

THEORY OF MACHINES

L T P
4 - -

RATIONALE

Diploma holder in Mechanical Engineering comes across many machines. He must have the knowledge of various mechanisms, power transmission devices, balancing of masses, vibrations etc. Hence this subject is offered.

DETAILED CONTENTS

1. Basic Concepts

- 1.1 Definition of statics, kinetics, kinematics and dynamics.
- 1.2 Rigid body and resistant body.
- 1.3 Links.
- 1.4 Kinematics pairs and their types.
- 1.5 Degree of freedom.
- 1.6 Kinematics chain and their types.
- 1.7 Constrained motion and mechanisms.
- 1.8 Classification of mechanisms.
- 1.9 Equivalent mechanism.
- 1.10 Laws of inversion of mechanisms.
- 1.11 Single slider crank chain and its inversions.
- 1.12 Quick return mechanism and IC engine mechanism.
- 1.13 Double slider crank chain mechanism and its inversions like scotch yoke mechanism.
- 1.14 Applications of mechanisms and their selection from manufacture catalogue.
- 1.15 Indicator mechanism, pantograph.
- 1.16 Steering gear mechanism.

2. Fly Wheel

- 2.1 Functions of fly wheel.
- 2.2 Types of fly wheels.
- 2.3 Mass and size calculations in different cases

3. Governors

- 3.1 Functions of governor
- 3.2 Types of governor - elementary knowledge of porter governor, watt governor, proell governor, Hartnell governor, spring controlled gravity governor
- 3.3 Hunting, isochronism, stability, sensitiveness of a governor
- 3.4 Simple problems related to watt, porter and proell governor

4. Cams

- 4.1 Definition of cam
- 4.2 Classification of cams
- 4.3 Followers and their classification
- 4.4 Brief description of different types of cams and followers with simple line diagram
- 4.5 Simple cam profile for uniform velocity, SHM and uniform acceleration and deceleration

5. Power Transmission Devices (Belt, Rope and Chain Drive)

- 5.1 Introduction.
- 5.2 Belt and rope drives, open and crossed belt drives, action of belt on pulleys, velocity ratio.
- 5.3 Material for belts and ropes.
- 5.4 Slip in belts, ropes, and chains.
- 5.5 Types of V Belt and Flat belt, joint preparation for flat belt.
- 5.6 Types of pulleys - step pulley, flat pulley, jockey pulley.
- 5.7 Crowning in pulley.
- 5.8 Laws of belting and length of belt
- 5.9 Ratio of tensions
- 5.10 Power transmitted and maximum power transmitted by belt
- 5.11 Centrifugal effect on belt
- 5.12 Initial tension, creep
- 5.13 Chain drive, chain length, classification of chains
- 5.14 Selection of belt, chain and pulley for different applications on the basis of centre distance between the shaft, power to be transmitted, availability of space, slip, velocity ratio
- 5.15 Selection of rope based on the load to be lifted
- 5.16 Simple problems on power transmitted by belts and ropes

6. Gear Drive

- 6.1 Functions of gear
- 6.2 Classification of gears
- 6.3 Gear nomenclature
- 6.4 Simple, compound, reverted and epicyclic
- 6.5 Horsepower transmitted by a gear train
- 6.6 Selection of gear trains- simple and epicyclic

7. Brakes and Dynamometers

- 7.1 Introduction
- 7.2 Brief description of different types of brake such as block or shoe brake, band brake, internal expanding, power brake and disc brake

- 7.3 Simple problems related to shoe brake and band brake
- 7.4 Definition and types of dynamometers, pony brake dynamometer, rope brake dynamometers, hydraulic dynamometer, belt transmission dynamometer and Bevis Gibson torsion dynamometer

8. Clutches

- 8.1 Function of clutch
- 8.2 Classification of clutches
- 8.3 Principle of working of single plate clutch and cone clutch with simple line diagram
- 8.4 Multi plate clutch
- 8.5 Calculation of frictional torque for uniform pressure and uniform wear
- 8.6 Horse power transmitted
- 8.7 Selection of clutches for different applications from hand book/catalogue

