

Chief Engineer STCW Reg. III/2 Written Examination Syllabus

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Chief Engineer STCW Reg. III/2

Engineering Knowledge

Candidates for a Steam Certificate will not be examined in items 13(a), (b), (c) and (d) and candidates for a motor Certificate will not be examined in items 10 (a) and (b)

Notes:

- (i) The engineering knowledge to be shown by candidates is that which is required for operation and maintenance of the machinery, equipment and ship structure usually in charge of the chief engineering officer. A candidate will also be required to understand the legal and management responsibilities of that rank.
- (ii) Candidates should be well acquainted with machinery and boiler causalities which may occur at sea and be able to state how these can be prevented or remedied.
- (iii) The oral examination syllabus is given in MGN 69
- (iv) Naturally there is a similarity between the Chief Engineer and Second Engineer Reg II/2 Engineering Knowledge syllabi, but as a general guide it is expected that the Chief Engineer candidate should be able to show a deeper knowledge of all aspects and a sounder understanding of the principles involved.

The candidate to have knowledge of the following:

1. Properties and characteristics of metals, materials, liquids, gases and vapours used in marine engineering.
2. Processes to which component parts of machinery and equipment are subjected which are relevant to their manufacture and safe use.

3. Principles and constructional details of sensing, monitoring and measuring devices associated with marine equipment.
4. Principles involved with the operation, testing and maintenance of propulsion transmission systems, including thrust and shaft bearings, stern tubes and propellers.
5. Principles involved with the operation, testing and maintenance of bilge and ballast pumps, pumping and priming systems including pollution prevention equipment and systems.
6. Principles involved with the operation, testing and maintenance of steering and stabilising systems, including bow thrusters.
7. Principles involved with the operation, testing and maintenance of refrigeration and air conditioning systems.
8. Principles involved with the operation, testing and maintenance of fresh water production and conditioning systems.
9. Principles involved with the operation, testing and maintenance of deck machinery and cargo handling systems.
10. Principles involved with the operation, testing and maintenance of:-
 - (a) Steam boilers, mountings and feed water systems.
 - (b) Steam turbines, gearing and lubrication systems, steam distribution systems and associated equipment.
 - (c) Auxiliary steam boilers and associated equipment.
 - (d) Control and alarm systems associated with automatic operation of marine steam plant.
11. Methods of assessment of power, output and efficiency of steam plant and action to be taken to maintain safe and efficient operation of steam plant.

12. Methods of boiler water testing and conditioning and action to be taken to maintain safe conditions.
13.
 - (a) Marine diesel engines (trunk and crosshead types), gearing systems and clutches.
 - (b) Starting and reversing systems.
 - (c) Cooling and lubrication systems.
 - (d) Fuel oil preparation systems.
 - (e) Air compressors, receivers and associated equipment.
 - (f) Auxiliary diesel engines and associated equipment.
 - (g) Control and alarm systems associated with automatic operation of a diesel plant.
14. Methods of assessment of power output and diesel plant efficiency, and action to be taken to maintain safe and efficient operation of plant.
15. Methods of testing fuel oil, lubricating oil and cooling water and action to be taken to maintain safe conditions.
16. Codes of Safe Working Practices as published and amended.
17. Types of information issued by the Department of Transport with respect to Safety at Sea.
18. Codes of Safe Working Practices associated with the carriage of dangerous substances.
19. Principles involved with the operation, testing and maintenance of plant and equipment specifically for use with dangerous substances.
20. Legal powers and responsibilities of a Chief Engineer.
21.
 - (a) Precautions against fires or explosions, explosive mixtures and sources of ignition.
 - (b) Principles and methods of fire prevention, detection and extinction in all areas of a ship
 - (c) Principles of the operation, testing and maintenance of fire detection and extinguishing systems.

- (d) Principles of the operation, testing and maintenance of fire pumps and associated pumping systems.
 - (e) Control and organisation of fire and damage control parties.
22. Principles of the operation, testing and maintenance of automatic control systems and alarm panels.
23. Organisation and control procedures necessary for the safe and efficient operation in the UMS mode.
24. Principles of the operation, testing and maintenance of
- (a) Alternators, generators, motors, switch gear and batteries.
 - (b) AC and DC distribution systems.
25. Fault finding and rectification of faults in electrical systems.
26. Administration duties of a Chief Engineer associated with
- (a) Organisation and training of staff for normal and emergency duties.
 - (b) Organisation of temporary and permanent repairs and surveys.
 - (c) Ensuring ship is in seaworthy condition prior to sailing taking into account nature of voyage.
27. Constructional details of ships.
28. Dry docking, hull surveys and repairs.

**CHIEF ENGINEER REG III/2
APPLIED HEAT**

LIST OF TOPICS

- A Thermodynamics Systems
- B Thermodynamic Processes
- C Heat Engine Cycles
- D IC Engine Performance
- E Reciprocating Air Compressors
- F Combustion
- G Heat Transfer
- H Properties of Steam and Steam Cycles
- I Nozzles and Steam Turbines
- J Refrigeration

The expected learning outcome is that the student:

A THERMODYNAMIC SYSTEMS

1. Defines and applies the fundamental concepts of thermodynamic properties to a system.

- 1.1. Defines a thermodynamic system.
- 1.2. Distinguishes between open and closed thermodynamic systems giving examples.
- 1.3. Defines Heat and Work with reference to a thermodynamic system.
- 1.4. States the conservation of energy in thermodynamic terms and identifies it as the First Law of Thermodynamics.
- 1.5. Defines enthalpy in terms of internal energy and flow work.
- 1.6. Defines a non-flow system and derives the non-flow energy equation $Q - W = \Delta U$
- 1.7. Defines a steady flow system and derives the steady flow energy equation $Q - W = \Delta H + \Delta KE$
- 1.8. Solves problems involving closed and open systems 1.1 to 1.7.

B THERMODYNAMIC PROCESSES

2. Defines and applies the fundamental properties of thermodynamics to a process.

- 2.1. Recalls Boyle's and Charles' Law and the combination law.
- 2.2. Recalls the Equation of State.
- 2.3. Derives the relationship between p, V and T for polytropic and adiabatic processes.

$$\frac{T_2}{T_1} = \frac{P_2^{\frac{n-1}{n}}}{P_1^{\frac{n-1}{n}}} = \frac{V_1^{n-1}}{V_2^{n-1}}$$

and

$$\frac{T_2}{T_1} = \frac{P_2^{\frac{\delta-1}{\delta}}}{P_1^{\frac{\delta-1}{\delta}}} = \frac{V_1^{\delta-1}}{V_2^{\delta-1}}$$

2.4. Derives graphically and analytically the polytropic index -n'.

2.5. Defines a reversible process.

2.6. States the conditions to be satisfied for a process to be reversible.

2.7. Defines a reversible process carried out with an ideal gas as follows:

- (a) Constant volume process;
- (b) Constant pressure process;
- (c) Isothermal process;
- (d) Isentropic or Adiabatic or constant heat process;
- (e) Polytropic process;
- (f) Defines Isentropic as Reversible Adiabatic and identifies the difference between - Isentropic and non-reversible adiabatic.

2.8. Derives the expression for the work transfer and heat transfer for each of, or combination of processes in 2.7.

2.9. Defines the specific heat of a gas and shows the difference between specific heat at constant pressure and constant volume

2.10. Shows the relationships

$$\Delta U = C_v$$

$$\Delta h = C_p$$

$$\delta = \frac{C_p}{C_v}$$

$$R = C_p - C_v$$

and is able to combine these relationships by substitution

2.11. Solves problems relating to 2.1 to 2.10

2.12. Discusses the concept of entropy as a thermodynamic property of a perfect gas.

2.13. Applies change of entropy.

$$m C_p \ln \frac{T_2}{T_1}$$

$$m C_v \ln \frac{T_2}{T_1}$$

- 2.14. Defines heat transfer and work transfer and represents on p - v and T - S diagrams.
- 2.15. Shows the processes in 2.7 on T - S diagram.
- 2.16. Solves problems 2.12 to 2.15.
- 2.17. States Avogadro's Law.
- 2.18. Defines kg - mol and uses it in the Equation of State.
- 2.19. Defines "Molar Volume" and gives its value at S.T.P.
- 2.20. Derives the Universal Gas Constant R and its relation to with M and R
- 2.21. Solves problems relating to 2.17 to 2.20.

C HEAT ENGINE CYCLES

3. Discusses the concept of heat engine cycles.

- 3.1. States the 2nd law of thermodynamics and relates this to the heat engine.
- 3.2. Describes the Carnot Cycle with reference to a heat engine.
- 3.3. Derives the thermal efficiency of a Carnot Cycle.
- 3.4. Application of Carnot's principle to show that no cycle can be more efficient without contravening the 2nd law.
- 3.5. Describe the ideal ie. engine cycles, Otto, Diesel, Dual Combustion and Joule and relates to p - v and T -S diagrams
- 3.6. Derives expressions for thermal efficiency, i.m.e.p. and net-work done, for the cycles in 3.5.
- 3.7. Derives Air Standard Efficiency.
- 3.8. Solves problems relating to 3.2 to 3.7.
- 3.9. Describes the practical counterparts of the cycles identified at 3.5.
- 3.10. Discusses simple ideal and actual open and closed cycle gas turbines, with two stage compressors and turbines, including reheat and optional heat exchanger.
- 3.11. Discusses heat exchanger "Effectiveness" and hence derives "Thermal Ratio".
- 3.12. Expresses 3.10 with respect to T - S diagrams.
- 3.13. Derives cycles thermal efficiencies, work and heat transfer with respect to 3.10.
- 3.14. Solves problems relating to 3.10 to 3.13.

