# SECOND ENGINEER REG. III/2
# APPLIED HEAT

LIST OF TOPICS

A Pressure, Temperature, Energy
B Heat Transfer
C Internal Energy, Thermodynamic systems. First Law of Thermodynamics
D Gas Laws, Displacement Work
E Ideal Cycles and IC Engines
F Air Compressors
G Working Fluids
H Nozzles and Steam Turbines
I Refrigeration
J Combustion
K Boiler Feed Densities

The expected learning outcome is that the student:

## A PRESSURE, TEMPERATURE, ENERGY

1. Recognises and measures the effect of pressure in fluid.
   1.1 Defines pressure as force per unit area.
   1.2 Recognises the effect of atmospheric pressure.
   1.3 States that standard atmospheric pressure is 1.01325 bar = 1.01325 x $10^5$N/$m^2$.
   1.4 Measures atmospheric pressure using a mercury barometer.
   1.5 Converts pressure units using water lead, mercury lead with bar units.
   1.6 Defines:

      a) vacuum;
      b) partial vacuum;
      c) gauge pressure;
      d) absolute pressure.

   1.7 Solves simple problems relating to 1.1 to 1.6.

2. Defines and measures temperature.
   2.1 Defines temperature.
   2.2 Defines the absolute scale of temperature.
   2.3 Differentiates between Celsius and Kelvin Scales.
   2.4 Defines Standard Temperature and Pressure (S.T.P.) and Normal Temperature and Pressure (N.P.T.).

3. Discusses heat as a form of energy, specific heat capacity, sensible heat, latent heat and solves associated problems.
   3.1 Defines heat energy.
   3.2 Defines specific heat capacity of a solid and of a liquid.
   3.3 Defines sensible heat.
   3.4 Explains phase change and defines the latent heat of fusion.

3.5 Sketches the change of phase (solid/liquid) diagram for water.
3.6 Determines the resultant temperature when a solid is placed in a liquid at a different temperature.
3.7 Determines the resultant temperature when up to three liquids at different temperatures are mixed.
3.8 Defines water equivalent.
3.9 Solves simple problems relating to 3.1 to 3.8.

4. Discusses the physical changes of solids and liquids associated with changes in temperature.
   4.1 Defines the coefficient of linear expansion.
   4.2 States the equation of linear expansion/contraction.
   4.3 States the equation of superficial expansion.
   4.4 States that the coefficient of volumetric expansion is three times the coefficient of linear expansion.
   4.5 States the equation of volumetric expansion.
   4.6 Defines differential expansion with reference to solids and liquids.
   4.7 Solves simple problems relating to 4.1 to 4.6.

## B HEAT TRANSFER

5. Describes the way in which heat may be transferred and the factors which may influence heat transfer. Solves simple problems involving conduction, convection and radiation.
   5.1 Describes heat transfer by conduction.
   5.2 Gives practical examples of heat transfer by conduction.
   5.3 Defines the term coefficient of thermal conductivity.
   5.4 States an expression for the rate of heat transfer through a single plane wall.
   5.5 States that for a composite wall the rate of heat transfer is constant.
   5.6 States an expression for the transfer of heat through a composite wall made up of not more than three flat layers in contact.
   5.7 Solves simple problems relating to 5.1 to 5.6.
   5.8 Describes heat transfer by convection.
   5.9 Lists practical examples of forced and natural convection.
   5.10 Defines the term 'coefficient of conductance'.
   5.11 States an expression for the rate of heat transfer from a flat surface to its surroundings.
   5.12 Solves simple problems relating to 5.8 to 5.11.
   5.13 Describes heat transfer by radiation.
   5.14 Gives practical examples of heat transfer by radiation.

## C INTERNAL ENERGY, THERMO-DYNAMIC SYSTEMS, FIRST LAW

6. Defines and describes Thermo-dynamic Systems and solves problems involving the First Law of Thermodynamics.
   6.1 Defines Internal Energy.
   6.2 States Joules Law for the internal energy of a gas.
   6.3 Defines a Thermodynamic system.

