary and clearly state any assumptions made.

Question One

(a)   Derive the expression for work done in a *"polytropic"* process.

(b)   A petrol engine drives an electric generator and looses *9%* of the power produced during transmission to the generator. If the electrical output of the generator which has an efficiency of *93%*, is *230 Volts* and *65 Amps*, determine:

      (i)   The power output of the engine.

      (ii)   The mass of petrol consumed by the engine per hour, given that petrol has a calorific value of *44MJ/kg* and your power output obtained in part (i) represents *32%* of the energy input to the engine.

(c)   Name the law of thermodynamics that concerns itself with the fuel consumption of the engine mentioned in Part (b) and explain its practical implication.

[7+10+3 =20 Marks]

Question Two

(a)   Explain using relevant sketches the working principle of the *"regenerative"* steam cycle.

(b)   A cooling tower used in a power plant consists of a number of fans. The quantity of cooling water circulated through the tower is *132,000 kg/h* and the temperature drop across the tower is *6°C*. Given that the atmospheric conditions are *38°C DBT* and *26°C WBT*, and that the air leaves the tower at *32°C* and *90% R.H.*, find:

      (i)   The number of fans required in the plant if a single fan delivers air at *400m³/min.*

      (ii)   The quantity of make up water in kg/h neglecting the loss due to carry over and heat losses.

(Take: $c_{p,water}$ = 4.187kJ/kg; Use the psychrometric chart provided)

[7+13 = 20 Marks]

Question Three

(a)   What is *"global warming"* which leads to climate change, and its causes?

(b)   Discuss the design features, with the help of sketches and appropriate *PV and TS thermodynamic ideal cycles*, of the following:

      (i)   Energy sources for electricity generation contributing to climate change.

      (ii)   Energy sources for electricity generation most likely to contribute towards the reduction of green house gases by 2050.

[5+10+5 = 20 Marks]

Question Four

(a)   Give a labelled sketch of the *PV and Ts diagrams* of the *Ericson cycle* and briefly state its significance.

(c)   A certain engine is based on the *diesel cycle*. At the beginning of compression, the pressure and temperature of gas is found to be *95kN/m²* and *45°C* and respectively. If the volume ratio of the compression is *16:1* and the materials used to build the engine can withstand a maximum temperature of *1500°C*, determine the following:

   (i)   The pressure and temperature at each of the cycle process change points *(Tabulate your results)*
   (ii)   The work done / kg of gas
   (iii)   The thermal efficiency
   (iv)   The work ratio
   (v)   The mean effective pressure
   (vi)   The Carnot efficiency within the temperature limits

Take $\gamma = 1.4$; $C_p = 1.004 kJ/kgK$; $C_v = 0.716\ kJ/kgK$; $R = 0.287\ kJ/kgK$

[4+16 = 20 Marks]

Question Five

The following readings were recorded at *2-minute* intervals during a laboratory session, using the Combined Separating and Throttling Calorimeter, to determine the dryness fraction of steam flowing through a steam main.

M	m	Before Throttling		After Throttling	
		Pressure (bar)	Temperature (°C)	Pressure (bar)	Temperature (°C)
(ml)	(ml)				
116	38	7.7	45	14	110
112	36	7.7	52	8	110
105	24	7.4	54	8	110

- Atmospheric pressure   =   658mmHg
- Density of mercury   =   13,600kg/m³
- Density of water   =   1000kg/m³
- M = Mass of condensate from the throttling calorimeter.
- m = Mass of suspended water separated in the separator.

(a)   Derive the expression for dryness fraction for the combined Separating and Throttling Calorimeter.

(b)   Use the expression derived in Part (a) to determine the dryness fraction in the steam main

[4+16 = 20 Marks]

Question Six

(a)   Using neat sketches of the *T-s* and *p-h diagram,* show the various stages of the refrigeration cycle and explain how the *refrigeration effect* can be increased..

(b)   Briefly explain why is it important for the refrigerant entering the compressor of a refrigeration plant to be *"dry saturated"*.

(c)   A vapour compression refrigerator uses methyl chloride and operates between the pressure limits of *146kN/m²* and *967kN/m²*. At the entry to the compressor, the methyl chloride is dry saturated and after compression has a temperature of *103°C*. The compressor has a bore and stroke of 80mm and runs at 8 revolutions per second, with a volumetric efficiency of *83%*. The temperature of the liquid refrigerant as it leaves the condenser is *33°C* and its specific heat capacity is *1.62kJ/kgK*. The specific heat capacity of superheated vapours may be assumed constant. Determine:

   (i)   C.O.P. of the refrigerator
   (ii)   Mass flow of refrigerant in kg/hr
   (iii)   Cooling water required by the condenser in kg/hr if cooling water temperature rise is limited to *11°C*.