I.C. ENGINE PERFORMANCE

4. Discusses internal combustion engines and engine performance.
 - 4.1. Recalls the following engine powers and formulae:
 - (a) Indicated power;
 - (b) Brake power;
 - (c) Friction power.
 - 4.2. Recalls indicated and brake mean effective pressure and how to derive them.
 - 4.3. Shows that brake mean effective pressure is directly-proportional to engine torque and independent of the engine speed.
 - 4.4. Determines the distribution of energy in an engine and produces a heat balance account.
 - 4.5. Describes the Morse Test and calculates power from given data.
 - 4.6. Recalls mechanical efficiency, indicated thermal efficiency, brake thermal efficiency.
 - 4.7. Defines specific fuel consumption.
 - 4.8. Sketches typical performance curves for I.C. engines.
 - 4.9. Solves problems relating to 4.1 to 4.8.

RECIPROCATING AIR COMPRESSORS

- 5. Discusses and describes the use of reciprocating air compressors.**
 - 5.1. Sketches and describes the basic cycle for a single stage compressor running without clearance.
 - 5.2. Derives the expression for indicated work transfer.
 - 5.3. Sketches and describes the basic cycle for a single stage compressor running with clearance.
 - 5.4. Derives the expression for net indicated work transfer given the area under the curve.
 - 5.5. Derives expressions for volumetric efficiency.
 - 5.6. States the effect of compressive index on net indicated work transfer.
 - 5.7. Relates ideal (isothermal) and actual (polytropic) compression cycles and derives isothermal efficiency.
 - 5.8. Discusses multi-stage compression and understands the advantages of same.

- 5.9. Defines conditions of minimum work with multi-stage compression.
- 5.10. Recognises multi-stage compression when 5.9 does not apply.
- 5.11. Distinguishes between indicated and input power requirements.
- 5.12. Discusses heat transfer during compression and interstage cooling.
- 5.13. States the significance of Clearance Ratio.
- 5.14. Solves problems relating to 5.1 to 5.13.

F COMBUSTION

- 6. Discusses combustion of solid, liquid and gaseous fuels by mass and by volume in terms of air requirements, excess air and products of combustion.
 - 6.1. Recalls the chemistry definitions: Atom, Molecule, Compound, Atomic Mass, Molecular Mass.
 - 6.2. Derives the equations of combustion by mass.
 - 6.3. Derives the equations of combustion by volume for gaseous fuels.
 - 6.4. Recalls stoichiometric and actual air requirements.
 - 6.5. Understands and applies Avogadro's Hypothesis to exhaust and flue gas analysis.
 - 6.6. Determines total flue gas and dry flue gas analysis by mass and by volume.
 - 6.7. Determines air supply from flue gas analysis.
 - 6.8. Derives the proportional gravimetric constituents of a fuel from flue gas analysis.
 - 6.9. Determines the exhaust products resulting from insufficient air supply and determines C burned to CO and C burned to CO₂.
 - 6.10. Determines the approximate HCV and LCV of a fuel from the heat energy released by the various constituents.
 - 6.11. Applies Dalton's laws to stoichiometric and other mixtures of gaseous fuels and air.
 - 6.12. Determines the mean molecular mass of a mixture of gases and the specific gas constant for the mixture.
 - 6.13. Determines the "dew point" of water vapour from flue gas analysis.
 - 6.14. Determines heat carried away in flue gases and determines heat transfer to gas to air and gas to water heat exchanges.
 - 6.15. Solves problems relating to 6.1 to 6.14.

Heat Transfer

7. Discusses modes of heat transfer by conduction, radiation convection.

- 7.1. States Fourier's Law for conductive heat transfer.
- 7.2. Applies 7.1 to single flat plate and composite flat plate and derives an expression for conductive heat transfer through composite flat plates.
- 7.3. Applies given formulae for heat transfer through thick cylinders.
- 7.4. Relates 7.3 to single and double lagged pipes, spheres and hemispherical ends of cylinders.
- 7.5. Discusses heat transfer through boundary layers and applies thermal conductance coefficients.
- 7.6. Determines the overall heat transfer coefficient "U" for composite flat plates and composite lagged pipes etc, using thermal conductivity and surface heat transfer coeff.
- 7.7. States the Stefan Boltzmann constant for heat transfer by radiation. Defines "black body" radiation and "emissivity factor" and applies this to a simple system.
- 7.8. Solves problems relating to 7.1 to 7.7.
- 7.9. Solves problems involving heat exchangers using "log mean temp difference".

H PROPERTIES OF STEAM AND STEAM CYCLES

- 8. Understands constant pressure steam formation, and the use of thermodynamic property tables and charts.
- 8.1. Understands steam formation, steam terms and demonstrates the use of thermodynamic property tables including interpolation of tables.
- 8.2. Recalls the formulae for boiler efficiencies.
- 8.3. Recalls formulae for "equivalent evaporation" and explains its use.
- 8.4. Determines the heat energy distribution in a boiler plant and compiles a heat balance account.
- 8.5. Applies thermodynamic properties of water and steam to solve problems on mixtures, evaporators and steam generators.
- 8.6. Discusses the concepts of throttling.
- 8.7. Discusses the concepts of entropy of liquid, vapour and super heated steam and their evaluation from steam tables and from given formulae.

- 8.8. Understand the construction and demonstrates the use of H-S and T-S charts.
- 8.9. Discusses the isentropic expansion of steam and demonstrates this process on H-S and T-S diagrams.
- 8.10. Discusses the Carnot Vapour Cycles and modifications resulting in the basic Rankine Cycle.
- 8.11. Discusses the improvements to the basic cycle from super-heating, reheating and feed heating.
- 8.12. Relates these cycles to P.V. and T.S. diagrams.
- 8.13. Derives an expression for thermal efficiency when operating on the above cycles.
- 8.14. Determines feed pump work and relates this to thermal efficiency of the plant.
- 8.15. Describes bled steam feed heating and determines heat transfer by steam and feed water through multi-stage contact and surface feed heating.
- 8.16. States Dalton's Law of partial pressures, its application to partial volumes and its application to steam/air mixtures in condensers and associated plant.
- 8.17. Solves problems relating to 8.1 to 8.16 by calculation, thermodynamic tables and H-S charts.

Nozzles and Steam Turbines

9. Understand the use of steam as a working fluid and discusses its behaviour during flow through nozzles under equilibrium conditions.
- 9.1. Applies steady flow energy equation to flow through steam nozzles and derives throat and exit velocities =
- 9.2. Distinguishes between isentropic and actual enthalpy drop in nozzles and defines nozzle efficiency.
- 9.3. States reasons for change of nozzle form and use of convergent and convergent/divergent sections.
- 9.4. Recognises critical pressure ratios for nozzle flow and applies the same, from given formulae.
- 9.5. Solves problems on 9.1 to 9.4 with equal regard to mass flow rates and flow areas.
- 9.6. Discusses compounding arrangements for simple turbines.
- 9.7. Recalls blade velocity diagrams for simple impulse turbine.
- 9.8. Defines kinetic or friction losses, leaving losses and derives expressions for same.
- 9.9. Constructs blade velocity diagrams for a Curtis stage.
- 9.10. Derives expressions for stage power, stage/diagram efficiency and stage axial

thrust for a velocity overall and pressure compounded turbines.

- 9.11. Derives an expression for degree of reaction.
- 9.12. Constructs blade velocity diagram for a reaction turbine pair.
- 9.13. Defines mean blade height and calculates blade height.
- 9.14. Calculates number of stages from given steam conditions for reaction blading only
- 9.15. Shows the effect of blade friction, (blade velocity coefficient) and blade speed ratio.
- 9.16. Solves problem relating to 9.7 to 9.15.

Refrigeration

- 10. Understands the concept of a reversed heat engine cycle and its application to refrigerating plant and heat pump, and recognises the properties of common refrigerants.
 - 10.1. Recalls the basic vapour compression refrigeration cycle.
 - 10.2. Recalls the use of thermodynamic tables including the interpolation of values.
 - 10.3. Applies the concepts of entropy and its evaluation from tables and from given formulae.
 - 10.4. Relates vapour compression cycles of p-H and T-S axes.
 - 10.5. Relates reversed Carnot cycle on p-H and T-S axes.
 - 10.6. Shows effects of superheating at evaporator outlet and undercooling at condensor outlet and relates to p-H and T-S.
 - 10.7. States relationship between mass flow rate of refrigerant, refrigerating effect, cooling load.
 - 10.8. Defines COP for heat pump and refrigerator.
 - 10.9. Derives expressions for COP of actual plant and compares to COP of plant working on reversed Carnot cycle.
 - 10.10. Defines volumetric efficiency of compressor and its effect on cylinder dimensions.
 - 10.11. Solves problems relating to 10.1 to 10.9.
 - 10.12. Understands the application of intermediate liquid cooling and solves simple problems involving flash chambers.

