ASSESSMENT QUESTIONS PART TWO

COMBUSTION

For all combustion questions take.
Atomic mass relationships as H = 1, C = 12, N = 14, O = 16,
Air contains 21% Oxygen by volume

49 A fuel contains 84% carbon and 16% hydrogen by mass. After combustion an Orsat analysis gave a reading of 10% CO_2, 1% CO and 5.35% O_2.

(a) Determine the combustion equation in Kmol per Kg of fuel.
(b) Calculate the percentage excess air supplied.

50 The volumetric analysis of a gaseous fuel consists of 8% CO_2, 23% CO, 20% H_2, 3% CH_4 and 46% N_2. The gas is burned with 10% excess air. Calculate

(a) The air fuel ratio by volume
(b) The volumetric analysis of the dry flue gas
(c) The gravimetric analysis of the wet flue gas

51 A pure hydro-carbon fuel was burned in air and gave the following dry gas analysis 5.27% CO_2, 13.38% O_2 and 81.35% N_2.
Determine

(a) the mass analysis of the fuel
(b) The air fuel ratio by mass

52 Ethyl alcohol (C_2H_6O) is burned completely with 10% excess air .

(a) Determine
  (i) The combustion equation in Kmol per kg of fuel
  (ii) The air fuel ratio by mass
(b) Briefly describe the effects of N_2 on the combustion process

53 An engine burns a fuel with a mass analysis of 88% Carbon and 12% Hydrogen. The Orsat analysis of the exhaust gas shows equal volumes of carbon dioxide and oxygen with no carbon monoxide.

(a) Write the complete combustion equation in Kmol per Kmol of fuel
(b) Determine the excess air supplied.

54 A pure hydro-carbon fuel of composition $C_{12}H_{26}$ is burned with an air fuel ratio by mass of 20 :1

(a) Write the complete combustion equation in Kmol per Kmol of fuel
(b) Calculate
  (i) the percentage excess air supplied
  (ii) The volumetric analysis of the dry exhaust gas
  (iii) The gravimetric analysis of the wet exhaust gas

MIXTURES

55 A vessel of 0.42 m^3 contains ethylene (C_2H_4) and air at 7.6 bar 32°C.
The mass of air is 20% more than that required for stoichiometric combustion.

Calculate

(a) The mass of air
(b) The mass of ethylene
(c) The partial pressures of the air and ethylene
(d) The characteristic constant for the mixture.

Universal gas constant R_o = 8.3145 kJ/Kmol K
Atomic mass relationships as H = 1, C = 12, N = 14, O = 16,
For air R= 287 J/kgK and 21% Oxygen by volume

56 A gaseous mixture contains 29% CO_2, 50% H_2, 21% N_2 by volume. 0.085 m^3 of the mixture at a pressure of 1 bar and temperature of 10°C is compressed according to the law $pV^{1.2}=C$, until the final volume is one sixth of the original volume.

Calculate

(a) For the mixture
   (i) The characteristic constant
   (ii) The Specific heats at constant pressure and constant volume

(b) For the process
   (i) The work transfer
   (ii) The heat transfer.

Specific heats at constant pressure
N_2 = 1.039 kJ/kgK, CO_2 = 0.828 kJ/kgK, H_2 = 14.235 kJ/kgK,
Universal gas constant R_o = 8.3145 kJ/Kmol K
Atomic mass relationships as H = 1, C = 12, N = 14, O = 16,

57 A receiver of 1.445 litres capacity contains a mixture of steam and air at 200°C and a gauge pressure of 2.2 bar. The mass of steam is 1 gram and the barometric pressure is 740 mm Hg.

Calculate

(a) The partial pressure of the steam
(b) The partial pressure of the air
(c) The total enthalpy of the mixture based on a datum at 0°C

For air R= 287 J/kgK c_v = 718 J/kgK . For mercury Density = 13.6 tonne/m^3
Acceleration due to gravity 9.81 m/s^2.

58 A vessel of 0.42 m^3 contains a mixture of dry saturated steam and gasses A and B at a temperature of 39°C. The total pressure of the mixture is 1.3 bar and the mass of gas "A" is three time the mass of gas "B".
Calculate The mass of each substance in the vessel.
Characteristic constant for "A" and "B" are R_A = 290 J/kgK R_B = 189 J/kgK

STEAM CYCLES

59 In a steam plant using reheat, the hp turbine the steam enters at 40 bar 350°C and expands down to 10 bar with an isentropic efficiency of 0.8. Following reheat at constant pressure to 350°C the stem is expanded to condenser pressure of 0.04 bar with an isentropic efficiency of 0.75.
The mass flow rate is 5 tonne per hour with no under-cooling at the condenser and negligible feed pump work.

(a) Sketch the temperature entropy diagram for the cycle
(b) Calculate
  (i) The cycle efficiency
  (ii) The power output
  (iii) The quality of the steam entering the condenser.

