South Tyneside College

DISTANCE LEARNING ASSESSMENT BOOKLET

CHIEF ENGINEER REG. III/2

APPLIED HEAT

WHY DO I NEED TO BE ASSESSED?

With the introduction of the STCW'95 requirements on Seafarer's Training Certification and Watchkeeping, each signatory agreed to meet certain minimum standards on the proficiency of Seafarers. Section A-III/2 states that for the Management Level in Engineering proficiency a defined scope of theoretical knowledge must be attained and displayed by each engineer.

HOW WILL I BE ASSESSED ?

To demonstrate that you have reached this standard you will be assessed by three distinct methods for each module within this distance learning programme:

1. Eighty multi-choice questions covering the full range of the course syllabus
2. Six formal written questions covering certain areas of the course syllabus
3. The Scottish Qualification Authority (SQA) examination at a UK centre

This booklet will contain the assessment areas for items 1 and 2. Once you have completed this assessment you will be eligible to undertake the SQA examination.

WHEN WILL I BE READY TO UNDERTAKE THE ASSESSMENT ?

Obviously you will need to complete ALL of the books that form the module under study. As these books contain many Self Assessed Questions (SAQ) then these will provide you with a good guide to your level of understanding of the subject matter. If you are having difficulty with certain sections, then carefully re-study the study material. Some areas may need more than one reading to gain the level of understanding required.

HOW WILL I SUBMIT THE ASSESSMENT MATERIAL ?

Your assessments should be forwarded by mail, fax or email to:

Marine Learning Centre,
South Tyneside College
St George's Avenue
South Shields
Tyne and Wear
NE34 6ET
UK

Fax: +44 191 427 3644, or
Email mlc@stc.ac.uk

An administrator at the College will make sure that all your records are kept accurately, and that you receive feedback from your tutor on your assignments. Note that these assessment questions are split into sections. We would advise you to submit your answers in stages, and then you will be able to gauge the progress and success of your distance learning.

The multi-choice questions should be submitted in the format shown, and the formal question will be submitted in hand-written format only, as this will provide a useful guide to examination conditions. Try to attempt the formal written questions in under 30 minutes. This time scale will provide a useful guide that you have attained the level required to attempt the SQA examination.

Multi-choice submission format. ***Type out the full answer not a) b) or c)***

Student name	JOHN BROWN
Student ID	009238
Q1	45.9N
Q2	34 degrees
Q3	89.8 V
Q4	12,900 tonne

WHAT MARKS DO I NEED TO OBTAIN ?

The Maritime and Coastguard Agency require that each student:

1. Submits over 70% of their assignments for marking
2. Obtain a pass grade of 50% overall

However we would require that ALL assessments are submitted for marking, and that you obtain the minimum pass grade from these assessments. This should ensure that you will be correctly prepared to attempt the SQA examination.

WHAT HAPPENS IF I FAIL THIS ASSESSMENT ?

You will require either

1. Complete re-assessment if you failed to reach a 30% overall grade
2. Part re-assessment depending upon the level of achievement.

The College will allow one part re-assessment free of charge, but a complete re-assessment or further re-assessments will require an assessment charge of £100 to be paid.

Hence it is imperative that you are ready and prepared, by fully understanding the learning material, before you submit your assessments

MULTI-CHOICE ASSESSMENTS

Steady flow energy equation

Question 1

Air flows through a compressor at the rate of 0.5 kg/s.

At entry the pressure is 1 bar, the specific volume 0.8 m^3/kg and velocity 6 m/s.
At exit the pressure is 6.9 bar, the specific volume 0.16 m^3/kg and velocity 4.5 m/s.
The internal energy increases by 80 kJ/kg.
The cooling water absorbs heat at the rate of 50 kJ/s.
The inlet and outlet connections are on the same level.

Calculate (i) The power required to drive the compressor
(ii) The inlet pipe diameter
(iii) The outlet pipe diameter

Answers	(A)	(i) 104.99 kW	(ii) 291 mm	(iii) 150 mm
	(B)	(i) 76.26 kW	(ii) 291 mm	(iii) 150 mm
	(C)	(i) 61.00 kW	(ii) 150 mm	(iii) 291 mm
	(D)	(i) 26.26 kW	(ii) 150 mm	(iii) 291 mm

Question 2

Air enters a horizontal diffuser at 2 bar 170°C with a velocity of 300 m/s and leaves with a velocity of 50 m/s.
For air R=0.287 kJ/kgK , c_p=1.005 kJ/kgK,
If the diffusion process is considered to be isentropic.
Calculate (i) The exit pressure of the air.

Answers (A) 0.155 bar (B) 1.622 bar (C) 2.0542 bar (D) 2.77 bar

Question 3

Air at 1 bar 16°C enters a compressor at a rate of 2550 m^3/hr and leaves it at 8.25 bar 77°C with negligible change in potential and kinetic energy.
The compressor suffers a heat loss rate of 755 kJ/min.
For air R=0.287 kJ/kgK , c_p=1.005 kJ/kgK,
Calculate (i) The power absorbed.

Answers (A) 39.53 kW (B) 48.725 kW (C) 64.77 kW (D) 73.88 kW

Question 4

Air at 10°C and 80 kPa enters the diffuser of a jet engine with a velocity of 200 m/s. The flow is considered to be steady and the exit velocity is negligible compared to the inlet velocity.
The inlet area is 0.4 m^2. For air R=0.287 kJ/kgK , c_p=1.005 kJ/kgK,
Calculate
(i) The mass flow rate air
(ii) The temperature of the air leaving the diffuser.