Take Specific Heat Capacity of water = 4.187kJ/kgK
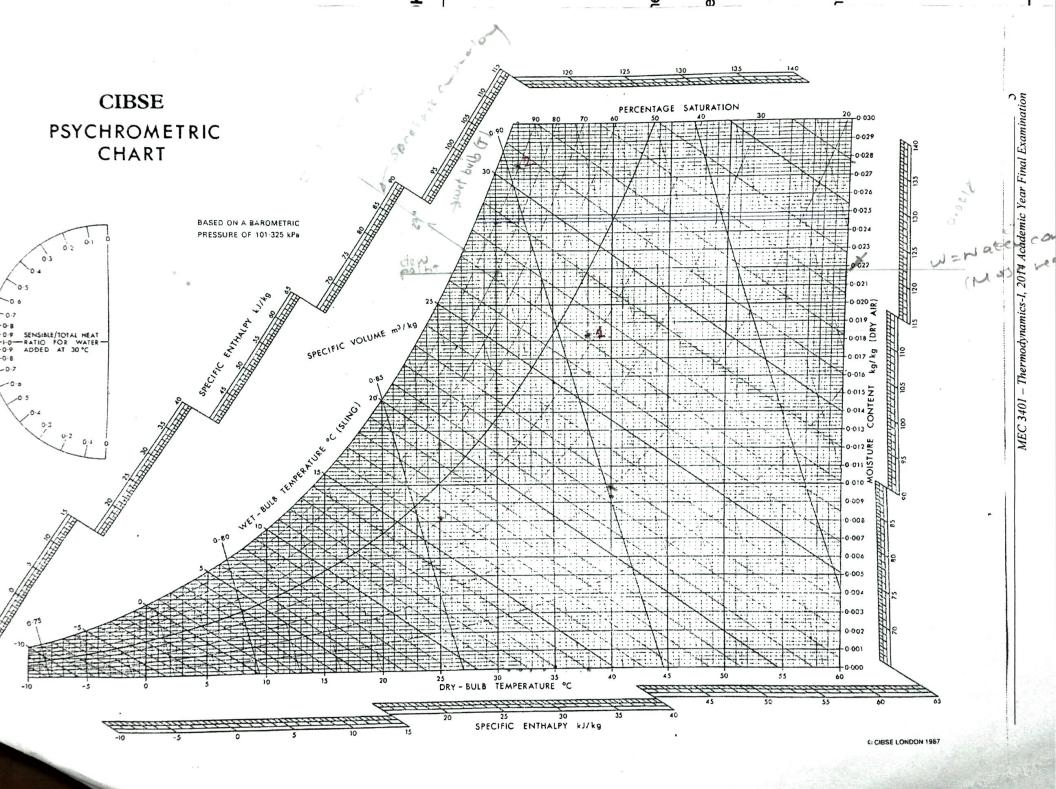
[5+2+13 = 20 Marks]

Question Seven

Metahne gas reacts in a combustion process under three conditions namely, complete stoichiometric combustion, lean combustion with *150%* theoretical excess air, and rich combustion with *20%* deficiency of air.

(a)   Formulate complete chemical reactions involved under these three combustion scenarios.

(b)   Determine the air requirements for combustion for the three scenarios if the excess air coefficient is given as *1.2* for lean combustion and *0.7* for rich combustion.

(c)   Determine the products of combustion by volumetric percentage under these three scenarios.

[6+6+8= 20 Marks]

End of MEC 3401 – 2014 Thermodynamics Mid Year Final Examination, March 2015.

**Prepared By:
Prof. F.D. Yamba and Mr. S.S. Virdy**

CIBSE
PSYCHROMETRIC CHART

BASED ON A BAROMETRIC
PRESSURE OF 101·325 kPa

SENSIBLE/TOTAL HEAT
RATIO FOR WATER
ADDED AT 30 °C

SPECIFIC ENTHALPY kJ/kg

SPECIFIC VOLUME m3/kg

WET-BULB TEMPERATURE °C (SLING)

PERCENTAGE SATURATION

wet bulb (T)

dew point

MOISTURE CONTENT kg/kg (DRY AIR)

DRY-BULB TEMPERATURE °C

SPECIFIC ENTHALPY kJ/kg

W = Water co
(M)

MEC 3401 – Thermodynamics-I, 2014 Academic Year Final Examination

UNIVERSITY OF ZAMBIA
SCHOOL OF ENGINEERING
DEPARTMENT OF MECHANICAL ENGINEERING

MID YEAR EXAMINATIONS FOR THE 2013 ACADEMIC YEAR

MEC 3401: THERMODYNAMICS

TIME ALLOWED: THREE (3) HOURS

CLOSED BOOK

INSTRUCTIONS

1. Answer a **TOTAL OF FIVE (5)** questions.

2. Answer:

   TWO (2) Questions from Section A.

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5. ALL Questions carry **20 Marks**

6. **THERMODYNAMIC STEAM TABLES ARE ALLOWED.**

7. Draw neat sketches and graphs where necessary and clearly state any assumptions made.

Question One ✓

(a) Define the following:

    (i)   Reversibility
    (ii)   Open system

(b) Explain the considerations made that led to the development of the *third law* of thermodynamics.

(c) Briefly explain how a *relationship between heat and work* can be developed and relate it to the laws of thermodynamics.

(d) Derive the expression for *work done* for a *polytropic* process.