60 Steam is expanded in a two stage turbine from 50 bar 350°C to a condenser pressure of 0.05 bar.
During the first stage expansion the entropy increases by 4.8%, after which some steam is bled to direct contact feed heater where the water temperature is raised to a temperature 7°C below the bled steam saturation temperature.
The remaining steam expands in the second stage to 0.05 bar 0.92 dry.
The condensate is cooled to 25°C.

(a) Sketch the cycle on a Temperature-Entropy diagram
(b) Determine
  (i) The mass flow of bled steam per kg of steam flow
  (ii) The thermal efficiency of the cycle.

61 In a high pressure turbine steam is expanded from 50 bar 400 °C to 12 bar with an isentropic efficiency of 80%. It is then passed to a low pressure turbine developing the same power and exhausting at 1 bar.

(a) Show the expansion on a Specific enthalpy – specific entropy diagram
(b) Calculate
  (i) The steam condition at inlet to the LP turbine
  (ii) The isentropic efficiency of the LP turbine
  (iii) The steam condition at LP turbine outlet.

62 A Rankine cycle operates between 30 bar and 0.04 bar. The steam consumption is 3.6 tonne per hour.
Calculate

  (a) The feed pump work per second
  (b) The cycle efficiency
  (c) The work ratio
  (d) The specific steam consumption

63 Steam at 60 bar 450°C is supplied to at three stage turbine:
1^{st} Stage the steam is expanded isentropically to 10 bar and then reheated to 370°C
2^{nd} Stage the steam is expanded isentropically to 2 bar and then reheated to 320°C
3^{rd} Stage the steam is expanded isentropically to 0.02 bar and then condensed to a saturated liquid.

(a) Calculate
  (i) The power developed per kg/s of steam flow
  (ii) The thermal efficiency of the cycle

(b) Calculate the thermal efficiency of the cycle if the inter-stage reheaters where bypassed.

(c) Show both expansions on an enthalpy entropy diagram and briefly explain why the reheat cycle would be preferred in practice.

64 A two stage pass out steam turbine develops 4 MW of power at a steam flow of 5 kg/s. Steam expands in the first stage from 50 bar 350°C to 2 bar with an isentropic efficiency of 85%. Some steam is then bled off for auxiliary purposes. The remaining steam is reheated at constant pressure to 250°C and then expanded in the second stage with an isentropic efficiency of 80% to a condenser pressure of 0.05 bar.

Calculate the mass flow of bled steam

NOZZLES

65 The isentropic mass flow rate of air through a convergent divergent nozzle discharging to atmospheric pressure of 1.013 bar is 6.5 kg/s.
The inlet pressure and temperature of the air into the nozzle are 8 bar 297°C respectively.

(a) Calculate
  (i) The area and velocity at the nozzle throat
  (ii) The area and velocity at the nozzle exit.

(b) Explain why a nozzle expanding fluids through a large pressure ratio need to be of the convergent divergent type.

66 Steam at 9 bar 400°C enters a convergent divergent nozzle with negligible velocity.
Expansion is isentropic to a pressure of 3 bar at the throat.
The mass flow through the nozzle is 2 tonne per hour with an exit pressure of 0.7 bar.
The specific enthalpy drop across the divergent section is 480 kJ/kgK
Calculate

(a) The area of the throat and exit
(b) The isentropic efficiency of the divergent section.

67 Dry saturated steam at 8 bar and with negligible velocity is accelerated through a nozzle to an exit pressure of 0.14 bar. The pressure and specific enthalpy drops in the convergent section are 3 bar and 110 kJ/kg respectively. The specific enthalpy drop in the divergent section is 572 kJ/kg.

(a) Show the expansion on a Specific enthalpy – specific entropy diagram

(b) Calculate

- (i) The diameter at the nozzle throat and exit
- (ii) The isentropic efficiencies of each section
- (iii) The overall isentropic efficiency of the nozzle.

68 Air at 3 bar 77°C enters a nozzle with a velocity of 50 m/s and leaves at 1 bar with a velocity of 320 m/s.

The nozzle has an inlet area of 100 cm^2 and losses 3.2 kJ of heat per kg of air flowing through it.

(a) List the major assumptions made

(b) Calculate

- (i) The exit temperature of the air
- (ii) The exit area of the nozzle

For air c_p = 1005 J/kgK.

STEAM TURBINES

69 Dry saturated steam enters the stage of a parsons 50% reaction turbine at 6 bar and expands isentropically across the stage.

The mean blade speed is 140 m/s while the blade inlet and outlet angles are 48° and 22° respectively. There is a pressure drop of 1.5 bar across the stage with a steam flow of 2.5 kg/s.

Determine

- (a) The stage power developed.
- (b) The diagram efficiency for the stage.
- (c) The specific enthalpy drop across the stage.

70 The first stage of an impulse turbine is velocity compounded with two rows of moving blades.

Steam leaves the nozzles at 710 m/s at an angle of 20° to the plane of blade rotation.

The mean blade speed is 160 m/s.

The exit angle from the fixed blade is 20° and the moving blades are symmetrical.