Answers	(A)	(i) 78.8 kg	(ii) 302.9 K
	(B)	(i) 78.8 kg	(ii) 535.5 K
	(C)	(i) 7.88 kg	(ii) 302.9 K
	(D)	(i) 7.88 kg	(ii) 285.5 K

Question 5

The power output from a steam turbine is 5 MW. The conditions at inlet and outlet are shown if fig Q5.
Calculate

(i) The work done per unit mass of steam
(ii) The mass flow rate of steam.

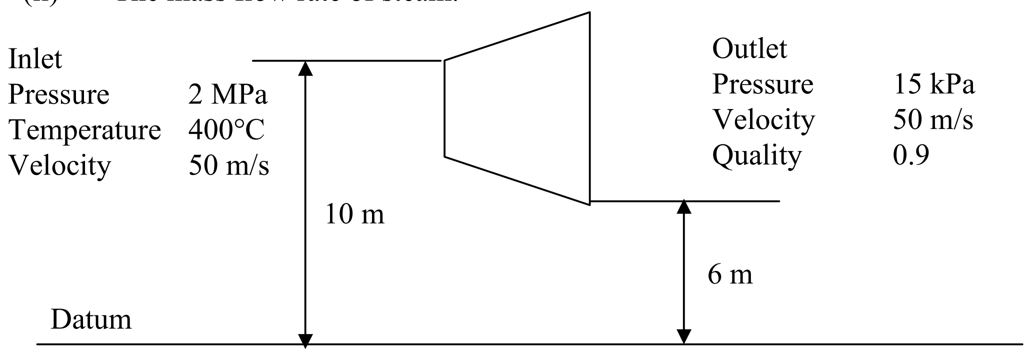

Fig Q5

Answers	(A)	(i)	14025.0 kJ/kg	(ii) 2.81 kg/s
	(B)	(i)	970.1 kJ/kg	(ii) 5.75 kg/s
	(C)	(i)	9374.2 kJ/kg	(ii) 1.88 kg/s
	(D)	(i)	893.5 kJ/kg	(ii) 5.60 kg/s

Question 6

The specific enthalpy drop of a fluid passing through a nozzle is 235 kJ/kg while the inlet velocity is 60 m/s.
At inlet, the area is 0.1 m^2 and the specific volume of the fluid is 0.19 m^3/kg.
Calculate

(i) The velocity at inlet
(ii) The mass flow rate of the fluid.

Answers	(A)	(i)	63.8 m/s	(ii) 35.77 kg/s
	(B)	(i)	530.0 m/s	(ii) 27.89 kg/s
	(C)	(i)	685.0 m/s	(ii) 31.60 kg/s
	(D)	(i)	688.0 m/s	(ii) 31.60 kg/s

Question 7

0.38 kg/s of steam enters a turbine operating at conditions of steady flow.
The steam conditions at inlet are
Pressure 13.8 bar, specific Volume 0.143 m^3/kg, Internal energy 25901 kJ/kg velocity 30 m/s
The steam conditions at outlet are
Pressure 0.35 bar, specific Volume 4.37 m^3/kg, Internal energy 23606 kJ/kg velocity 90 m/s
Heat lost to the surroundings is 0.25 kJ/s
Calculate

The power developed

Answers (A) 100.57 kW (B) 102.8 kW (C) 102.9 kW (D) 1263 kW

Question 8

At a certain moment during the running up period of a gas turbine, 45 MW of power is produced when 230 tonne/gas having an enthalpy of 2912 kJ/kg passes through.
The gas enters the turbine 3 m above the floor level at a velocity of 1100 m/min and leaves at a point 1.5 m below the floor level at a velocity of 1800 m/min.
The enthalpy of the gas at exit is 2080 kJ/kg.
At this instant the energy lost to the surroundings is 5300 kJ/s
Calculate

The rate at which energy is being stored by the turbine

Answers (A) 2.83 MW (B) 3.57 MW (C) 13.43 MW (D) 16.25 MW

Non flow process

Question 9

1.5 kg of air at NTP is heated at constant pressure until the temperature is 350°C. It is cooled at constant volume back to the initial temperature.
For Air R=0.287 kJ/kgK , c_p=1.005 kJ/kgK,
Calculate

(i) The net heat flow
(ii) The net change in entropy

Answers	(A)	(i) + 144.2 kJ	(ii) +0.332 kJ/K
	(B)	(i) - 144.2 kJ	(ii) +1.332 kJ/K
	(C)	(i) - 96 kJ	(ii) +0.903 kJ/K
	(D)	(i) + 96 kJ	(ii) +0.221 kJ/K

Question 10

3 kg of air undergoes a reversible polytropic expansion process from 4 bar 150°C to 1 bar 40°C.
This process is replaced by another process comprising an isentropic expansion and a reversible heat addition at constant pressure.
For Air c_p=1.005 kJ/kgK, γ =1.4
Calculate

(i) The difference in the work transfer between the two processes
(ii) The change of entropy

Answers	(A)	(i) +19.72 kJ	(ii) +0.286 kJ/K
	(B)	(i) +105.1 kJ	(ii) +0.0955 kJ/K
	(C)	(i) +123.68 kJ	(ii) +0.7 kJ/K
	(D)	(i) + 114 kJ	(ii) +2.1 kJ/K

Question 11

0.6 m^3 of Nitrogen at 18 bar 17°C is contained in a rigid vessel.
The discharge valve is opened until the pressure drops to 9 bar, the remaining gas expanding isentropically to fill the vessel.
When the vessel temperature is stable at 17°C the pressure was found to 10 bar.
R_O = 8.3415 kJ/kmolK , Atomic mass relationship for nitrogen =14
Calculate The adiabatic exponent for the expansion process