CHIEF ENGINEER REG III/2
MARINE ELECTRO-TECHNOLOGY

LIST OF TOPICS

A	Electric Circuit Principles
B	Electronic Circuit Principles
C	Generation
D	Distribution
E	Utilisation

The expected learning outcome is that the student:

A ELECTRIC CIRCUIT PRINCIPLES

1. Solves dc linear circuit problems under steady and transient conditions.

- 1.1 States Kirchhoff's current and voltage laws.
- 1.2 Solves steady-state dc circuit problems involving not more than three unknowns using Kirchhoff's laws.
- 1.3 Predicts graphically transient voltage and current relationships in simple resistance-inductance (R-L) and resistance-capacitance (R-C) circuits when switched on and off a steady dc supply.
- 1.4 States the time constants of simple R-L and R-C circuits as
$$\tau = \frac{L}{R} \text{ and } \tau = CR \text{ respectively}$$
- 1.5 States the form of exponential growth and decay formulae applied to R-L and R-C circuits.

- 1.6 Uses exponential growth and decay formulae to obtain particular values of current or voltage at a given time or vice-versa in simple R-L and R-C circuits.

2 Solves dc non-linear circuit problems under steady-state conditions.

- 2.1 States that a non-linear device is one that does not obey ohm's law.
- 2.2 Shows that a non-linear element may be described by its V/I characteristic in a graphical or mathematical form.
- 2.3 Lists typical examples of non-linear devices eg generators, rectifier elements, transistors, thermistors etc.
- 2.4 Estimates dc and ac resistances of a non-linear element under given operating conditions.
- 2.5 Derives graphically an overall (dynamic) V/I characteristic for a simple dc series or parallel circuit including a non-linear element and a linear resistor.
- 2.6 Solves simple dc non-linear circuits mathematically given the V/I law of the non-linear element.
- 2.7 Solves simple dc non-linear circuits graphically using load-line technique or dynamic characteristics.

3 Understands operation of single-phase and three-phase ac circuits.

- 3.1 Describes using phasor diagrams, voltage and current relationships obtained in pure resistance, pure inductance and pure capacitance circuits when energised from a single phase sinusoidal ac supply.
- 3.2 Calculates impedance Z of simple R-L-C circuit combinations in series and in parallel.
- 3.3 Defines circuit power factor as ratio of active power to apparent power and as $\cos \phi = R/Z$.
- 3.4 Solves simple series and parallel ac circuit problems including pf correction.
- 3.5 Sketches voltage and current phasor diagrams representing simple R-L-C series and parallel circuits.
- 3.6 Recognises that voltage and current resonance occurs when series and parallel R-L-C circuits respectively operate at unity power factor.
- 3.7 Derives $f = \frac{1}{2\pi\sqrt{LC}}$ as the resonant frequency of a series R-L-C circuit.
- 3.8 Defines active power (P), apparent power (S) and reactive power (Q).

- 3.9 Sketches a power triangle (P Q and S) to represent operating conditions in a single-phase circuit.
- 3.10 Solves single-phase circuit problems using P Q and S quantities.
- 3.11 Sketches the interconnection of three separate single phases to form 3-phase star and delta connections.
- 3.12 Sketches 3-phase voltage and current phasor diagrams to represent balanced star or delta connection.
- 3.13 Derives relationships $V_L = \sqrt{3} V_{ph}$ for star and $I_L = \sqrt{3} I_{ph}$ for delta balanced connections using phasor diagrams.
- 3.14 Shows mathematically that total 3-phase power is given as

$$P = \sqrt{3} V_L I_L \cos \theta$$
for both star and delta connections.
- 3.15 Solves 3-phase balanced circuit problems using voltage, current and power relationships.

B ELECTRONIC CIRCUIT PRINCIPLES

4 Understands the operation of junction diodes in rectification circuits.

- 4.1 Recognises typical forward and reverse V/I characteristics for Si and Ge diodes.
- 4.2 Compares half-wave, bi-phase and bridge rectification circuits supplied from single and three phase power supplies.
- 4.3 Sketches typical dc output waveforms from rectifier circuits in 4.2.
- 4.4 Calculates mean dc voltage at output of half and full-wave single-phase circuits given the ac input supply and vice-versa.
- 4.5 Describes the action of a simple C-only smoothing circuit in conjunction with a rectifier.

4.6 Tests complete dc power supply circuits.

5 Understands the operation of the Thyristor as a controlled rectifier.

5.1 Describes the construction of a thyristor as a 4-layer p-n device with anode, cathode and gate terminals.

5.2 States bias voltage polarities necessary for "turn-on" of a thyristor.

5.3 States conditions necessary for thyristor turn-off.

5.4 Sketches simple circuit diagram of series connected thyristor controlling a dc load from an ac supply (no gate circuitry required).

5.5 Describes circuit action of 5.4 under variable phase shift gate pulse control and block firing control.

5.6 Sketches typical load current and voltage in a simple ac driven thyristor controller with variable phase shift gate control.

5.7 Tests a complete single-phase thyristor power controller.

6 Understands the function of a Zener Diode as a dc voltage stabilizer.

6.1 Defines voltage stabilisation as the ability of a power supply to maintain its output voltage against changes in loading and input voltage.

6.2 Describes the action of a p-n junction Zener diode with forward and reverse bias voltages applied.

6.3 Recognises that a Zener diode must be worked with reverse voltage bias to become a stabilising element.

- 6.4 States that a Zener diode is rated in terms of its Zener voltage (V_Z) and its power handling ability.
- 6.5 Describes the action of a simple voltage stabilising circuit of a Zener diode and current limiting resistor in series across an unregulated dc supply.
- 6.6 Calculates values of voltages, currents and powers in a given simple dc stabiliser circuit under changes in supply voltage and loading conditions.
- 6.7 Tests a complete dc voltage stabiliser circuit.

7 Understands the action of a transistor and its function as a switch and signal amplifier device.

- 7.1 Describes the basic construction of p n p and n p n bi-polar transistors.
- 7.2 Describes the current distribution in p n p and n p n transistors when the emitter-base junction is forward biased and the collector-base junction is reverse biased.
- 7.3 Defines dc current relationships as $h_{FB} = \frac{I_c}{I_e}$ and $h_{FE} = \frac{I_c}{I_b}$
- 7.4 Sketches the basic common-base, common-emitter and common-collector connections of a transistor.
- 7.5 Recognises static transistor characteristics in common-emitter and common-base mode.
- 7.6 Describes the "cut-off" condition of a transistor when the base-emitter junction is zero or reverse biased.
- 7.7 Describes the "fully-on" (saturated) condition of a transistor when the base-emitter junction is heavily forward biased.
- 7.8 Compares cut-off and saturation of a transistor with an ideal electric switch.
- 7.9 Describes the action of a simple transistor switching circuit used for alarm and/or control purposes.
- 7.10 Sketches a practical common-emitter circuit arrangement showing dc bias arrangements, temperature stabilisation resistor and input and output signal connections.
- 7.11 Describes the action of a common-emitter circuit as a small-signal amplifier.

- 7.12 Draws a load-line onto the static output characteristics of a transistor to predict current gain.

C GENERATION

8 Understands the principles of operation of a dc generator.

8.1 Reviews basic operation of a dc generator.

8.2 Derive the emf equation $E = 2 p \Phi \frac{Z}{A} \quad n = k \Phi n$.

8.3 Evaluates generated emf.

8.4 Describes self excitation and states factors which may prevent it.

8.5 Estimates generated emf from magnetisation curve and given shunt field resistance.

8.6 Estimates critical shunt field resistance from a given magnetisation curve.

8.7 Sketches field and armature circuits for shunt and compound wound machines (long shunt and short shunt).

8.8 Explain voltage control using shunt field regulator.

8.9 Describes armature reaction and its effects.

8.10 Describes commutation, its effect and method of improving commutation eg brush shifting and interpoles.

8.11 Solves problems involving E, V, Ia, Rf and Ra.

8.12 Sketches V/I load characteristics of shunt and compound generators (cumulative and differential connections).

8.13 Estimates voltage regulation from $\frac{E - V}{V}$

8.14 Lists typical marine applications of generators in 8.7.

8.15 Calculates series turns required to produce given terminal voltage on load.

- 8.16 Describes the connection of a dc compound generator to live busbars and effects of varying excitation.
- 8.17 Explains the use of the equalising connection.
- 8.18 Describes method of disconnecting a generator from the busbars.
- 8.19 Solves load sharing problems graphically and mathematically for shunt and compound generators.
- 8.20 States the reasons for a d.c. generator failing to excite.
- 8.21 Describes the methods of exciting d.c. generators that have lost their residual magnetism.
- 8.22 Explains the need for preference trips.
- 8.23 Describes, with the aid of a schematic diagram, the operation of a preference trip.
- 8.24 Explains the need for a reverse current relay.
- 8.25 Describes the operation of a reverse current relay.