6.4 Differentiates between an open and a closed system.
6.5 Give examples of:
a) closed system with fixed boundary (constant volume);
b) closed system with elastic boundary (constant pressure);
c) open system with fixed boundary.

6.6 Defines work with reference to a thermodynamic system.
6.7 States the First Law of Thermodynamics in terms of heat energy, work energy and internal energy.
6.8 States that Q = W + U and that this is the non-flow energy equation.
6.9 States that power is the rate of transfer of energy.
6.10 States that H + Q = H + W and that this is the flow energy equation.
6.11 Solves simple problems relating to 6.1 to 6.10.

**D GAS LAWS, DISPLACEMENT WORK**

7. Solves simple problems involving the basic gas laws.
7.1 Defines a perfect gas.
7.2 States Boyles Law.
7.3 States Charles Law.
7.4 Shows Boyles Law and Charles Law on a pV diagram.
7.5 Combines Boyles Law and Charles Law and states that for a perfect gas pV/T = a constant.
7.6 Derives the Characteristic Gas Equation pV = mRT.
7.7 Derives the units of the Characteristic Gas Constant R from the units of pressure, volume, temperature and mass.
7.8 Solves simple problems relating to 7.1 to 7.7.

8. Describes processes which will produce a change of state in a non-flow system and solves problems concerned with non-flow processes.
8.1 Differentiates between constant pressure and constant volume operations.
8.2 Defines specific heat capacities of a gas at constant pressure and at constant volume.
8.3 States that the ratio of the specific heat capacities of a gas Cp/Cv = $\gamma$ (gamma) the adiabatic index.
8.4 Defines:

a) an Isothermal operation;
b) an Adiabatic operation;
c) a Polytropic operation.

8.5 Shows the Isothermal, Adiabatic and Polytropic Operations on a pV diagram
8.6 Shows that the area of the pV diagram represents W.D. during the operation.
8.7 States expressions for the work done during isothermal, adiabatic and polytropic non-flow processes.

$$\frac{T_2}{T_1} = \frac{P_2}{P_1} = \frac{V_1}{V_2}$$

8.8 States the temperature - pressure and temperature -volume relations for an operation to the law pV = a constant.

8.9 States that change in internal energy is given by $mC_v\ (T_2 - T_l)$.

8.10 States that the relationship between the Characteristic Gas Constant and the specific heat capacities of a gas is

$$R = (C_p - C_v).$$

8.11 Solves simple problems relating to 8.1 to 8.10.

## E IDEAL CYCLES AND I.C. ENGINES

9. Sketches p - V diagram and describes the operation for the ideal constant volume (Otto) cycle, the Diesel cycle and the Dual Combustion cycle.
   - 9.1 Sketches the pV diagram for the ideal Otto, Diesel and Dual Combustion cycles and names the processes making up these cycles.
   - 9.2 Names the practical engines that operate on these cycles.
   - 9.3 Compares the ideal cycle with the practical four stroke cycle.
   - 9.4 Gives reasons for the differences between the ideal and the practical cycle.
   - 9.5 Answers simple descriptive questions only on the Otto, Diesel and Dual Combustion cycles.
   - 9.6 Defines air standard efficiency and solves problems involving engine cycles.

10. Determines indicated power, brake power and mechanical efficiency of an I.e. engine and solves problems involving power, efficiency, fuel consumption and heat balance.
    - 10.1 Defines mean effective pressure (m.e.p.).
    - 10.2 Determines the area of an indicator card using the mid-ordinate rule.
    - 10.3 States the terms, spring rate, spring stiffness and spring constant when referred to indicators.
    - 10.4 Determines the indicated m.e.p. from an actual indicator diagram.
    - 10.5 Defines indicated power.
    - 10.6 Derives an expression for calculating indicated power.
    - 10.7 Defines brake power.
    - 10.8 Defines brake mean effective pressure (b.m.e.p.) and uses this term in the determination of brake power.
    - 10.9 Derives an expression for brake power in terms of torque and angular velocity.
    - 10.10 Determines mechanical efficiency.
    - 10.11 Calculates indicated power, brake power and mechanical efficiency from engine test data.
    - 10.12 Defines thermal efficiency for an actual engine.
    - 10.13 Differentiates between brake and indicated thermal efficiencies.
    - 10.14 Calculates thermal efficiency from engine data.
    - 10.15 Defines specific fuel consumption based on indicated power and brake power.
    - 10.16 Relates specific fuel consumption to thermal efficiency.