Answers (A) 1.7 (B) 1.399 (C) 1.179 (D) 1

Question 12

Two containers each of volume 0.75 m^3 are filled with gas at 1 bar 15°C.
In one container the gas is heated at constant volume until its pressure is 3 bar.
In the second container the gas is compressed adiabatically to a pressure of 3 bar.
For the gas R=0.259 kJ/kgK , c_p= 0.921 kJ/kgK,
Calculate for each case
(i) The mass of the gas
(ii) The final temperature of the gas
(iii) The quantity of heat added or rejected

Answers

(A)	(i) 1.005 kg, 1.005 kg	(ii) 591°C, 291°C,	(iii) 383 kJ, 0 kJ
(B)	(i) 1.005 kg, 1.005 kg	(ii) 591°C, 1328°C,	(iii) 533 kJ, 0 kJ
(C)	(i) 0. 01005 kg, 0.01005 kg	(ii) 591°C, 120°C,	(iii) 3.83 kJ, 0 kJ
(D)	(i) 1.005 kg, 1.005 kg	(ii) 591°C, 1328°C,	(iii) -194.6 kJ, 691.9 kJ

Question 13

An ideal gas at 1.05 bar 15°C is compressed in a cylinder to 4.2 bar.
The reversible polytropic compression is such that one third of the work done on the gas is rejected as heat to the cylinder walls.
For the gas atomic mass relationship is 32 and , c_v= 0.649 kJ/kgK.
R_O = 8.3415 kJ/kmolK
Calculate
(i) The index of compression
(ii) The final temperature of the gas
(iii) The work done during compression

Answers

(A)	(i) 1.267	(ii) 112.7°C	(iii) -95.15 kJ/kg
(B)	(i) 1.4	(ii) 155.2°C	(iii) -91.00 kJ/kg
(C)	(i) 1.267	(ii) 113.0°C	(iii) 170.40 kJ/kg
(D)	(i) 1.4	(ii) 115.0°C	(iii) 112.45 kJ/kg

Question 14

During a polytropic compression process the temperature of a gas rises from 16°C to 260°C and its volume is reduced to 1/5th of its initial volume.

For the gas R=0.297 kJ/kgK

Calculate

(i) The polytropic index of compression

(ii) The work done per kilogram of gas

Answers

(A) (i) 1.38 (ii) -190.7 kJ/kg

(B) (i) 2.73 (ii) 41.89 kJ/kg

(C) (i) 1.38 (ii) 190.7 kJ/kg

(D) (i) 2.73 (ii) -41.89 kJ/kg

Question 15

0.4 m^3 of perfect gas at initial conditions of 1 bar 20ºC is compressed according to the law $pV^{1.3}$=C until its pressure is 10 bar. It then undergoes a constant pressure cooling process to its original temperature followed by an isothermal process to its original volume.

For the gas R=0.256 kJ/kgK , c_p= 0.820 kJ/kgK,

Calculate

(i) The work transfer for the cycle

(ii) The change in entropy for the cycle

Answers

(A) (i) +471 kJ (ii) 0 J/K

(B) (i) -251 kJ (ii) -156 J/K

(C) (i) -471 kJ (ii) 0 J/K

(D) (i) +349 kJ (ii) +830 J/kg

Question 16

0.57 m^3 of air at 1 bar and 20.5ºC is compressed according to the law $pV^{1.36}$ = C until its volume is 0.148 m^3.

For air=0.287J/kgK , c_p= 1.005 kJ/kgK

Calculate

(i) The work transfer

(ii) The heat transfer

(iii) The change in entropy

Answers

(A) (i) -99.02 kJ (ii) -9.86 kJ (iii) -25.91 J/K

(B) (i) -99.02 kJ (ii) -36.79 kJ (iii) -25.87 J/K

(C) (i) -990.2 J (ii) -900.84 J (iii) -2.338 J/K

(D) (i) +99.02 kJ (ii) +9.86 kJ (iii) +25.91 J/K

Ideal Cycles

Question 17

1 kg of air at initial conditions of 1 bar 27°C undergoes the following reversible non flow processes.
1-2 isentropic compression through a volume ratio of 11 to 1
2-3 Constant volume heat addition to a pressure of 45 bar
3-4 constant pressure heat addition to a temperature of 1650°C
4-5 isentropic expansion back to the initial volume.
5-1 constant volume heat rejection to the initial conditions
For Air R=0.287 kJ/kgK , c_v=0.718 kJ/kgK,

Calculate the total change in entropy during the heat addition processes

Answers (A) 774.65 J/K (B) 1575 J/K (C) 1897.8 J/K (D) 2701 J/K

Question 18

A single cylinder four stroke engine running at 250 rev/min operates on an ideal Otto cycle.
The swept volume is 4100 cm^3 with a compression ratio of 6 to 1.
The compression and expansion processes take place according to the law $pV^{1..3} = C$.
The maximum and minimum cycle pressures are 34.5 bar and 0.932 bar respectively.
Calculate
(i) The work done
(ii) The mean effective pressure
(iii) The indicated power.

Answers	(A)	(i) 14.16 kJ	(ii) 6.91 bar	(iii) 29.5 kW
	(B)	(i) 2.832 kJ	(ii) 6.908 bar	(iii) 5.9 kW
	(C)	(i) 3.593 kJ	(ii) 8.76 bar	(iii) 7.48 kW
	(D)	(i) 2.832 kJ	(ii) 6.908 bar	(iii) 11.8 kW

Question 19

A compression ignition engine working on an ideal dual combustion cycle has a compression ratio of 14 to 1. The conditions at the beginning of compression are 0.95 bar, 30°C.
The maximum pressure in the cycle is 44 bar while the constant pressure heat supply occurs for $1/18^{th}$ of the stroke.
Calculate
(i) The heat supply per kg of working fluid
(ii) The heat rejected per kg of working fluid
(iii) The thermal efficiency of the cycle.