9. Balancing

- 9.1 Need of balancing
- 9.2 Concept of static and dynamic balancing
- 9.3 Balancing of rotating mass by another mass in the same plane
- 9.4 Forces due to revolving masses
- 9.5 Concept of reference plane
- 9.6 Balancing of several masses rotating in same plane
- 9.7 Balancing of several masses rotating in different planes

10. Vibrations

- 10.1 Introduction
- 10.2 Types of vibration - longitudinal, transverse and torsional vibration
- 10.3 Damping of vibrations

INSTRUCTIONAL STRATEGY

1. Use teaching aids for classroom teaching.
2. Give assignments for solving numerical problems.
3. Arrange industry visits to augment explaining use of various machine components like belt, rope, chain, gear drives, action due to unbalanced masses, brake clutch, governors, fly wheels, cams and gear drives.
4. Video films may be used to explain the working of mechanisms and machine components like clutch, governors, brake etc.

RECOMMENDED BOOKS

1. Mechanism and Machine Theory; JS Rao and Dukkipati; Wiley Eastern, New Delhi.
2. Theory of Mechanism and Machine; A Ghosh and AK Malik, East West Press (Pvt.) Ltd., New Delhi.
3. Theory of Machines; SS Rattan: Tata McGraw Hill, New Delhi.
4. Theory of Machines by RS Khurmi and JK Gupta; S.Chand and Company Ltd., New Delhi.
5. Theory of Machines and Mechanisms by PL Ballaney; Khanna Publishers, New Delhi.

SUGGESTED DISTRIBUTION OF MARKS

<u>Topic No.</u>	<u>Time Allotted (Hrs)</u>	<u>Marks Allotted (%)</u>
1.	6	10
2.	8	12
3.	8	12
4.	8	12
5.	8	12
6.	8	12
7.	4	6
8.	4	6
9.	8	12
10.	2	6
Total	64	100

METROLOGY

L T P
3 - 2

RATIONALE

Diploma holders in these courses are required to measure and inspect for ensuring quality of product. For this purpose, knowledge and skills about standards of measurement, limit, fits and tolerances, types of inspection and various measuring instruments are required. Hence this subject is offered

DETAILED CONTENTS

1. Introduction

- 1.1 Definition of metrology
- 1.2 Standard of measurement
- 1.3 Types of errors- Controllable and random errors
- 1.4 Precision, accuracy, sensitivity, hysteresis, response time, repeatability, calibration, uncertainty of measurement

2. Linear Measurement

- 2.1 Construction features and use of instruments for non precision linear measurement: steel rule, callipers, surface plate, angle plate, V-block.
- 2.2 Construction features and use of instruments for precision measurements : vernier calipers, vernier height and depth gauges, micrometers.
- 2.3 Slip gauges, Indian standards of slip gauges, sets of slip gauges, use of slip gauges.
- 2.4 Cylinder bore gauges, feeler and wire gauges.
- 2.5 Comparators – Characteristics, uses, working principles of different types of comparators: mechanical, electrical, electronics and pneumatic comparator.

3. Angular Measurement

- 3.1 Construction and use of instruments for angular measurements: bevel protector, sine bar, angle gauges, clinometer.
- 3.2 Optical instruments for angular measurement, auto collimator.

4. Measurement of Surface Finish

- 4.1 Terminology of surface roughness.
- 4.2 Concept of primary texture and secondary texture.
- 4.3 Factors affecting surface finish.
- 4.4 CLA, RMS and RA value.
- 4.5 Principle and operation of stylus probe instruments for measuring surface roughness

5. Measurements of Screw threads and Gears

- 5.1 Measurement of screw threads- Introduction, measurements of external and core diameters, checking of pitch and angle of threads with gauges.
- 5.2 Effective diameter measurement by three wire method.
- 5.3 Measurements of gears (spur) – Measurement of tooth thickness, pitch, testing of alignment of teeth.
- 5.4 Profile projector, Coordinate Measuring Machine (CMM), Tool maker's microscope.

6. Machine Tool Testing

- 6.1 Alignment test on lathe, drilling machine and milling machine.

7. Limits, Fits and Tolerances

- 7.1 Definition and terminology of limits, fits and tolerances.
- 7.2 Hole basis and shaft basis systems.
- 7.3 Type of fits.
- 7.4 Limit gauges.