[2+6+6+6 =20 Marks]

Question Two ✓

Explain the following using relevant sketches:

    (i)   The working principle and significance of the *reheat* steam cycle.   *sketch.*
    (ii)   The working principle of a *cooling tower* in a steam plant.
    (iii) *Open* and *closed* type *feed water heaters*.

[6+6+8 = 20 Marks]

Question Three

(a) Define *combustion* and its *stages*.

(b) What do you understand are the *pollutants* and *green house gases* from combustion of fossil fuels and air?

(c) With the help of a diagram, explain what is *global warming* and its causes.

[20 Marks]

Question Four

(a)   Give a labelled sketch of the *PV and Ts diagrams* of a *Stirling cycle* and briefly explain why it is not suitable for use in practice.

(b)   A Carnot cycle involves circulation of One kilogram of gas. The initial pressure and temperature of the gas are 1.75MN/m² and 312°C respectively. From these initial conditions, the gas is expanded isothermally to three times its initial volume and then further expanded adiabatically to six times its initial volume. The cycle is completed by an isothermal compression followed by adiabatic compression. Represent the cycle on *PV* and *TS* diagrams and determine:

   (i)   The pressure, volume and temperature at each of the cycle process change points. *Present your answers in a table.*
   (ii)   The thermal efficiency of the cycle
   (iii)   The work done per cycle
   (iv)   The work ratio

(Take: Universal Gas Constant, R = 0.29kJ/kgK; Adiabatic Index, γ = 1.39)

[4+16 = 20 Marks]

Question Five

The following readings were recorded at 10 minute intervals during a session to assess the efficiency of a Fulton boiler.

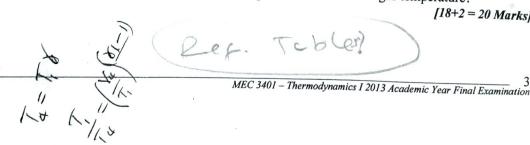| Interval (10mins)	1	2	3	4	5	6
Feed Water Flow Rate (cm³/s)	31.37	31.38	31.38	31.38	31.38	31.37
Feed Water Temperature (°C)	25.0	25.0	25.0	25.0	25.0	25.0
Steam Gauge Pressure (Bar)	0	1.38	7.24	6.62	6.90	6.90
Fuel flow by volume (cm)	7.5	7.0	6.5	6.2	6.0	6.0
Fuel Temperature (°C)	24.0	25.0	25.0	25.0	25.0	24.0
Steam Temperature (°C)	25	25	90	124	134	138
Exhaust Flue Gas Temperature (°C)	25	288	245	185	194	215

- Room temperature and humidity before taking readings   =   26.5°C ; 36%
- Room temperature and humidity after taking readings   =   27.0°C ; 36%
- Atmospheric pressure   =   657.7mmHg
- Density of mercury   =   13,600kg/m³
- Fuel gauge conversion (cm to cm³)   =   cm x 5360 = cm³
- Density of the fuel used   =   810kg/m³
- Calorific Value of the fuel used   =   46MJ/kg

(a)   Determine the efficiency of the boiler and comment on the value obtained.

(b)   Why was it necessary to take readings for the exhaust flue gas temperature?

[18+2 = 20 Marks]

Question Six

(a) Explain with the help of a neat sketch the purpose of introducing a *slight degree of superheat* at the end of the compression stroke in a vapour compression refrigeration cycle?

(b) A simple heat pump is to be used for space heating. It consists of an evaporator, compressor, condenser and a throttle regulator and the heat transfer required from the condenser unit is 105 MJ/h. The refrigerant used is Freon-12, which works between temperature limits of 10°C and 45°C. At the beginning of compression, the refrigerant is assumed dry saturated and after compression, it has a temperature of 57°C. At the end of the condensation process, the refrigerant is liquid but not under-cooled. Assuming the specific heat capacity of the superheated vapour to be constant, determine:

(i) The mass flow rate of the refrigerant in kg/h assuming no energy loss.
(ii) The dryness fraction of the refrigerant at entry to the evaporator.
(iii) The power of the driving motor assuming that only 73% of the power of the driving motor is available in the refrigerant.
(iv) The ratio of the heat transferred from the condenser to the power required to drive the motor in the same time.

[5+15 = 20 Marks]

Question Seven

During a test on a Lister engine in a Thermal laboratory, the following parameters were measured:

- Crank shaft speed = 1,750rpm
- Load on dynamometer = 220N
- Radius of dynamometer = 1.5m
- Fuel consumption = 18.7kg/h
- Calorific value = 42,300kJ/kg
- Mechanical efficiency = 83%

(i) Determine the brake power.
(ii) Determine the *theoretical* and *actual* amount of *air* required for combustion if the diesel fuel used on the Lister engine had the following composition:

Carbon (86.2%); Hydrogen (12.9%); Sulphur (0.9%)

Take excess air coefficient = 1.1

[20 Marks]

End of MEC 3401 – Thermodynamics Examination March, 2014.

Prepared By:
Prof. F.D. Yamba and Mr. S.S. Virdy