9 Understands the principles of operation of ac generators.

- 9.1 Describes the arrangement of an armature *winding to* produce a three phase emf.
- 9.2 Sketches wave form diagram of three phase voltages.
- 9.3 Derives relationship between frequency, poles *and* speed.
- 9.4 Derives emf equation $E = 2 \cdot 22 \cdot \Phi \cdot z \cdot f$

9.5 Sketches equivalent circuit per phase including E_{ph} , X_s assuming resistance to be negligible.

9.6 Explains the effect of load and power factor on terminal voltage.

9.7 Calculates emf given terminal voltage inductive load conditions and winding reactance.

9.8 Estimates voltage regulation from $\frac{E - V}{V}$

9.9 Describes connection of a three phase generator to live busbars, disconnection and shut-down.

9.10 Explains the effects of operating:

- (a) governor;
- (b) field regulator.

9.11 Solves load sharing problems where information is limited to kW, kVA, kVAR.

9.12 Describes the construction of salient and cylindrical pole a.c. generators.

9.13 Appreciate the reason for the 2 types of rotor.

9.14 Explains why an AVR is required for a.c. generators.

9.15 Describes the methods of exciting a.c. generators.

9.16 Describes, with the aid of diagrams, how brushless a.c. generators are excited using:

- (a) rectifiers;

- (b) silicon controlled rectifiers (thyristors).

9.17 Describes, with the aid of a schematic diagram, the operation of a compounded a.c. generator.

9.18 States the advantages and disadvantages of:

- (a) the insulated neutral system;
- (b) the earthed neutral system

for marine a.c. generators.

9.19 Explains the need for a reverse power relay.

9.20 Describes the operation of a reverse power relay.

9.21 Explains the need for preference trips.

D DISTRIBUTION

10 Understands typical arrangements of marine ac and dc distribution systems.

10.1 Calculates current distribution and load potentials in dc:

- (a) radial feeders;
- (b) ring mains;
- (c) double fed systems using dissimilar voltages.

10.2 Describes three phase, three wire and four wire systems.

10.3 Calculates value of the neutral current in a three phase, four wire unbalanced system.

10.4 Describes the function of the transformer in an a.c. distribution system.

11 Understands the principles of operation of a transformer.

11.1 Relates induced emf. to rate of change of flux linkages.

11.2 Derives voltages and currents from turns ratios of single phase transformer.

11.3 Derives emf equation $E = 4.44 \cdot f \Phi_m$.

11.4 Sketches phasor diagrams on and off load lag pf only and solves related problems.

11.5 Sketches three phase connections e.g. star/delta, star/star etc. using correct terminal markings.

11.6 Solves problems involving three phase transformers using turns and voltage ratios.

11.7 Sketches circuit diagram of auto-transformer.

11.8 Explains principles of operation of auto-transformer.

11.9 Solves problems on auto-transformers involving voltages, turns and tapping point.

11.10 Lists losses which occur in transformers.

11.11 Calculates efficiency of a transformer given load conditions and losses.

11.12 Explains the need for instrument transformers.

11.13 Explains the reasons for earthing the secondary winding of instrument transformers.

E UTILIZATION

12 Understands the principles of operation of a dc motor.

Reviews the basic operation of shunt, series and compound dc motors.

12.1 Derives speed equation $n = \frac{V - I_a R_a}{k\Phi}$.

12.2 Explains speed control using shunt field regulator, diverter resistance, tapped field or armature voltage control methods.

12.3 Derives torque equation $T = p\Phi \frac{Z}{a} \quad \frac{I_a}{2\pi} = k\Phi I_a$

12.4 Sketches torque/armature current, speed/armature current characteristics and derives from these torque/speed curves for shunt, series and compound motors (cumulative only).

12.5 Solves problems involving changing load, field and/or circuit conditions.

12.6 Lists the losses which occur in d.c. motors and generators.

12.7 Calculates constant losses from no-load input as a motor and hence estimates efficiency of motor or generator under load conditions.

12.8 Tests a dc motor using Swinburne test and assesses efficiency under stated load conditions.

13 Understands the principles and operation of the three-phase induction motor.

13.1 Explains the production of a magnetic field rotating at synchronous speed by a three phase stator winding.

- 13.2 Calculates slip given number of poles, frequency and motor speed.
- 13.3 Evaluates rotor frequency.
- 13.4 Shows that input to rotor equals motor input minus stator losses and that this input equals $2\pi T n_s$ watts.
- 13.5 Calculates rotor output = $2\pi T n_r$ watts.
- 13.6 Evaluates rotor resistive power loss from difference between 13.4 and 13.5.
- 13.7 Calculates motor output = $2\pi T_L n$.
- 13.8 Calculates efficiency from 13.4 to 13.7.
- 13.9 Describes the construction of single, double-cage and slip ring motors.
- 13.10 Sketches typical torque/slip curves for single, double-cage and slip-ring motors.
- 13.11 Describes with the aid of sketches the following starters:
- D.O.L.: Star/Delta : slip-ring.
- 13.12 Explains the reasons why a motor may "single-phase".
- 13.13 Describes the effect of a motor "single-phasing"
- 13.14 Describes the motor enclosures used in the marine environment.
- 13.15 Describes the methods of varying the speed of a.c. induction motors.

14 Understands principles of operation of 3-phase synchronous motor.

14.1 Relates synchronous motor to ac generator.

14.2 Describes pony motor and induction motor starting methods.

14.3 Describes effects of changing load and excitation.

14.4 Solves problems of pf improvement type.

14.5 States marine applications of the synchronous motor.

15

15.1 Describes with the aid of a sketch, the operation of a fluorescent lighting circuit.

15.2 Sketches a navigation lighting circuit.

15.3 Describes, with the aid of sketches, how earth faults are detected for (i) 1-phase and (ii) 3-phase supplies.

CHIEF ENGINEER REG III/2
NAVAL ARCHITECTURE

LIST OF TOPICS

- A Simpson's Rule
- B Free Surface Effect
- C Stability
- D Trim .
- E Rudders
- F Ship Resistance
- G Shear Force and Bending Moments
- H Ship Stresses
- I Ship Construction
- J Classification, Structural Fire Protection, Life-Saving Appliances and Pollution Control
- K Vibration and Noise

The expected learning outcome is that the student*.

A SIMPSON'S RULE

- 1. Applies Simpson's first rule (including subdivided intervals) to the determination of second moments of area.**
 - 1.1. Derives the method of calculating the second moment of area of a plane about an end ordinate using Simpson's Rule.
 - 1.2. Derives the method of calculating the second moment of area of a plane about its base using Simpson's Rule.
 - 1.3. Calculates the second moment of area of a plane using 1.1 and 1.2.
 - 1.4. Uses the Theorem of parallel Axen in conjunction with 1.3 to determine the second moment of area of a plane about its neutral axis.
 - 1.5. Calculates the second moment of area of a waterplane about the centreline.
 - 1.6. Calculates the second moment of area of a waterplane about a transverse axis passing through its centroid.
 - 1.7. Calculates the second moment of area of an unsymmetrical tank top about a longitudinal axis passing through its centroid.

B FREE SURFACE EFFECT

- 2. Understands the effect of free surface liquids on transverse stability and solves problems involving free surface effect**
 - 2.1. Explains that the effect of a free surface is to cause a transverse shift of a ship's

- centre of gravity when vessel heels.
- 2.2. Explains that this transverse shift of centre of gravity has the same effect on the stability as a reduction in the transverse metacentric height.
- 2.3. States an expression for the loss in metacentric height due to the free surface.
- 2.4. Explains the meaning of "effective metacentric height".
- 2.5. Discusses the effect of tank divisions on free surface effect.
- 2.6. Solves problems involving free surface effect.
- 2.7. Discusses practical considerations of free surface of liquids, eg, the importance of restricting same and the methods of which it may be reduced.

C STABILITY

Stability at Large Angle of Heel

3. Uses cross-curves of stability to produce curves of statical stability

- 3.1. Discusses the limitation of metacentric stability at large angles of heel.
- 3.2. Explains how the cross-curves of stability can be obtained from ship sections for an assumed position of a ship's centre of gravity.
- 3.3. Uses the cross-curves of stability to predict the righting lever for any given displacement and for an assumed position of the centre of gravity.
- 3.4. Calculates the necessary corrections to righting levers for the actual position of the ship's centre of gravity.
- 3.5. Sketches the final righting levers in the form of a statical stability curve.
- 3.6. Shows that the initial slope of the stability curve may be obtained from the metacentric height.
- 3.7. Defines range of stability.
- 3.8. Solves problems on stability at large angles of heel.
- 3.9. Defines dynamical stability.
- 3.10. Calculates dynamical stability from statical stability curve or curve of righting moments.