8. Instrumentation

Brief description about the measurement of displacement, vibration, frequency, pressure, temperature and humidity by electromechanical transducers

LIST OF PRACTICALS

- 1. Internal and external measurement with vernier caliper and micrometer.
- 2. Measurement with height gauge and depth gauge.
- 3. Measurement of flatness with dial indicator.
- 4. Measurement with combination set and bevel protector.
- 5. Study and use of slip gauges.
- 6. Measurement of gear characteristics
- 7. Measurement of angle with sine bar and slip gauges
- 8. Measurement of worn out IC engine piston clearance between cylinder and piston.
- 9. Measurement of flatness using comparator.
- 10. Determination of temperature by (i) pyrometer (ii) thermocouple.
- 11. Use of feeler gauge, wire gauge, radius gauge and fillet gauges for checking of standard parameters.
- 12. Measurement of surface roughness of a surface

INSTRUCTIONAL STRATEGY

- 1. Demonstrate use of various measuring instruments while imparting theoretical instructions.

2. Stress should be laid on correct use of various instruments.

RECOMMENDED BOOKS

1. Engineering Metrology by RK Jain; Khanna Publishers, New Delhi.
2. A Text Book of Production Engineering by PC Sharma; S Chand and Company, New Delhi.
3. Metrology Laboratory Manual by M Adithan and R Bahl; NITTTR, Chandigarh.
4. Engineering Metrology by RK Rajput; SK Kataria and Sons, Ludhiana.

SUGGESTED DISTRIBUTION OF MARKS

Topic No.	Time Allotted (Hrs)	Marks Allotted (%)
1.	4	10
2.	8	18
3.	7	14
4.	6	12
5.	6	12
6.	6	12
7.	5	10
8.	6	12
Total	48	100

PRODUCTION TECHNOLOGY- I

L T P
3 - 6

RATIONALE

This subject provides knowledge and develops skills on various machine operations viz capstan and turret Lathe, milling, grinding, gear manufacturing, broaching and automatic machines which is very essential for Mechanical diploma holders to work in manufacturing industries

DETAILED CONTENTS

1. Capstan and Turret Lathe

- 1.1 Concept of capstan and turret lathe
- 1.2 Principal parts of capstan and turret lathe
- 1.3 Turret indexing mechanism, Bar feeding mechanism
- 1.4 Work holding devices – Jaw and collet chucks
- 1.5 Tool holding devices – Slide tool holder, Knee tool holder, knurling tool holder, recessing tool holder, form tool holder, tap and die holder, V-steady box tool holder, roller steady, box tool holder, bar stops.
- 1.6 Introduction to turret tooling layout
- 1.7 Comparison of capstan, turret and conventional lathe.

2. Milling

- 2.1 Specification and working principle of milling machine
- 2.2 Classification, brief description and applications of milling machines
- 2.3 Details of column and knee type milling machine
- 2.4 Milling machine accessories and attachment – Arbors, adaptors, collets, vices, circular table, indexing head and tail stock, vertical milling attachment, spiral milling attachment, slotting attachment and rack milling attachment.
- 2.5 Milling methods - up milling and down milling
- 2.6 Identification of different milling cutters and work mandrels
- 2.7 Work holding devices
- 2.8 Milling operations – face milling, angular milling, form milling, straddle milling and gang milling.
- 2.9 Cutting speed and feed, simple numerical problems.
- 2.10 Indexing on dividing heads, plain and universal dividing heads.

3. Grinding

- 3.1 Purpose of grinding
- 3.2 Various elements of grinding wheel – Abrasive, Grade, structure, Bond
- 3.3 Common wheel shapes and types of wheel – built up wheels, mounted wheels and diamond wheels. Specification of grinding wheels as per BIS.

- 3.4 Truing, dressing, balancing and mounting of wheel.
- 3.5 Grinding methods – Surface grinding, cylindrical grinding and centreless grinding.
- 3.6 Grinding machine – Cylindrical grinder, surface grinder, internal grinder, centreless grinder, tool and cutter grinder.
- 3.7 Selection of grinding wheel

4. Gear Manufacturing Processes

- 4.1 Gear hobbing
- 4.2 Gear shaping

5. Broaching

- 5.1 Introduction
- 5.2 Types of broaching machines – Single ram and duplex ram horizontal type, vertical type pull up, pull down, push down.
- 5.3 Elements of broach tool, broach teeth details – nomenclature, types, tool material.