Answers	(A)	(i) 878.73 kJ/kg	(ii) 342.8 kJ/kg	(iii) 60.98 %
	(B)	(i) 821.75 kJ/kg	(ii) 318.75 kJ/kg	(iii) 61.25 %
	(C)	(i) 81.89 kJ/kg	(ii) 31.55 kJ/kg	(iii) 61.46 %
	(D)	(i) 341.45 kJ/kg	(ii) 14.76 kJ/kg	(iii) 95.6 %

Question 20

A compression ignition engine working on the ideal dual combustion cycle has a compression ratio of 16 to 1. the pressure and temperature at the beginning of compression are 98 kN/m^3 and 30°C respectively. The pressure and temperature at the completion of heat supply are 60 bar 1300°C.

Calculate The thermal efficiency of the cycle

Answers (A) 48.8 % (B) 62.5 % (C) 65.5 % (D) 68.3 %

Question 21

Air at a pressure and temperature of 1 bar and 20°C enters an open gas turbine plant at a rate of 240 kg/min.

The maximum pressure and temperature in the plant are 6 bar and 710°C respectively. The isentropic efficiency of the compressor is 0.78 while that of the turbine is 0.837.

Calculate

(i) The net power output of the plant.
(ii) The thermal efficiency of the plant

Answers	(A)	(i) 317.6 kW	(ii) 18 %
	(B)	(i) 19056 kW	(ii) 18 %
	(C)	(i) 796 kW	(ii) 40 %
	(D)	(i) 47760 kW	(ii) 40 %

Question 22

In a gas turbine plant, air is compressed from a pressure of 0.985 bar and temperature of 17°C through a pressure ratio of 4.25 with an isentropic efficiency of 0.82. The turbine has an entry temperature is 677°C and expands the gas to the original pressure with an isentropic efficiency of 0.88.

A regenerator with a thermal ratio of 1 is used to heat the air before it enters the combustion chamber.

Calculate

(iii) The work ratio.
(iv) The thermal efficiency of the plant

Answers	(A)	(i) 0.36	(ii) 21.3 %
	(B)	(i) 0.36	(ii) 36 %
	(C)	(i) 0.54	(ii) 39 %
	(D)	(i) 0.54	(ii) 54 %

Question 23

In an open cycle gas turbine plant, 4.5 kg/s of air is induced in a rotary compressor at a pressure and temperature of 1 bar and 18°C respectively. It is compressed through a pressure ratio of 5 to 1 with an isentropic efficiency of 0.85 and then heated to a temperature of 810°C in the combustion chamber.
The air is expanded in a gas turbine to a pressure of 1 bar with an isentropic efficiency of 0.88.
The mass of fuel may be neglected.
Calculate

(i) The net power output of the plant
(ii) The thermal efficiency

Answers	(A)	(i) 152	kW	(ii) 25.5 %
	(B)	(i) 685	kW	(ii) 25.6 %
	(C)	(i) 1036	kW	(ii) 36.8 %
	(D)	(i) 2494	kW	(ii) 35 %

Question 24

The compressor of an aero engine is driven by a gas turbine producing 30 MW.
Air enters the compressor at 1.01 bar 26°C with an axial velocity of 250 m/s which is constant across the inlet duct.
The compressor has an isentropic efficiency of 0.85 and an exit pressure of 4.4 bar.
Heat losses and changes in potential and kinetic energy can be ignored.
Calculate

(i) The Mass flow rate of the air into the compressor
(ii) The diameter of the compressor inlet duct

Answers	(A)	(i) 162 kg/s	(ii) 517 mm
	(B)	(i) 191 kg/s	(ii) 561 mm
	(C)	(i) 162 kg/s	(ii) 838 mm
	(D)	(i) 191 kg/s	(ii) 910 mm

Engine Performance

Question25

A six cylinder, 4 stroke diesel engine has a bore of 210 mm and a stroke of 315 mm.
The brake mean effective pressure is 4.89 bar when the intake conditions are 0.95 bar 17°C.
At the conditions the brake specific fuel consumption is 0.195 kg/kWh while the fuel air ratio is 0.0357:1 by mass. For air R = 287 J/kgK
Calculate; The volumetric efficiency

Answers (A) 29.8 % (B) 49 % (C) 65% (D) 129%

Question 26

The test bed results for a naturally aspirated, six cylinder, four stroke compression ignition engine with a bore of 90 mm and stroke of 110 mm, are as follows.

Test speed 3700 rev/min

Fuel Net Calorific value 42 MJ/kg consumption 26 kg/h

Air consumption 17.66 m^3/kg of fuel at intake conditions of 1 bar 20°C

Brake load 0.408 kN at a radius of 0.5 m

Average indicated mean effective pressure for the engine 7.82 bar.

For air R = 287 J/kgK

Calculate

(i) The mechanical efficiency

(ii) The Volumetric efficiency

(iii) The brake thermal efficiency

(iv) The brake specific fuel consumption

Answers	(A)	(i) 78 %	(ii) 98%	(iii) 26 %	(iv) 0.329 kg/kWhr
	(B)	(i) 39 %	(ii) 49 %	(iii) 26 %	(iv) 0.329 kg/kWhr
	(C)	(i) 37.5 %	(ii) 98 %	(iii) 12.5 %	(iv) 0.684 kg/kWhr
	(D)	(i) 78 %	(ii) 22.76 %	(iii) 26 %	(iv) 0.329 kg/kWhr

Question 27

A four cylinder four stroke engine has the following cylinder dimensions bore 75 mm , stroke 100 mm, clearance volume 0.04 litres.