Stability of Wall-Sided Vessels

4. Makes use of particular features of wall-sided vessels to obtain an approximation to the stability of a ship.

- 4.1. States wall-sided formula for GZ values.
- 4.2. Discusses the limitations of the wall-sided formula.
- 4.3. Solves simple problems using the wall-sided formula.
- 4.4. Applies the wall-sided formula to vessel with negative metacentric height to derive an expression for "Angle of Loll".
- 4.5. Solves problems using the Angle of Loll expression.
- 4.6. Discusses procedures used to improve stability when at Angle of Loll.

Effect of Form on Stability

5. Understands the effects of form on stability.

- 5.1. Discusses the effect of change of beam on the statical stability curve.
- 5.2. Discusses the effect of freeboard on the statical stability curve.
- 5.3. Discusses the effect of metacentric height on the statical stability curve.
- 5.4. Sketches typical stability curves for different types of ship.

6. Stability information supplied to ships.

- 6.1. Discusses the statutory requirements for the carriage of stability data on ships.
- 6.2. Discusses the relevance of the area under the stability curve.

D TRIM

Small Masses

7. Understands how to calculate the effects on the end draughts of addition, removal, or longitudinal movement of small masses

- 7.1. Defines Trim.
- 7.2. Explains importance of the longitudinal centre of flotation (L.C.F.) in relation to trim problems.
- 7.3. Explains that the mean draught of a ship is the draught at the L.C.F.
- 7.4. Defines longitudinal metacentre.
- 7.5. Defines longitudinal metacentric height.
- 7.6. States an expression for the distance of the longitudinal metacentre above the centre of buoyancy.
- 7.7. Derives an expression for the moment to change trim 1 cm.
- 7.8. Determines change of trim due to longitudinal movement of small masses already on board.
- 7.9. Determines the effect of small additions or removals mass on end draughts of a ship.
- 7.10. Solves problems involving the end draughts after masses have been added, removed or moved longitudinally.

Large Masses

8. Understands how to use hydrostatic data to determine end draught of a ship.

- 8.1. Demonstrates how geometrical properties are presented in the form of hydrostatic curves enumerating the curves concerned.
- 8.2. Sketches a set of hydrostatic curves.
- 8.3. Determines end draughts for loading conditions using hydrostatic curves or hydrostatic data.
- 8.4. Determines the displacement of a ship, lying at a trimmed waterline.

Bilging

9. Solves problems on the change in end draughts of a box-shaped vessel due to

bilging a compartment which is not at midships.

- 9.1. Shows that when a compartment is bilged there can be changes in heel and or. in trim in addition to the change in mean draught.
- 9.2. Calculates the displacement of B and G due to bilging
- 9.3. Calculates the second moment of area of the intact waterplane about its neutral axis.
- 9.4. Calculates the effects of bilging on a non-midship compartment of a box-shaped vessel.

10. Understands the elements in ship design which are included in order to reduce the effects of bilging.

- 10.1. Discusses the effects of bilging.
- 10.2. Discusses subdivision of vessels with transverse and longitudinal watertight bulkheads in cargo and passenger ships.
- 10.3. Discusses the requirements indicated in 10.2

E RUDDERS

11. Understands the principal forces acting on a ship and rudder, when helm is applied to a vessel.

- 11.1. Explains that when the rudder is moved to an angle, from a moving ship's centreline, a pressure build up on the forward side and a suction on the aft side of the rudder gives rise to a force (F) acting parallel to the ship's centreline.
- 11.2. States that the force acting on a rudder parallel to the ship's centreline is given by $F = kAV^2$
- 11.3. Expresses the force normal to the rudder as a component of the rudder force acting parallel to the ship's centreline.
- 11.4. Explains that the normal force acts at the centre of effort
- 11.5. Calculates the torque applied by the rudder to the rudder stock.
- 11.6. Applies the torsion equation in order to determine the minimum diameter of rudder stock given the maximum allowable shear stress in the stock material.
- 11.7. Determines the work done in turning the rudder to a given angle from a graph of Torque against Rudder Angle.
- 11.8. Derives an expression for the angle of heel produced due to the force on the rudder.
- 11.9. Derives an expression for the angle of heel produced by a ship moving in a circular path.
- 11.10. Solves problems involving heeling of a ship due to rudder being applied to the vessel.
- 11.11. Describes types of rudder in use on merchant ships.
- 11.12. Discusses the reasons for using balanced rudders.

F SHIP RESISTANCE

12. Calculates the power required to drive a ship from the resistance to motion exerted by the water on a ship at any given speed.

- 12.1. Applies the expression $R_f = fsv^n$ to determine frictional resistance to motion of a vessel given the empirical formulae for frictional coefficient 'f' of the form:
: $F = A + \frac{B}{L+C}$

- 12.2. States Froudes Laws of Comparison.
- 12.3. Explains the meaning of the term "corresponding speed"
- 12.4. Applies the law of comparison to determine the residuary resistance of a ship if the residuary resistance of a scale model of the vessel is known or can be determined.
- 12.5. Explains the meaning of the terms:
 - (a) Effective Power (naked);
 - (b) Effective Power;
 - (c) Ship Correlation factor.
- 12.6. Calculates the effective power requirements of a full sized ship given the total resistance to motion measured on a scale model of the vessel towed at the corresponding speed.

Propellers

13. Understands the relationships between powers measured at points between the ship's engines and the propeller.

- 13.1. Explains the meaning and use of:
 - (a) thrust deduction factor;
 - (b) hull efficiency;
 - (c) propeller efficiency;
 - (d) transmission efficiency;
 - (e) mechanical efficiency;
 - (f) propulsive coefficient;
 - (g) quasi propulsive coefficient
- 13.2. Develops the relationships between indicated power, shaft power, delivered power, thrust power and effective power.
- 13.3. Solves numerical problems using the relation between powers.

14. Understands the phenomenon of propeller cavitation, its causes and its effects.

- 14.1. Explains what is meant by cavitation.
- 14.2. Explains that cavitation may cause erosion of the blade surface, vibration and reduction in efficiency.
- 14.3. Explains that cavitation depends upon the net pressure of the blade surface and the vapour pressure of the water.
- 14.4. Discusses the factors in propeller design which reduce cavitation.
- 14.5. Discusses the practical reduction of cavitation by a ship's staff.

Ships' trials

15. Understands the reasons for carrying out ships' trials, and the value of the data obtained from them.

- 15.1. Explains that ship trials are carried out primarily to measure power and its related speed
- 15.2. Explains that there are progressive speed trials and full speed trials.
- 15.3. Explains the value to ship staff and designers of the data measured during progressive trials.
- 15.4. Explains that the opportunity is taken on ship trials to test all systems under working conditions.

Shear Force and Bending Moments in Still Water

16. Evaluates shear forces and bending moments on ships of simple geometric form.

- 16.1. Identifies the purpose of a loading manual for a ship.
- 16.2. Outlines the use of a stress indicator for a ship.
- 16.3. Explains:
 - (a) weight curve of a ship;
 - (b) buoyancy curve of a ship
- 16.4. Shows that the load curve is the difference between the weight curve and the buoyancy curve.
- 16.5. Illustrates that the shear force at any point in the length of a ship is represented by the area of the load curve on one side of the point.
- 16.6. Uses 16.5 to produce a shear force diagram.
- 16.7. Illustrates that the bending moment at any point in the length of a ship is represented by the area of the shear force on one side of the point.
- 16.8. Uses 16.7 to produce a bending moment diagram.
- 16.9. Solves problems on box shaped vessels floating in still water on level keel.

H SHIP STRESSES

17. Recognises the causes and effects of stresses acting on ships.

- 17.1. Explains the circumstances under which the following stresses may occur in a ships structure:
 - (a) torsional stresses;
 - (b) whipping stresses.
- 17.2. Explains the steps taken to avoid or resist the stresses in 17.1.
- 17.3. Explains the circumstances which may result in the following occurring in ships structures:
 - (a) brittle fracture;
 - (b) fatigue.
- 17.4. Explains the steps taken to prevent the occurrence of brittle fracture and fatigue.
- 17.5. Identifies the points of discontinuity in a ships structure and explains measures adopted to minimise their effects.

I SHIP CONSTRUCTION

Ship types

18. Recognises the problems associated with and the structural arrangements for the carriage of liquified gases.

- 18.1. Explains the difference between LNG and LPG by describing their origins and quoting the following physical properties:
- a) boiling point;
 - b) critical temperature

- 18.2. Describes the following cargo systems and identifies the gases for which they are suitable:

- a) fully pressurised;
- b) semi pressurised/semi refrigerated;
- c) semi pressurised/fully refrigerated;
- d) fully refrigerated at atmospheric pressure.

- 18.3. Explains 'secondary barrier' and why it is required.

- 18.4. Describes with the aid of sketches the following containment systems and how they are insulated:

- a) free standing-prismatic;
- b) free standing-spherical;
- c) membrane.

- 18.5. Describes in broad outline how cargo boil-off is dealt with.

- 18.6. Lists the safety devices fitted on board to ensure safe loading and unloading explaining their function.