PRACTICAL EXERCISES

- 1. Exercise on Turrent/ Capstan Lathe to prepare a job of given dimensions
- 2. To produce a rectangular block by face milling and prepare a slot on one face.
- 3. Exercise on milling- slab milling, Gang milling and straddle milling
- 4. To produce a gear by indexing device on a milling machine
- 5. Preparing job on following machines:-
 - a) Surface grinder
 - b) Cylindrical grinder
- 6. Exercise on tool and cutter Grinder
 - a) To grind Lathe tools
 - b) To grind a drill bit
 - c) To grind a milling cutter

INSTRUCTIONAL STRATEGY

- 1. Teaches should lay special emphasis in making the students conversant with concept, principle, procedure and practices related to various manufacturing processes
- 2. Focus should be laid on preparing jobs using various machines/ equipment in the workshop
- 3. Aids/ Video films should be used to show operations

RECOMMENDED BOOKS

1. Manufacturing technology by Rao; Tata McGraw hill Publishers, New Delhi
2. Manufacturing technology by M. Adithan and AB. Gupta; New Age International (P) Ltd, New Delhi
3. Workshop Technology vol I, II, III by Champman; Standard publishers Distributors
4. Practical hand book for Mechanical Engineers by AB Gupta; Galgotia publications, New Delhi
5. Production technology by HMT, Tata McGraw Publishers; New Delhi
6. Principle of metal cutting by Bhattacharya, Standard publishers Distributors, New Delhi
7. Fundamentals of metal cutting and machine tools by Juneja and Sekhon; Wiley Eastern Ltd., New Delhi

SUGGESTED DISTRIBUTION OF MARKS

Topic No.	Time Allotted (Hrs)	Marks Allotted (%)
1.	12	28
2.	12	28
3.	8	12
4.	10	20
5.	6	12
Total	48	100

COMPUTER AIDED DRAFTING

L T P
- - 6

1. Introduction to AutoCAD commands

- 1.1 Concept of AutoCAD, Tool bars in Auto CAD, coordinate system, snap, grid, and ortho mode
- 1.2 Drawing commands – point, line, arc, circle, ellipse,
- 1.3 Editing commands – scale, erase, copy, stretch, lengthen and explode.
- 1.4 Dimensioning and placing text in drawing area
- 1.5 Sectioning and hatching
- 1.6 Inquiry for different parameters of drawing entity

2. Assembly and detail drawings of the following using AUTOCAD (9 sheets)

- 2.1 Tool post
- 2.2 Tail stock
- 2.3 Screw jack
- 2.4 Safety valve
- 2.5 Stuffing Box
- 2.6 Bench vice

3. Isometric Drawings by CAD

Drawings of following on computer:

- Cone
- Cylinder
- Isometric view of objects

4. 3D Modelling

3D modelling, Transformations, scaling, rotation, translation

INSTRUCTIONAL STRATEGY

1. Teachers should show model or realia of the component/part whose drawing is to be made.
2. Emphasis should be given on cleanliness, dimensioning, layout of sheet.
3. Teachers should ensure use of IS codes related to drawing.

RECOMMENDED BOOKS

1. AutoCAD 2000 for you by Umesh Shettigar and Abdul Khader; Janatha Publishers, Udupi.
2. Machine Drawing by P.S. Gill; Kataria and Sons, Ludhiana.
3. A Text book of Machine Drawing by R.K. Dhawan , S.Chand and Company Ltd., New Delhi.
4. Engineering Drawing with AutoCAD 2000 by T. Jeyapooran; Vikas Publishing House, Delhi.
5. AutoCAD for Engineering Drawing Made Easy by P. Nageswara Rao; Tata McGraw Hill, New Delhi.

MACHINE DESIGN

L T P
4 - -

RATIONALE

The contents of this subject are organised to understand the intricacies of different engineering design aspects. This will also help the students to enhance their imagination, innovative skill, adaptability to new situation and continued learning skills for problem solving.