It produces a brake power of 15.5 kW when burning 4.9 kg/h of fuel with a calorific value of 44 MJ/kg.

A Morse test gave the following levels of brake power.

Cylinder 1 cut out 10.6 kW

Cylinder 2 cut out 10.5 kW

Cylinder 1 cut out 10.4 kW

Cylinder 1 cut out 10.6 kW

Calculate

(i) The Indicated power

(ii) The indicated thermal efficiency

(iii) The air standard efficiency

Answers	(A)	(i) 19.6 kW	(ii) 9.25 %	(iii) 61.6 %
	(B)	(i) 19.9 kW	(ii) 33.25 %	(iii) 63.0 %
	(C)	(i) 19.9 kW	(ii) 1.62 %	(iii) 96.9 %
	(D)	(i) 19.6 kW	(ii) 29.9 %	(iii) 96.5 %

Question 28

A single cylinder four stroke engine has a swept volume of 4100 cm^3, a compression ratio of 6:1 and runs at 250 rev/min. Compression and expansion are according to the law $pV^{1.3}$= constant and heat is received and rejected at constant volume. The maximum cycle pressure is 34.5 bar whilst the minimum cycle pressure is 0.932 bar.

Calculate

(i) The indicated mean effective pressure

(ii) The indicated power.

Answers	(A)	(i) 4.3 bar	(ii) 3.75 kW
	(B)	(i) 6.9 bar	(ii) 11.8 kW
	(C)	(i) 6.9 bar	(ii) 5.9 kW
	(D)	(i) 4.3 bar	(ii) 7.35 kW

Question 29

A 4 cylinder 4 stroke diesel engine has a bore of 212 mm and a stroke of 292 mm. At a full load speed of 720 rev/min the brake mean effective pressure is 5.9 bar and the specific fuel consumption is 0.22 kg/kWhr when the ambient conditions are 1.01 bar 15°C

The air fuel ratio by mass is 25/1 and the Net Calorific value of the fuel is 44.2 MJ/kg.

For air R = 287 J/kgK

Calculate

(i) The brake thermal efficiency

(ii) The volumetric efficiency of the engine

Answers	(A)	(i) 37 %	(ii) 18.5 %
	(B)	(i) 37 %	(ii) 74.0 %
	(C)	(i) 37 %	(ii) 37.0 %
	(D)	(i) 37 %	(ii) 148.0 %

Question 30

A 4 stroke engine is required to give 186.5 kW at 440 rev/min. The brake thermal efficiency is assumed to be 32 %The air fuel ratio by mass is 12:1 while the volumetric efficiency is 69 % at free air conditions of 1.013 bar 15°C. For air R = 287 J/kgK.

Calculate

The engine displacement required

Answers (A) 0.51 litres (B) 5.1 litres (C) 51 litres (D) 6.85 litres

Question 31

A 2 stroke compression ignition engine has a stroke of 1500 mm, brake mean effective pressure of 7 bar and mean piston speed of 6 m/s.

Calculate (i) the stroke (ii) the bore of a similar engine which is to develop 370 kW per cylinder and have the same power to swept volume ratio with a stroke bore ratio of 2:1.

Answers	(A)	(i) 1390 mm	(ii) 695 mm
	(B)	(i) 1104 mm	(ii) 552 mm
	(C)	(i) 876 mm	(ii) 438 mm
	(D)	(i) 819 mm	(ii) 409 mm

Question 32

A 4 stroke engine has a bore of 85 mm and a stroke of 75 mm with a compression ratio of 9.

When run on test at 5000 rev/min the following results were obtained.

Output torque 177.6 Nm   Air flow 340 m^3/h at 1.1 bar 17°C.

Fuel consumption 27 kg/h   Fuel calorific value 44 MJ/kg.

Torque required to motor the engine 18.2 Nm.

Calculate

(i) The indicated thermal efficiency

(ii) The brake specific fuel consumption

(iii) The volumetric efficiency

Answers	(A)	(i) 0.253	(ii) 0.323 kg/kWh	(iii) 0.99
	(B)	(i) 0.28	(ii) 0.263 kg/kWh	(iii) 0.44
	(C)	(i) 0.31	(ii) 0.290 kg/kWh	(iii) 0.89
	(D)	(i) 0.31	(ii) 0.345 kg/kWh	(iii) 0.51

Air compressors

Question 33

A two stage reciprocating air compressor designed for minimum work with perfect inter cooling.

It takes in 17 m^3/min of air at 1 bar 33°C and delivers it at 16 bar.

The index of compression and expansion in both stages is 1.3

For air R = 287 J/kgK c_p =1005 J/kgK.

Calculate

(i) The power absorbed by the compressor

(ii) The rate of heat rejection in the inter-cooler

Answers	(A)	(i) 46.3 kW	(ii) 37.4 kW
	(B)	(i) 92 kW	(ii) 37.4 kW
	(C)	(i) 109.8 kW	(ii) 88.9 kW
	(D)	(i) 9.9 kW	(ii) 4.1 kW

Question 34

A two stage single acting air compressor, operates at minimum work conditions.
The inlet conditions are 1 bar 28°C with a discharge pressure of 16 bar.
The index of compression and expansion in both stages is 1.3.
The compressor free air delivery is 30 m^3/min at NTP.
For air R = 287 J/kgK.
Calculate

(i) The power absorbed in compressing the air
(ii) The isothermal efficiency

Answers			
	(A)	(i) 173 kW	(ii) 84.9 %
	(B)	(i) 163.3 kW	(ii) 84.8 %
	(C)	(i) 9.8 MW	(ii) 84.7 %
	(D)	(i) 98 kW	(ii) 84.8 %

Question 35

A six stage reciprocating air compressor is designed for minimum work requirements with perfect inter-cooling.
The inlet conditions are 0.9 bar 27°C, the delivery pressure is 300 bar.
The compressor delivers 2.5 m^3/min at STP.
The mechanical efficiency of the drive is 85%.
The index of compression and expansion is 1.3
For air R = 287 J/kgK c_p =1005 J/kgK.
Calculate

(i) The power input to the compressor.
(ii) The heat absorbed in the inter-coolers.