19. Recognises the problems associated with and the structural arrangements for the carriage of chemical cargoes.

- 19.1. Explains what is meant by compatibility and how it is catered for in chemical carriers with respect to:

- a) different cargoes;
- b) air;
- c) water;
- d) tank coatings;
- e) temperature;
- f) self reaction.

- 19.2. Explains that chemical cargoes may be designated A, B or C according to the degree and nature of the hazard involved in their carriage.

- 19.3. Explains that the cargo tank arrangements are governed by the cargo designation.

- 19.4. Explains with the aid of sketches the tank arrangements for the cargoes designated in 19.2.
- 19.5. Explains that protection of the structure in 19.4 can be achieved by suitable materials or coatings.
- 19.6. Identifies the coatings and materials in 19.5 and cargoes for which they are suitable.
- 19.7. Explains measures which should be taken by crew members to ensure personal safety.

20. Recognises the problems associated" with the carriage of various cargoes.

- 20.1. Summarises the conditions by arrangement of the loadline.
- 20.2. Sketches the loadline naming the lines.
- 20.3. Explains the problems involved in the carriage of the following cargoes:
 - a) deck timber;
 - b) grain;
 - c) iron" ore;
 - d) concentrates.
- 20.4. Explains the precautions which must be taken when carrying the cargoes in 20.3.

Tonnage and Freeboard

21. Analyses the Loadline Rules with particular reference to the "conditions of assignment".

- 21.1. Distinguishes terminology, "freeboard", "freeboard deck", "superstructure deck", "Type A ship", "Type B ship", "superstructure".
- 21.2. Enumerates the criteria used as a basis for assigning freeboards:
 - a) adequate ship strength;
 - b) adequate reserve buoyancy;
 - c) prevention of entry of water into hull;
 - d) safe height of working platform and protection of crew;
 - e) deck wetness in relation to bow height;
 - f) stability and compartmentation.
- 21.3. Explains various seasonal and fresh water loadline markings.
- 21.4. Enumerate conditions for assigning basic minimum freeboard to tankers.
- 21.5. Distinguishes main factors and describes maintenance required to maintain "conditions of assignment":
 - a) hatchways;
 - b) machinery space openings;
 - c) openings in freeboard and superstructure decks;
 - d) vents, air pipes, cargo doors and other openings in hull below the freeboard deck;
 - e) side scuttles, freeing ports;

f) guard rails, gangways.

- 21.6. Distinguishes between tabular freeboard, basic freeboard, assigned freeboard.
- 21.7. Explains the conditions under which Type 'B' ship may be assigned a reduced freeboard
- 21.8. Distinguishes between gross and net tonnages
- 21.9. Determines the information required for tonnage measurement
- 21.10. Distinguishes between enclosed and excluded spaces.
- 21.11. Analyses the function of the tonnage certificate and discusses the statement of information given

Structural Materials

22. Integrates learning from different areas to explain the uses of materials other than mild steel for ships structures.

- 22.1. Identifies the advantages and disadvantages of higher tensile and other special steels, aluminium alloys and glass reinforced plastics as constructional materials.
- 22.2. Explains the uses of materials in 22.1 in ship construction.
- 22.3. Identifies the problems encountered in the connection of aluminium to steel in ship construction.
- 22.4. Illustrates a method used to overcome 22.3.

J CLASSIFICATION, STRUCTURAL FIRE PROTECTION, LIFE SAVING APPLIANCES AND POLLUTION CONTROL.

23. Analyses the function and influence of Classification Societies on the construction of ships.

- 23.1. Determines the role of Classification Society in the design, building and operation of ships.
- 23.2. Determines the nature of initial survey for award of class and intermediate/continuous surveys for retention of classification.
- 23.3. Distinguishes between surveys for the various ship types i.e. oil tankers, dry cargo ships, refrigerated cargo ships, chemical tankers, gas carriers.
- 23.4. Shows an understanding of classification notation.

Structural Fire Protection

24. Identifies in general terms the methods of structural fire protection for passenger ships and cargo ships.

- 24.1. Explains that fire divisions are classified according to their degree of fire resistance.
- 24.2. Describes, in broad outline only, the structural arrangements for fire protection of passenger ships.
- 24.3. Outlines the requirements regarding:
 - a) openings in A-class divisions;
 - b) the protection of stairways, lift shafts and

ventilation trunks.

24.4. Describes the structural arrangements for fire protection of:

- a) dry cargo ships,-
- b) oil tankers.

Life-Saving Appliances

25. Understands in broad outline the life-saving requirements for merchant ships.

25.1. Lists the following types of life-saving equipment:

- a) lifeboats;
- b) liferafts;
- c) lifebelts;
- d) life jackets;
- e) buoyancy equipment.

25.2. Describes, with the aid of a sketch, a set of lifeboat gravity davits.

25.3. Describes, with the aid of a sketch, the braking arrangements for the davits described in 25.2.

25.4. Describes a launching procedure using the davits described in 25.2.

Pollution Control by Construction

26. Understands the facts and principles underlying the regulations for marine pollution control by construction.

26.1. Explains the following:

- a) segregated ballast tanks;
- b) clean ballast tanks;
- c) protective locations;
- d) slop tanks.

26.2. Explains the regulations relating to the items in 26.1,

26.3. Explains the crude oil washing (COW) system for cargo tank cleaning.

26.4. States the advantages and disadvantages of COW.

Vibration and Noise

27. Integrates learning from different areas to explain the causes and adverse effects of ship vibration and the methods used to prevent same.

27.1. Defines the terms:

- a) frequency;
- b) amplitude;
- c) resonance;
- d) mode;
- e) node;
- f) anti-node.

27.2. Explains that a ship will have natural frequencies of hull vibration.

27.3. Points out that vibration may be caused by:

- a) the action of the sea;
- b) out-of-balance forces in main or auxiliary machinery;
- c) fluctuating forces on the propeller;
- d) propeller-hull interaction;
- e) operation of deck machinery.

27.4. Points out that vibration may cause:

- a) structural failure;
- b) failure of equipment;
- c) discomfort to passengers and crew.

27.5. Explains the effect of the following with regard to preventing or reducing vibration:

- a) stern design;
- b) propeller design;
- c) machinery seating arrangements;
- d) alteration of ships loading condition.

Noise

28. Recognises the problems of noise on ships and the methods used to reduce same.

28.1. Discusses the sources of noise and how it is transmitted throughout a ship.

28.2. Discusses how structural and machinery arrangement can reduce noise levels

CHIEF ENGINEER REG III/2

APPLIED MECHANICS

LIST OF TOPICS

- A Vector Representation
- B Statics
- C Friction
- D Kinematics
- E Dynamics
- F Machines
- G Strength of Materials
- H Hydrostatics
- I Hydrodynamics
- J Control System Mathematics

The expected learning outcome is that the student:

A VECTOR REPRESENTATION

1 Understands the use of vectors for graphical solutions.

- 1.1 Recalls the procedures for the addition and subtraction of parallel and non-parallel vectors by both graphical and analytical methods.
- 1.2 Recalls the terms: Resultant and Equilibrant.
- 1.3 Explains that three non-parallel vectors must be concurrent for equilibrium.
- 1.4 Resolves vectors into mutually perpendicular components.

- 1.5 Solves problems involving coplanar-concurrent and coplanar non-concurrent vector quantities.
- 1.6 Solves problems involving non-coplanar concurrent vector quantities.

B STATICS

2 Understands the conditions of equilibrium of a body subject to a system of coplanar and non-coplanar forces and/or moments, and applies the conditions of equilibrium to solve relevant practical problems.

- 2.1 Recalls a moment of force.
- 2.2 Resolves forces applied obliquely into perpendicular components.
- 2.3 States the Principle of Moments.
- 2.4 States the conditions for equilibrium of a rigid body subject to a number of non-concurrent coplanar forces.
- 2.5 Describes the classification of the lever:
 - (a) as one of three orders;
 - (b) straight or cranked;
 - (c) simple or compound.
- 2.6 Solves problems related to 2.1 to 2.5.
- 2.7 Describes concurrent coplanar force systems.
- 2.8 Solves problems on 2.7 involving up to four forces in equilibrium to include the static condition of crank and overhung connecting rod.
- 2.9 Describes concurrent non-coplanar force systems.
- 2.10 Solves problems on 2.9 involving up to four forces in equilibrium.
- 2.11 Resolves forces acting on a body resting on a frictionless plane inclined to the horizontal.

2.12 Defines moments of mass, volume and area.

2.13 Understands the principle of Rapson's slide.

2.14 Solves problems related to 2.11 to 2.13.

C FRICTION

3 Discusses the effect of friction when one rigid body slides or tends to slide over another rigid body, and applies the principles established to the solution of practical problems.

3.1 States the 'laws of dry friction'.

3.2 Defines the terms for a body sliding or tending to slide over a horizontal plane.

- (a) static friction;
- (b) sliding friction;
- (c) normal reaction;
- (d) plane reaction;
- (e) friction angle;
- (f) limiting friction force.

3.3 Discusses the forces involved when a body is stationary or sliding at uniform speed on a plane inclined to the horizontal.