10.17 Calculates specific fuel consumption from engine data.
10.18 Draws up a heat energy balance for an I.e. engine.
10.19 Solves simple problems relating to 10.1 to 10.18.
10.20 Solves problems involving thermal, mechanical and overall efficiency.

## F AIR COMPRESSORS

11. Describes the factors which influence the performance of a reciprocating air compressor and solves simple problems involving single stage single acting compressors.S

11.1 Sketches the ideal p - V diagram for a compressor without clearance volume.
11.2 Sketches the ideal p - V diagram for a compressor with clearance volume.
11.3 Defines clearance volume.
11.4 Defines induced volume.
11.5 Defines 'free air' delivery for an air compressor.
11.6 Defines volumetric efficiency based on 'free air1 and actual air conditions.

$$V = \frac{ActualVolumeInduced}{SweptVolume}$$

11.7 Solves simple problems relating to 11.1 to 11.6.
11.8 Solves problems involving work input and mechanic efficiency.

## G WORKING FLUIDS

12. Recognises the differences in the properties of vapours, gases and the perfect gas and uses the steam tables to solve simple problems related to water and steam in the wet, saturated and superheated states.

12.1 Differentiate between a gas and a perfect gas.
12.2 Differentiate between a gas and a vapour.
12.3 Defines the term ENTHALPY (h).
12.4 States that h = u + pV.
12.5 Defines the term pV as flow energy.
12.6 Shows that pV is the work transfer in pumping a fluid under constant pressure conditions.
12.7 Defines the term 'saturated' when applied to a vapour.
12.8 Defines saturation temperature.
12.9 Differentiates between wet, dry-saturated and superheated vapours.
12.10 Defines the term dryness fraction.
12.11 Defines the terms 'quality' and 'degree of superheat' as applied to a vapour.
12.12 Demonstrates how to obtain values of specific enthalpy, specific volume and internal energy for water and for wet dry saturated and superheated vapours from the Thermodynamic Properties tables by direct reading or interpolation.

12.13 Sketches a pressure-enthalpy diagram.
12.14 States that the specific enthalpy of a wet vapour is given by hf + x hfg.
12.15 States that the specific internal energy of a wet vapour is given by uf + x ufg.
12.16 States that the specific volume of wet vapour is given by x Vg + (1 - x) Vf.
12.17 Determines from information given in the tables the pressure-temperature relationship for a saturated vapour.
12.18 Determines the mass of a given volume of wet, dry or superheated vapour.
12.19 Calculates changes in the enthalpy and internal energy of a vapour during constant pressure and constant volume operation.
12.20 States that an operation following the law $pV^n$ = a constant is a hyperbolic operation when the working fluid is a vapour.
12.21 Calculates the final condition of the vapour after an operation to the law $pV^n$ = a constant.

12.22 States that for a throttling operation on a vapour enthalpy before throttling = enthalpy after throttling.
12.23 Solves problem relating to 12.1 to 12.22.
12.24 Sketches the arrangement of a combined separator and throttling calorimeter.
12.25 Determines the quality of steam in a main line from data obtained using the combined separator and throttling calorimeter.
12.26 States the limitations of pressure and dryness fraction which apply to the throttling calorimeter.
12.27 Determines Boiler Efficiency and Equivalent Evaporation rates from given plant data.
12.28 Solves simple problems relating to 12.1 to 12.27.