Answers			
	(A)	(i) 177 kW	(ii) 20.1 kW
	(B)	(i) 18 kW	(ii) 24.1 kW
	(C)	(i) 150.4 kW	(ii) 20.1 kW
	(D)	(i) 257 kW	(ii) 173.2 kW

Question 36

A two stage reciprocating air compressor runs at 200 rev/min and has a low pressure cylinder bore of 30 cms. And stroke of 25 cms. The volumetric efficiency of this stage is 82 %.
The expansion and compression processes are polytropic with an index of 1.5.
The inlet conditions are 1 bar 15°C at the first stage and 6 bar 20°C at the second stage. The delivery pressure is 30 bar
For air R = 287 J/kgK c_p =1005 J/kgK.
Calculate

The power absorbed by the compressor.

Answers (A) 6.43 kW (B) 21.42 kW (C) 17.4 kW (D) 20.3 kW

Question 37

A single stage reciprocating air compressor has a free air delivery of 4 m^3 at STP, when running at 200 rev/min. The mechanical efficiency of the drive is 85 % while the efficiency of the electrical conversion is 90 %.
The bore stroke ratio is 0.7:1 and the clearance volume is 1 % of the swept volume.
At the beginning of compression the air in the cylinder is at 0.9 bar 25°C, the delivery pressure is 5.4 bar.
For air R = 287 J/kgK c_p =1005 J/kgK.
The index of compression and expansion is 1.3.
Calculate

(i) The electrical power required to drive the compressor
(ii) The cylinder bore and stroke.

Answers	(A)	(i) 16.36 kW	(ii) 603 mm, 422 mm
	(B)	(i) 19.3 kW	(ii) 358 mm, 251 mm
	(C)	(i) 21.4 kW	(ii) 378 mm, 265 mm
	(D)	(i) 21.4 kW	(ii) 403 mm, 283 mm

Question 38

A reciprocating air compressor designed for minimum work with perfect inter-cooling has four stages.
The inlet conditions are 0.95 bar 20°C, the delivery pressure is 243.2 bar.
The free air delivery at NTP is 120 m^3/min
The index of compression and expansion is 1.25.
For air R = 287 J/kgK c_v =717.5 J/kgK.
Calculate

(i) The compressor power required in each stage.
(ii) The heat removed in each inter-cooler.

Answers	(A)	(i) 329 kW	(ii) 230.4 kW
	(B)	(i) 303.5 kW	(ii) 212.5 kW
	(C)	(i) 300.3 kW	(ii) 228 kW
	(D)	(i) 319.5 kW	(ii) 223.6 kW

Question 39

A single cylinder single acting air compressor induces 360 m^3/min when running at 300 rev/min. The clearance volume is 2 % of the swept volume.
The inlet conditions are 1 bar 15°C, the delivery pressure is 8 bar.
The stroke : bore ratio is 1:2
The index of compression and expansion is 1.25.
Calculate

(i) The volumetric efficiency.
(ii) The cylinder bore and stroke.

Answers	(A)	(i) 95.72 kW	(ii) 118.4 mm, 237 mm
	(B)	(i) 95.72 kW	(ii) 236.9 mm, 438 mm
	(C)	(i) 99.48 kW	(ii) 233.9 mm, 468 mm
	(D)	(i) 99.48 kW	(ii) 116.9 mm, 234 mm

Question 40

Both stages of a single acting inter-cooled air compressor have a stroke of 160 mm and clearance volume of 1 % of the respective swept volume. The bore of the low-pressure stage is 300 mm.

Inlet conditions for the first stage are 0.96 bar 25°C and for the second stage 3 bar 30°C.

The delivery pressure is 8.5 bar.

The compressor runs at 400 rev/min and has a mechanical efficiency of 75 %.

The index of expansion and compression is 1.28.

For air R = 287 J/kgK.

Calculate

(i) The compressor power requirements

(ii) The bore of the high pressure cylinder.

Answers			
	(A)	(i) 23.6 kW	(ii) 169.8 mm
	(B)	(i) 24.6 kW	(ii) 169.8 mm
	(C)	(i) 23.6 kW	(ii) 170.9 mm
	(D)	(i) 3.6 kW	(ii) 171 mm

<u>Heat transfer questions</u>

Question 41

A 50 mm bore pipe with a wall thickness of 25 mm carries dry saturated steam at 40 bar in an atmospheric temperature of 36ºC.

The pipe is insulated with 20 mm of material.

Given;

Thermal conductivity of steel = 52 W/mK

Thermal conductivity of insulation = 0.04 W/mK

Inner surface heat transfer coefficient = 15 W/m^{2}K

Outer surface heat transfer coefficient = 10 W/m^{2}K

Calculate:

(i) The heat transfer per unit length of pipe

(ii) The interface temperature between the steel pipe and insulation.

Answers			
	(A)	(i) 0.502 W/mK	(ii) 204.5ºC
	(B)	(i) 1.991 W/mK	(ii) 68.2ºC
	(C)	(i) 0.692 W/mK	(ii) 35.7ºC
	(D)	(i) 1.444 W/mK	(ii) 184.4ºC

Question 42

A 20 m section of steel pipe has an internal diameter of 200 mm, a wall thickness of 19 mm, thermal conductivity of 45 W/mK and carries dry saturated steam at 130ºC.