3.4 Solves problems involved in holding or causing the body to ascend and descend the plane at uniform speed by means of:

- (a) a force acting parallel with the plane;
- (b) a force acting horizontally;
- (c) the least force;
- (d) forces acting at any angle.

3.5 Solves problems involving wedges and cotters.

3.6 Solves problems involving static equilibrium when friction forces are involved.

3.7 Solves problems involving work lost due to friction.

D KINEMATICS

4 Solves problems involving linear, angular and relative motion.

- 4.1 Recalls the terms: displacement, speed, velocity and acceleration and states the units for both linear and
angular cases.
- 4.2 Sketches distance/time graphs for both constant speed and uniform acceleration and defines the slope.
- 4.3 Sketches velocity/time graphs for both constant speed and uniform acceleration and relates the slope and area to the motion.
- 4.4 States the equations of motion for constant acceleration in both linear and angular terms.
- 4.5 Derives the relationship between linear and angular motion.
- 4.6 Solves problems related to 4.1 to 4.5.
- 4.7 Derives the equations for the horizontal and vertical components of the motion of a projectile.
- 4.8 Solves problems on individual and double projectiles.
- 4.9 Defines relative and absolute velocity.
- 4.10 Determines the relative velocity of unconnected bodies.
- 4.11 Solves problems involving closest approach and elapsed time related to 4.10 above.
- 4.12 Determines the relative velocity of connected bodies in simple mechanisms.

N.B. (Objectives 4.7 to 4.12 to be solved by analytical and/or graphical methods).

E DYNAMICS

5 Applies the laws of motion to translational dynamics.

- 5.1 Recalls Newton's laws of motion and discusses the concept of inertia.
- 5.2 Defines power.
- 5.3 Defines linear momentum and impulse.
- 5.4 Discusses the Conservation of Momentum.
- 5.5 Defines kinetic energy, potential energy and work done.
- 5.6 Discusses the Conservation of Energy.
- 5.7 Solves problems involving momentum, impulse, energy, work done and power, to include impact of non-elastic bodies.
- 5.8 Explains the traction of vehicles on horizontal and inclined planes.
- 5.9 Considers tractive effort as the algebraic sum of the forces arising from:
 - (a) force to overcome the component of weight of the vehicle on the inclined plane
 - (b) acceleration forces;
 - (c) friction forces.
- 5.10 Expresses the friction forces as tractive resistance in terms of force per tonne of vehicle.
- 5.11 Solves problems involving motion on an inclined plane.
- 5.12 Solves problems in which bodies are hauled by a connected body or winch in ascent and/or descent of an inclined plane.

- 5.13 Solves problems in which bodies are hauled up inclined planes and the hauling force is limited by conditions of overturning of the body.

6 Applies the laws of motion to rotational dynamics.

- 6.1 Derives the relationship between torque, angular acceleration and moment of inertia.
- 6.2 States the expression for the moment of inertia of an annular disc.
- 6.3 Determines the moment of inertia for composite flywheels comprising of plain and annular discs.
- 6.4 Explains the concept of radius of gyration.
- 6.5 Discusses the concept of a thin rim type flywheel.
- 6.6 States the expression for the work done by a torque.
- 6.7 Represents graphically angular work done.
- 6.8 States the expression for the power developed by a torque.
- 6.9 Derives the expression for the kinetic energy of rotation.
- 6.10 Shows that the vertical force acting on a freely suspended mass is given by the expression: $mg \pm ma$.
- 6.11 Solves problems involving connected masses passing over

frictionless light pulleys, including inclined planes.

- 6.12 Solves problems involving masses connected to separate ropes on stepped flywheels and to include inertia and friction.
- 6.13 Discusses the concept of fluctuation of speed and energy.
- 6.14 Solves problems involving 6.13 above.
- 6.15 Solves problems involving combinations of translational and rotational motion.
- 6.16 Defines angular momentum (moment of momentum).
- 6.17 States the conservation of angular momentum.
- 6.18 Derives the expression for the rate of change of angular momentum and hence angular impulse.
- 6.19 Solves problems involving angular momentum and impulse.
- 6.20 Derives the simple expression for the torque to overcome friction on a thrust collar bearing.
- 6.21 Solves problems on 6.20 above.
- 6.22 Solves problems involving torque and power transmitted

by single flat plate friction clutches; relevant formulae to be given.

6.23 Repeats 6.22 for cone friction clutches.

7. Describes centripetal and centrifugal effects and solves associated problems.

- 7.1 Derives the expression for the centripetal acceleration of a body moving in a circular path with uniform angular velocity.
- 7.2 Relates centripetal acceleration and centripetal force.
- 7.3 Recognises that centrifugal force is an inertial reaction to centripetal force.
- 7.4 Determines by graphical or analytical means whether a rotating coplanar force system is in equilibrium.
- 7.5 Determines the out-of-balance force and the balancing mass required for systems not in equilibrium.
- 7.6 Calculates the forces on bearings supporting out-of-balance shafts.
- 7.7 Discusses the conical pendulum.
- 7.8 Solves problems involving conical pendulums.

- 7.9 Discusses centrifugal governors.
- 7.10 Sketches and describes the Watt governor, Porter governor and the Hartnell governor.
- 7.11 Solves problems related to 7.10 by analytical and graphical methods.
- 7.12 Describes the effects of vehicles negotiating curved paths.
- 7.13 Solves problems due to the overturning effect on a vehicle negotiating a curved track in the horizontal plane.
- 7.14 Solves problems due to the centrifugal force on a vehicle negotiating a banked or superelevated track, neglecting overturning.
- 7.15 Solves problems when frames are subjected to a dynamic force, such as the centrifugal force, arising when the mass on the end of a crane cable swings in the plane of the frame.
- 7.16 Solves problems involving torque and power transmitted by centrifugal clutches.

8 Describes and solves problems involving simple harmonic motion SHM.

8.1 Defines SHM.

8.2 Derives expressions for displacement, velocity and acceleration of the projection, on a diameter, of a point moving in a circular path at constant angular velocity and hence concludes the motion is SHM.

8.3 Defines amplitude, frequency and periodic time.

8.4 Derives the general expression: frequency =

$$\frac{1}{2\pi} \sqrt{\frac{Acceleration}{Displacement}}$$

8.5 Derives the expression for the acceleration of a mass vibrating on a helical spring and concludes the motion is SHM.

8.6 Derives the expression for the frequency of a mass vibrating on a helical spring.

8.7 States the assumptions made for the spring mass effect.

8.8 Repeats 8.5 and 8.6 above for a simple pendulum.

8.9 Repeats 8.5 and 8.6 above for a liquid in a U-Tube.

8.10 Repeats 8.5 and 8.6 above for a simply supported

massless beam with a central point load (expression for deflection to be given).

- 8.11 Solves problems on 8.2 to 8.10 above.
- 8.12 Discusses Scotch Yoke mechanism as pure SHM.
- 8.13 Discusses the reciprocating crank/connecting rod mechanism with reference to SHM and modified SHM.
- 8.14 Describes the component forces of the piston effort.
- 8.15 Explains the effect of friction at the crosshead.
- 8.16 Discusses crankshaft torque with reference to piston effort.
- 8.17 Solves problems involving 8.13 to 8.16 above (expressions for instantaneous displacement, velocity and acceleration of piston to be given as required).
- 8.18 Determines crankshaft speed from piston speed.
- 8.19 Discusses cam operation.
- 8.20 Describes the following cam profiles:
 - (a) giving SHM motion to the follower;
 - (b) a motion resulting from a cam which has an elliptical silhouette;

- (c) a motion resulting from a cam which is cylindrical but eccentrically mounted;
- (d) a motion in which the cam provides a Period of dwell of the follower.

8.21 Solves problems involving spring force, friction, gravitational force, accelerating force and reaction force for on centre line followers for the cams at 8.22.

F MACHINES

9. Understands the principles involved in the determination of movement ratio for geared mechanisms.

- 9.1 Recalls the term movement ratio (velocity ratio).
- 9.2 Determines the movement ratio for simple and compound gear trains.
- 9.3 Solves problems related to 9.2 above.

G STRENGTH OF MATERIALS

10. Revises the terminology and solves simple problems in strength of materials.

- 10.1 Recalls the terms, with units as appropriate: direct stress and strain; shear stress and strain; Modulus of Elasticity E; Modulus of Rigidity G; proof stress; and

factor of safety.

- 10.2 Solves problems involving simple and stepped bars subjected to axial loading.
- 10.3 Solves problems involving the shear stress in simple components e.g. jointed stays.
- 10.4 Discusses the effect of axial loading on compound members.
- 10.5 Solves problems involving compound members subjected to direct axial loads.

11. Discusses the effect of temperature change on the physical dimensions of components.

- 11.1 Determines the stresses set up in simple and stepped bars subjected to linear thermal strain.
- 11.2 Discusses the effects of temperature change on composite members.
- 11.3 Solves problems involving differential thermal expansion (and contraction).
- 11.4 Solves problems involving compound members subjected to both direct loading and temperature change, e.g. nut, bolt and tube assembly.