DETAILED CONTENTS

1. Introduction

- 1.1 Design – Definition, Type of design, necessity of design
 - 1.1.1 Comparison of designed and undesigned work
 - 1.1.2 Design procedure
 - 1.1.3 Practical examples related with design procedure
 - 1.1.4 Characteristics of a good designer
 - 1.1.5 Characteristics of environment required for a designer
- 1.2 Design terminology: stress, strain, factor of safety, factors affecting factor of safety, stress concentration, methods to reduce stress concentration, fatigue, endurance limit. General design considerations
- 1.3 Engineering materials and their mechanical properties :
 - 1.3.1 Properties of engineering materials: elasticity, plasticity, malleability, ductility, toughness, hardness and resilience. Fatigue, creep, tenacity, strength
 - 1.3.2 Selection of materials, criterion of material selection

2. Design Failure

- 2.1 Various design failures
 - Maximum principal stress theory.
 - Maximum shear stress theory
 - Maximum strain theory
- 2.2 Design for tensile, compressive and torsional loading
- 2.3 Design for combined torsion and bending

3. Design of Shaft

- 3.1 Type of shaft, shaft materials, Type of loading on shaft, standard sizes of shaft available
- 3.2 Shaft subjected to torsion only, determination of shaft diameter on the basis of :
 - Strength criterion
 - Rigidity criterion
- 3.3 Shaft subjected to bending
- 3.4 Shaft subjected to combined torsion and bending

4. Design of Key

- 4.1 Types of key, materials of key, functions of key
- 4.2 Failure of key (by Shearing and Crushing).
- 4.3 Design of key (Determination of key dimension)
- 4.4 Effect of keyway on shaft strength. (Figures and problems).

5. Design of Joints

Types of joints - Temporary and Permanent, utility of joints

5.1 Temporary Joint:

- 5.1.1 Knuckle Joints – Different parts of the joint, material used for the joint, type of knuckle Joint, design of the knuckle joint. (Figures and problems).
- 5.1.2 Cotter Joint – Different parts of the joint, type of cotter joint – spigot and socket joint, gib and cotter joint, sleeve and cotter joint, Design of cotter joint (Figures and problems).

5.2 Permanent Joint:

Welding symbols, standards and materials having high weldability.

- 5.2.1 Welded Joint - Type of welded joint, strength of parallel and transverse fillet welds.
- 5.2.2 Strength of combined parallel and transverse weld.
- 5.2.3 Axially loaded welded joints.
- 5.2.4 Riveted Joints. : Rivet materials, Rivet heads, leak proofing of riveted joint – caulking and fullering.
- 5.2.5 Different modes of rivet joint failure.
- 5.2.6 Design of riveted joint – Lap and butt, single and multi riveted joint, Diamond (Lozenzo) joint, circumferential and longitudinal boiler joints

6. Design of Flange Coupling

Necessity of a coupling, advantages of a coupling, types of couplings, design of flange coupling. (both protected type and unprotected type).

7. Design of Pulley

- 7.1 Types of pulley, crowning of pulley, pulley materials, components of a pulley.
- 7.2 Determination of pulley dimensions (Figures and problems).

8. Design of Screw, Nut, Bolt and Thread

- 8.1 Form of thread (ISO), Type of nut heads, type of threads and their nomenclature.
- 8.2 Nature of loads on nut and bolts, types of failure of nut and bolts.
- 8.3. Initial stresses due to screwing up, stresses due to combination of different loads.

INSTRUCTIONAL STRATEGY

- 1. Use models of machine parts/components.
- 2. Presentation should be arranged for various topics.

REFERENCE BOOKS

- 1. Machine Design by R.S. Khurmi and JK Gupta; Eurasia Publishing House (Pvt.) Limited, New Delhi.
- 2. Machine Design by V.B.Bhandari; Tata McGraw Hill, New Delhi.
- 3. Machine design by R.A Agarwal; Nav Bharat parkashan, Meerut.
- 4. Machine Design by Sharma and Agrawal; Katson Publishing House, Ludhiana.
- 5. Machine design by J.K. Kapoor, B. Bharat Parkashan, Meerut.