The pipe is coated in a 50 mm thick layer of insulation which has a thermal conductivity of 0.1 W/mK.

The surface heat transfer coefficient from the insulation to the atmosphere is 9.7 W/m^{2}K in an ambient temperature of 36ºC.

Calculate:

The heat lost per hour.

Answers (A) 17.42 MJ (B) 4.43 MJ (C) 10.32 MJ (D) 2.63 MJ

Question 43

Water passes through the core of a concentric tube cooler in the opposite direction to air which flows in the annular space.
The cooler is 4 m in length and has a core diameter of 30 mm and an outer shell external diameter of 80 mm. The wall thickness of both tubes is 5 mm.
The air enters the cooler at 130ºC with a velocity of 30 m/s.
The water enters with a temperature of 6ºC at a velocity of 0.5 m/s.
The cooler has a thermal ratio of 0.85.
For air c_p = 1.012 kJ/kgK density 1.009 kg/m^3
For water c_p = 4.193 kJ/kgK density 1012 kg/m^3
Calculate:

(i) The outlet temperature of the air.
(ii) The outlet temperature of the water.
(iii) The overall heat transfer coefficient between the air and the water per unit length of cooler.

Answers

(A)	(i) 24.6ºC	(ii) 13.44°C	(iii) 51.62 W/mK
(B)	(i) 15.9ºC	(ii) 12.05°C	(iii) 51.99 W/mK
(C)	(i) 24.6ºC	(ii) 11.58°C	(iii) 77.6 W/mK
(D)	(i) 15.88ºC	(ii) 14.03°C	(iii) 69.88 W/mK

Question 44

A 40 m section of steel pipe carries dry saturated steam at 36 bar.
The pipe has an outside diameter of 150 mm and is lagged with two layers of insulation each 5 cm thick. The thermal conductivity of the inner layer is 0.08 W/mk while that of the outer layer is 0.15 W/mk.
The outside surface temperature of the insulation is 70ºC.
Assume that the thermal resistance of the pipe is negligible.
Calculate:

(i) The rate of heat transfer from the pipe.
(ii) The interface temperature of the two layers of insulation.

Answers

(A)	(i) 5.08 kW	(ii) 115.26ºC
(B)	(i) 5.71 kW	(ii) 166.26ºC
(C)	(i) 8.62 kW	(ii) 120.99ºC
(D)	(i) 9.31 kW	(ii) 173.26ºC

Question 45

Water at 65ºC flows through a pipe with a 50 mm bore and 10 mm thickness, the thermal conductivity of the pipe material is 52 W/mK.
The inner and outer surface heat transfer coefficients in this condition are 11.36 W/m^2K and 13 W/m^2K respectively.
A 30 mm layer of insulation thermal conductivity 0.17 W/mK is now added to the pipe and the outer surface heat transfer coefficient becomes 9.7 W/m^2K.
If the ambient temperature is 20ºC.
Calculate the percentage reduction in

(i) The heat transfer.
(ii) The surface temperature.

Answers	(A)	(i) 34.58 %	(ii) 78 %
	(B)	(i) 42.47 %	(ii) 22.6 %
	(C)	(i) 34.56 %	(ii) 4.2 %
	(D)	(i) 34.56 %	(ii) 8.1 %

Question 46

A 20 m section of 150 mm outer diameter steam pipe carries 1.22 tonne per hour at a pressure of 15 bar.
The steam enters as dry saturated and leaves as wet steam with a dryness fraction of 0.992.
The pipeline is coated with a single layer of moulded insulation which has a thermal conductivity of 0.128 W/mK.
The outer surface temperature of the insulation is 32ºC.
The thermal resistance of the pipe may be ignored.
Calculate; The thickness of the insulation.

Answers (A) 3.7 mm (B) 49.5 mm (C) 99 mm (D) 194 mm

Question 47

A cold room wall is 100mm thick and has a thermal conductivity of 0.14 W/mK. It is lined internally with 80 mm of cork which has a thermal conductivity of 0f 0.052 W/mK.
The surface heat transfer coefficient of both exposed surfaces is 11.5 W/m^2K.
The ambient temperature is 22ºC and the heat transfer rate is 35 W/m^2.
Calculate

(i) The temperature of the air in the cold room.
(ii) The temperature at the cork/wall interface.

Answers	(A)	(i) -59.56ºC	(ii) -6.04ºC
	(B)	(i) -59.5ºC	(ii) -31.5ºC
	(C)	(i) -33.9ºC	(ii) 16.5ºC
	(D)	(i) -33.9ºC	(ii) -8.9ºC

Question 48

A counter flow surface feed heater operates under the following conditions.
Steam supply, 2 bar 0.95 dry exit condition saturated liquid.
Feed water 20 tonne per hour entry temperature 53ºC exit temperature 105ºC.
The overall heat transfer coefficient between the steam and water is 4540 W/mK.
Calculate

(i) The mass flow rate of the steam.
(ii) The effective area of the heating surface.

Answers	(A)	(i) 1998 kg/hr	(ii) 7.45 m^2
	(B)	(i) 2328 kg/hr	(ii) 3.8 m^2
	(C)	(i) 1998 kg/hr	(ii) 6.33 m^2
	(D)	(i) 2328 kg/hr	(ii) 4.47 m^2

SUBMIT YOUR ANSWERS TO THE COLLEGE OF THESE QUESTIONS 1 TO 48 BEFORE PROCEEDING.