12. Solves problems involving shear forces and bending moments on simply supported and cantilever beams.

- 12.1 Determines the support reactions for beams subjected to point and/or uniformly distributed loads.
- 12.2 Recalls the terms Shear Force, SF, and Bending Moments, BM.
- 12.3 Calculates the SF and BM at any point along a beam.
- 12.4 Explains the need for a sign convention when dealing with SFs and BMs.
- 12.5 Sketches the SF and BM diagrams for the four standard cases:
 - (a) simply supported beam with point load at mid span;
 - (b) cantilever with point load at free end;
 - (c) simply supported beam with UDL along total length;
 - (d) cantilever with UDL along total length.
- 12.6 Draws to scale SF and BM diagrams for beams subjected to combinations of point loads and uniformly distributed loading.
- 12.7 Repeats 12.6 above when beam is subjected to an offset bracketed load.

- 12.8 Explains the relationship between SF and BM.
- 12.9 Calculates the position and magnitude of maximum bending moment.
- 12.10 Defines 'point of contraflexure'.
- 12.11 Calculates the position of any point of contraflexure on a loaded beam.
- 12.12 Discusses the concept of uniformly varying distributed loading, e.g. hydrostatic loading.
- 12.13 Sketches SF and BM diagrams for the loading case given at 12.12 above.
- 12.14 Discusses slope and deflection of loaded beams.
- 12.15 States the expression for the maximum deflection for the four standard cases listed at 12.5 above.

13. Solves problems related to the Theory of Simple Bending.

- 13.1 Lists the assumptions necessary in deriving the bending theory.
- 13.2 Derives the expression: $\frac{M}{I} = \frac{\sigma}{y} = \frac{E}{R}$
- 13.3 Shows that the NA of the section passes through the centroid.

- 13.4 Defines Section Modulus 'Z'.
- 13.5 Sketches simple diagrams showing the bending stress distribution across the beam section.
- 13.6 Solves problems using the bending theory, together with the concepts of 12.6 and 12.15.
- 13.7 Discusses the concept of combined bending and direct stress.
- 13.8 Describes how eccentric and inclined loading can induce both bending and direct stresses.
- 13.9 Solves problems referring to the loading cases identified above involving sections symmetrical and non-symmetrical above their NA.
- 13.10 Sketches the stress distribution diagrams for the above, inserting principal values and position of zero stress.
- 14. Solves problems relating to the stability of axially loaded columns.**
 - 14.1 Discusses the concept of buckling and defines the term 'slenderness ratio'.
 - 14.2 Discusses the four basic end conditions for struts.

14.3 Discusses the use of the Euler formulae for struts.

14.4 Solves problems using given Euler formulae, for any of the four basic conditions.

15. Derives and uses the simple theory of torsion for members of circular sections.

15.1 Lists the assumptions necessary in deriving the torsion theory.

15.2 Derives the expression: $\frac{T}{J} = \frac{G\theta}{L} = \frac{\tau}{R}$

15.3 Recalls the expression for the power transmitted by a rotating shaft.

15.4 Defines torsional stiffness.

15.5 solves problems applying the expressions above to uniform and stepped shafts of solid and/or hollow section and to shaft and pulley arrangements.

15.6 States the relationship between the torque transmitted by a shaft and the shear force induced in the coupling bolts.

15.7 Solves problems involving shaft coupling bolts associated with 15.5 above.

15.8 Compares the masses of solid and hollow shafts.

15.9 Determines the stresses set up in the materials of compound shafts.

16. Applies the theory of torsion to close coiled helical springs.

16.1 Develops the formula for stress and deflection of a helical spring subjected to an axial load.

16.2 Solves problems on the design of such springs.

17. Solves problems relating to the concept of elastic strain energy.

17.1 Defines strain energy and resilience.

17.2 Derives the expression: $U = \frac{\sigma^2 AL}{2E}$

17.3 Solves problems by applying 17.2 above for members subjected to gradually applied loading.

17.4 Discusses the concept of impact loading.

17.5 Solves problems involving conversion of PE and/or KE into strain energy to determine the maximum

instantaneous stress and deformation.

17.6 Derives expressions for the strain energy of a helical spring in terms of both linear deflection and torque.

17.7 Solves problems involving strain energy of springs.

18. Solves problems involving the concept of stresses on oblique planes of stressed material.

18.1 Shows that a material subjected to a direct force experiences both direct and shear stresses on an oblique plane.

18.2 Determines the direct and shear stresses on an oblique plane of a material subjected to axial force and mutually perpendicular forces (or stresses).

18.3 Shows that the maximum shear stress occurs on a 45° plane.

18.4 Discusses the concept of complementary shear stress.

18.5 Repeats 18.2 above, including applied shear stress.

18.6 Recalls the expressions for hoop and longitudinal stress in a thin cylinder subjected to internal pressure.

18.7 Solves problems involving direct and shear stresses on oblique seams of thin cylinders.

H HYDROSTATICS

19. Solves problems involving hydrostatic forces on immersed areas.

- 19.1 Recalls the terms: mass, density, relative density, pressure, gauge pressure and absolute pressure.
- 19.2 Derives the expression for the pressure at any depth in a liquid.
- 19.3 Determines pressures from given piezometer, manometer and barometer readings.
- 19.4 Derives the general expression for the resultant hydrostatic force on an area immersed at any depth in a liquid.
- 19.5 Defines the term 'centre of pressure'.
- 19.6 Derives the general expression for the position of the Centre of Pressure of an area immersed at any depth in a liquid.
- 19.7 Solves problems relating to the resultant thrust and centre of pressure for: bulkheads, tanks, door and lock gates, positioned vertically and inclined.(Immersed areas limited to rectangular, circular, triangular and trapezoidal).
- 19.8 Determines the resultant thrust and centre of pressure for a vertical rectangular area wetted by two immiscible liquids.
- 19.9 Repeats 19.7 and 19.8 above when the free surface is subjected to a gas pressure.

20. Applies Archimedes Principle to solve problems.

- 20.1 States Archimedes Principle with reference to floating and submerged bodies.
- 20.2 Solves problems applying 20.1 above and to include bodies floating in two immiscible liquids.
- 20.3 Solves problems applying 20.1 above for bodies descending vertically through liquids, the motion being frictionless.

I HYDRODYNAMICS

21. Discusses the concepts of energy related to the steady flow motion of liquids and solves associated problems.'

- 21.1 Discusses the volumetric and mass flow rates of liquids and states the continuity equation.
- 21.2 Explains the concept of coefficient of velocity C_v , coefficient of contraction C_c , and coefficient of discharge C_d for a sharp edged orifice.
- 21.3 Applies 21.2 above to solve problems involving flow of liquids through sharp edged orifices.

- 21.4 Identifies the various forms of energy possessed by a liquid in motion and states the expression for these in terms of energy and equivalent head.
- 21.5 Applies the principle of the conservation of energy and hence derives the Bernoulli expression.
- 21.6 Discusses the effect of friction related to flow problems and explains how this is included with the Bernoulli statement.
- 21.7 Applies the above to a venturi meter.
- 21.8 Explains the concept of the coefficient of discharge, C_d , with reference to a venturi meter.
- 21.9 Solves problems applying 21.5 above to: parallel and tapering pipes and venturi meters positioned horizontally, vertically and inclined; both frictionless and systems with friction to be included.
- 21.10 States D'Arcy's formula for friction losses in pipelines.
- 21.11 Discusses 'equivalent length' of pipes to allow for energy losses at bends and valves.
- 21.12 Solves problems related to 21.9 and 21.10 above.
- 22. Solves problems related to changes in momentum of liquids in motion.**

- 22.1 Recalls that force is equal to the rate of change of momentum.
- 22.2 Derives an expression for the instantaneous pressure rise due to rapid valve closure and solves associated problems.
- 22.3 Determines the resultant force on pipe bends due to change of momentum.
- 22.4 Determines the reaction force at hydraulic nozzles.
- 22.5 Determines the power of a hydraulic jet.
- 22.6 Solves problems related to the impact of jets on stationary flat plates positioned perpendicular and inclined to jet.
- 22.7 Repeats 22.6 above for moving plates.
- 22.8 Draws the velocity diagram for the impact of a jet on a curved vane.
- 22.9 Discusses the principles of a centrifugal pump.
- 22.10 Determines impeller width for constant and variable radial flow velocity through impeller.
- 22.11 Determines volumetric flow rate through impeller.

22.12 Determines the work done on the fluid passing through a centrifugal pump.

22.13 Derives the expression for manometric head and determines manometric efficiency.

22.14 Solves problems involving: impeller speed, blade angles for shockless flow, fluid velocity, pump efficiency, capacity and power.

J MATHEMATICAL SOLUTIONS OF CONTROL SYSTEM PROBLEMS

23. Derives equations and in certain cases solves mathematical problems related to control.

23.1 Solves mathematical problems related to pneumatic and hydraulic systems given, where necessary, the relevant formulae.

23.2 Be able to analyse a simple pneumatic or hydraulic control system and derive the equation of motion.