The blade velocity coefficient is 0.88 over each of the three rows of blades.

The mass flow of steam is 5.4 tonne /hour.

Determine

- (a) The power developed
- (b) The diagram efficiency.

71 A single stage impulse turbine has a nozzle angle of 25 ° and is designed for zero axial thrust. The blades are symmetrical and the steam leaves the blades at an absolute velocity of 300 m/s at 60 ° to the plane of rotation.

Determine

(a) The blade angle
(b) The stage power per kg/s of steam flow
(c) The diagram efficiency

72 A two row velocity compounded turbine has symmetrical moving blades. The mean blade speed is 150 m/s. The enthalpy drop through the nozzles is 180 kJ/kg and the nozzle outlet angle is 22°. The velocity at stage inlet and any velocity drops due to friction may be neglected.

Determine

(a) The blade angles of the first row of moving blades.
(b) The blade angles of the guide blades.
(c) The blade angles of the second row of moving blades.
(d) The specific power output of the stage.

73 A 50% reaction turbine runs at 3000 rev/min and is supplied with 600 tonne/hour of steam.

A stage of the turbine has a mean blade diameter of 1 m, blade inlet angles of 50° and outlet angles of 30°. The stage efficiency is 85%.

Determine

(a) The stage power output
(b) The specific enthalpy drop in the stage
(c) The percentage increase in relative velocity through the moving blades.

74 A turbine impulse stage has nozzles set at an angle of 20°. Steam enters the nozzle with negligible velocity at 7 bar 300°C and is expanded to 3 bar with 90% isentropic efficiency.

The rotor blades are symmetrical and are subject to a negligible friction loss.

The stage operates at the optimum blade speed ratio and produces 75 kW.

Determine

(a) The absolute inlet velocity of the steam entering the rotor blades.
(b) The blade angle.
(c) The steam mass flow rate.

REFRIGERATION

75 During a vapour compression cycle dry saturated Freon 12 is compressed isentopically from 0.0871 bar to 6.516 bar.
The heat extracted in the condenser 158.4 kJ/kg.

(a) Sketch the cycle on Pressure-Enthalpy and Temperature Entropy diagrams
(b) Calculate
  (i) The temperature of the refrigerant at the end of compression
  (ii) The temperature of the refrigerant leaving the condenser
  (iii) The quality of the vapour entering the evaporator
  (iv) The coefficient of performance.

76 In a vapour compression refrigeration plant R12 is condensed at 30°C and leaves the condenser with 10° of under cooling.
The liquid is then throttled to a temperature of -20°C.
The vapour enters the compressor at -5°C and is compressed to a temperature of 60°C.
Calculate
  (a) The refrigeration effect
  (b) The quality of the refrigerant entering the evaporator.
  (c) The isentropic efficiency of the compressor
  (d) The coefficient of performance.

77 A vapour compression refrigeration plant using R12 operates between temperature limits of -5°C and 40°C.
The refrigerant enters the compressor as dry saturated vapour and compression is isentropic.
Calculate
(a) The coefficient of performance if the refrigerant leaves the condenser as a saturated liquid..
(b) The change in coefficient of performance if the refrigerant leaves the condenser at 20°C.
(c) Briefly explain why the coefficient of performance changes.

78 An ammonia refrigeration plant operates between 2.265 bar and 10.34 bar and has a compressor power requirement of 1.96 kW at a mass flow of 24 kg/hr.
The refrigerant leaves the evaporator at -10°C and the condenser at 26°C.

(a) Sketch the cycle on pressure-enthalpy and temperature-entropy diagrams
(b) Calculate
  (i) The quality of the refrigerant at entry to the evaporator
  (ii) The temperature at the compressor outlet
  (iii) The heat rejected in the condenser
  (iv) The cooling load
  (v) The coefficient of performance

79 Two vapour compression refrigeration plants one using ammonia the other R12 operate between saturation temperatures of 20°C and -30°C.
The refrigerant is a dry saturated vapour at the evaporator outlet and the compression process is isentropic in both cases.
If each plant has the same cooling load and each compressor has the same speed and volumetric efficiency

(a) Calculate for each plant
  i. The compressor outlet temperature
  ii. The refrigeration effect
  iii. The coefficient of performance

(b) Determine the ratio of compressor swept volumes between the two refrigerators.

(c) Comment on the difference in compressor volumes and the amount of superheat at the compressor discharge.

80 A vapour compression refrigerator operating between the limits of -8°C and 22°C produces 690 kg/h of ice at -5°C from water at 22°C.
The ammonia refrigerant enters the compressor with a temperature of 42°C and a mass flow of 232 kg/hour.

(a) Calculate
  (i) The quality of the refrigerant entering the evaporator
  (ii) The degree of under cooling in the condenser

(b) State the assumptions made to determine the under cooling

For water c_p= 4.2 kJ/kgK,
For ice c_p= 2.1 kJ/kgK, Enthalpy of fusion 334 kJ/kg