WRITTEN ASSESSMENT

As stated earlier, you will be required to submit a hand written answer to SIX of these NINE questions. Please ensure your writing is neat and eligible, and all stages of your working and calculations are shown. During the written submission ensure you state any assumptions you have made, as this is considered good practice, and shows your understanding of the subject.

All formulae use must be stated, the method of working and all intermediate steps must be made clear in the answer.
Indicate the meaning of all symbols used to denote physical quantities, a suitably annotated diagram will usually suffice.
Show the units alongside numerical quantities where appropriate.

1 A two stage single acting compressor runs at 400 rev/min and delivers air at 14 bar from inlet conditions of 1.01325 bar 15°C with a second stage inlet pressure of 4 bar. The cylinder bore of the low pressure stage is 150 mm with a stoke of 300 mm. The clearance between the flat top of the piston and the flat cylinder head is 5 mm.
The index of compression and expansion in both stages is 1.3
For air R = 287 J/kgK c_p =1005 J/kgK.

a) Discuss with suitable diagrams why inter-cooling is used in multi-stage compressors. (4 marks)

b) Calculate

   i) The input power without inter-cooling. (4 marks)

   ii) The power reduction if perfect inter-cooling is employed (4 marks)

   iii) The rate of heat extraction in the intercooler. (4 marks)

2 A deck steam line is 50 m long with an outside diameter of 150 mm. It is covered with two layers of insulation, the inner layer 50 mm thick, the outer layer 20 mm thick.
500 kg/h of dry saturated steam enter the pipe, which is in an ambient temperature of 15°C.
The coefficient of thermal conductivity of the inner layer of insulation is 0.075 W/mK, and that of the outer layer is 0.15 W/mk.
The heat transfer coefficient of the outer surface is 15 W/m^{2}K.
The thermal coefficients of the pipe and inner surface may be neglected.
Calculate

a) The quality of the steam leaving the pipe. (10 marks)

b) The outer surface temperature of the pipe. (6 marks)

3 Benzene (C_6H_6) is burned in air and the analysis of the dry products of combustion gives

$CO = 10.45$ %, CO_2=10.6 %, N_2=78.95%.

a) Write the full combustion equation in Kmol/kg of fuel (8 marks)

b) Calculate

(i) The percentage air supply with respect to stoichiometric requirements (4 marks)

(ii) The gravimetric analysis of the wet products of combustion.(4 marks)

Air contains 21 % oxygen by volume

Relative atomic masses Carbon = 12, Hydrogen = 1, oxygen = 16, Nitrogen = 14

4 A 2 cylinder steam turbine plant operates on a superheat cycle with reheat. The high pressure turbine expands the steam isentropically from 70 bar 450°C to an inter-stage pressure of 10 bar. The steam is reheated at constant pressure to a temperature of 350°C and then expanded isentropically in the low pressure turbine to a condenser pressure of 0.035 bar.

The feed water leaves the condenser under cooled by 6K.

a) Sketch the cycle on a temperature-specific entropy diagram (2 marks)

b) Determine

(i) The quality of the steam entering the condenser (7 marks)

(ii) The feed pump work (2 marks)

(iii) The thermal efficiency of the cycle (3 marks)

(iv) The specific steam consumption. (2 marks)

5 The nozzle angle of a two row Curtis wheel is 20° to the plane of rotation of the wheel and the isentropic enthalpy drop is 200 kJ/kg.

All moving and fixed blades are symmetrical while the mean blade speed is 150 m/s. Assume that friction across the blades reduces the velocity by 95 % and the isentropic efficiency of the nozzles is 90 %.

Determine

a) The blade angles. (10 marks)

b) The specific power output (6 marks)

6 A perfect gas at a pressure and temperature of 8 bar 90°C enters a convergent-divergent nozzle with a velocity of 2 m/s.

The expansion, which may be considered to be isentropic is into a space at 3.6 bar.

The diameter of the nozzle throat is 500 mm.

For the gas molecular mass = 30 kg-kmol c_v =1383 J/kgK R_o = 8314.4 J/kmolK.

a) Determine if the nozzle is choked (6 marks)

b) Calculate the mass flow through the nozzle. (10 marks)

7

(a) From first principles derive an expression for the work transfer in a reversible polytropic expansion process in terms of the temperature. (6 marks)

(b) 0.5 kg of gas expands in a reversible polytropic process from 79 bar 500°C to 1 bar 100°C.

Calculate

(i) The heat transferred (4 marks)

(ii) The change in entropy (6 marks)

8 A vapour compression refrigeration plant produces 170 kg/h of ice at -8°C from water at 22°C.

The evaporation and condensation temperatures of the Freon are -15°C and 25°C respectively. The compression process may be considered to be isentropic while the liquid leaves the condenser as saturated liquid.

The mass flow of refrigerant around the plant is 600 kg/h.

The specific heat capacity of water is 4.2 kJ/kgK

The specific heat capacity of ice is 2.2 kJ/kgK

The enthalpy of fusion for ice is 332 kJ/kgK

Calculate

a) The quality of the refrigerant entering the compressor (10 marks)

b) The temperature of the gas at compressor exit. (6 marks)

9 A gas turbine plant fitted with a regenerator using 30% of the available heat in the exhaust gas, operates with a pressure ratio of 7:1 from inlet conditions of 1.1 bar 27°C .

The isentropic efficiency of the turbine is 90% while that of the compressor is 85%.

The air to fuel ratio by mass is 70:1 while the calorific value of the fuel is 44 MJ/kg.

a) Sketch the process on a temperature –specific entropy diagram (4 marks)

b) Calculate

i) The plant efficiency with the regenerator by-passed. (8 marks)

ii) The increase in efficiency with the regenerator in operation (4 marks)