## H NOZZLES AND STEAM TURBINES

13. Solves simple problems involving the flow of steam through a nozzle.
13.1 Defines a nozzle and gives practical applications of where nozzles are used in a steam turbine.
13.2 Recognises that increase in K.E. at nozzle exit is proportional to the enthalpy drop.
13.3 Solves simple problems relating to 13.1 to 13.2.
13.4 Sketches the combined velocity diagrams and determines the power developed in a single stage impulse turbine and a single stage reaction turbine.
13.5 Draws the vector diagrams for inlet and outlet steam velocities over a turbine blade for shockless flow.
13.6 Combines the inlet and outlet diagrams to form a single diagram.
13.7 Shows velocity of whirl on a combined diagram.
13.8 Shows the effect of blade friction (blade velocity coefficient).
13.9 States an expression for the power developed in a single stage of an impulse turbine.
13.10 Solves problems relating to 13.1 to 13.5.
13.11 Draws the combined velocity diagram for a single stage reaction turbine.
13.12 Discusses degree of reaction and states that 50% reaction is usual and refers to a Parsons turbine.
13.13 States an expression for the power developed in a reaction turbine pair.
13.14 Solves simple problems relating to 13.12 to 13.13.

13.15 Solves problems involving axial force on blades.

## I REFRIGERATION

14. Understands the concepts of the reversed heat engine cycle and its applications to vapour compression refrigeration plant and solves simple problems.
    - 14.1 Sketches the circuit diagram for the basic vapour compression refrigeration cycle.
    - 14.2 Identifies the principal components of a vapour compression refrigerator and describes its operation.
    - 14.3 Sketches a vapour compression cycle on a p - h diagram showing:

        a) wetness before entering compressor;
        b) dryness before entering compressor;
        c) superheat before entering compressor;
        d) superheat after entering compressor;
        e) undercooling after condenser.

    - 14.4 Defines 'refrigerating effect' in kJ/kg, mass flow rate in kg/s and 'cooling load' in kW.
    - 14.5 Shows that work transfer from the compressor during an adiabatic operation is equal to the enthalpy change of the vapour.
    - 14.6 Defines 'coefficient of performance' of a refrigeration plant.
    - 14.7 Defines 'capacity' of a refrigeration plant.
    - 14.8 Uses property tables to determine the specific enthalpy and specific volume of wet, dry and superheated refrigerants.
    - 14.9 Solves simple problems relating to 14.1 to 14.8.

## J COMBUSTION

15. Discusses the combustion of solid and liquid fuels by mass in terms of theoretical air and excess air required and the products of combustion. Solves problems involving the combustion of a fuel.

    - 15.1 Defines the chemical definitions of atom, molecule, atomic mass, molecular mass, element, compound and a mixture.
    - 15.2 States the combustion equations for the complete combustion of Carbon to Carbon Dioxide, Hydrogen to Water, and Sulphur to Sulphur Dioxide.
    - 15.3 States the equation for the partial combustion of Carbon to Carbon Monoxide.
    - 15.4 Derives the equations for the combustion of simple hydro-carbon fuels.
    - 15.5 States that air contains approximately 23% oxygen and 77% nitrogen by mass.
    - 15.6 Determines the stoichimetric mass of air required for the complete combustion of a hydro-carbon fuel.
    - 15.7 Determines the percentage excess air required for complete combustion of a hydro-carbon fuel.
    - 15.8 Defines the Higher Calorific Value and the Lower Calorific Value of a fuel.

15.9 Determines the Higher and Lower Calorific Values of a fuel given the calorific value of its constituents.
15.10 Lists on a percentage basis the products of combustion of a fuel, burned in excess air, by mass.
15.11 Solves problems relating to 15.1 to 15.10.

## K BOILER FEED DENSITIES

16. Discusses the effects of using feed water containing dissolved
2. solids on boiler and evaporator plant. Solves simple problems on the change in density of boiler and evaporator plant due to build up of dissolved solids during intermittent and continuous blowdown.

16.1 Defines parts per million (ppm).
16.2 Discusses the meaning of density when referring to dissolved solids in boiler or evaporator feed water.
16.3 Determines the change in density of the boiler or evaporator water content when operating with:
a) no blowdown;
b) ntermittent blowdown
c) continuous blowdown.

16.4 Determines the heat lost to blowdown.
16.5 Defines boiler efficiency.
16.6 Solves simple problems relating to 16.1 to 16.5.