SUGGESTED DISTRIBUTION OF MARKS

<u>Topic No.</u>	<u>Time Allotted (Hrs)</u>	<u>Marks Allotted (%)</u>
1.	6	10
2.	3	5
3.	14	22
4.	4	6
5.	20	30
6.	6	10
7.	3	5
8.	8	12
Total	64	100

CNC MACHINES AND AUTOMATION

L T P
3 - 4

RATIONALE

Students are required to supervise and handle specialized machines and equipments like CNC machines. This subject aims at development of knowledge and skill about CNC machines tools, equipment and use of high tech. machines

DETAILED CONTENTS

1. Automation

- 1.1 Definition
- 1.2 Types of Automation
- 1.3 Need of Automation
- 1.4 Advantages of Automation

2. Introduction to Numerical Control

Computer applications in manufacturing, basic concepts of NC, CNC, DNC and adaptive control, advantages and application of CNC machines in industry

3. Components of CNC System

Machine control unit, NC control and PLC control system, introduction to C axis and special constructional requirements of CNC machines, machine bed, slide ways, bolt, screw and nut assembly, lubrication and cooling system, spindle and spindle motors, axis drive motors, automatic tool changers, multiple pallets, swarf removal mechanisms and safety provision

4. Part Programming

Part programming and basic concepts of part programming, NC words, part programming formats, simple programming for rotational components, part programming using canned cycles, subroutines and do loops, tool off sets, cutter radius compensation and wear compensation

5. Common Problems in CNC Machines

Common problems in mechanical, electrical, pneumatic, electronic and PC components of CNC machines, diagnostic study of common problems and remedies, use of on-time fault finding diagnosis tools in CNC machines

6. Other Automation Equipment

CNC turning centres, CNC vertical and horizontal machining centre, CAM,

introduction to flexible manufacturing system (FMS) and robotics

LIST OF PRACTICALS

1. Study the constructional details of CNC lathe.
2. Study the constructional details and working of following:-
 - Automatic tool changer and tool setter
 - Multiple pallets
 - Swarf removal system
 - Safety devices
3. Develop a part programme for following lathe operations:
 - Plain turning and facing operations
 - Taper turning operations (internal and external)
 - Thread cutting operations (internal and external)
4. Preparation of preventive maintenance schedule for CNC machine.

INSTRUCTIONAL STRATEGY

This is a highly practice-based course. Efforts should be made to develop programming skills amongst the students. During practice work, it should be ensured that students get opportunity to individually perform practical tasks.

RECOMMENDED BOOKS

1. CNC Machines –Programming and Applications by M Adithan and BS Pabla, New Age International (P) Ltd., Delhi.
2. Computer Aided Manufacturing by Rao, Kundra and Tiwari; Tata McGraw Hill, New Delhi.
3. Numerical Control of Machines Tools by Yorem Korem and IB Uri, Khanna Publishers, New Delhi.

SUGGESTED DISTRIBUTION OF MARKS

Topic No.	Time Allotted (Hrs)	Marks Allotted (%)
1.	4	8
2.	6	14
3.	10	20
4.	16	30
5.	6	14
6.	6	14
Total	48	100

GENERIC SKILL DEVELOPMENT CAMP – I

As per general feedback received from the employers regarding Technician Engineers during formal interactions, the pass outs of polytechnics are labeled of falling short of employable skills which comprises of Communication, inter-personal relationship, leadership qualities, team work, problem solving, managing task, managing self etc. in addition to technical knowledge and skills. We have, therefore, added papers such as English and Communication Skills and Entrepreneurship Development and Management in the curriculum in addition to proposed camps of 3-4 days to be conducted in polytechnics on common and vital issues e.g. Environmental Awareness, Entrepreneurship Development and Generic Skill Development.

It is proposed that a camp of 3-4 days duration on Generic Skills Development (GSD) during 5th semester be organized by arranging expert lectures/discussion sessions either by polytechnic teachers or by eminent educationists from the neighborhood to deal with the following topics. Few students may also be encouraged to prepare on some of these topics and make presentation during the camp. Expert lectures must be followed by distribution of relevant handouts for further study. The attendance of students should be compulsory and marks be awarded under provision of Student Centred Activities.

It is envisaged that such camps will bring in a significant improvement in confidence level and personality of the pass outs from polytechnics.

Suggested list of topics for arranging lectures/discussion sessions:

1. Independent Study Technique
 - 1.1 Information search, information extraction, storage and retrieval
 - 1.2 Reading skills
 - 1.3 Life long learning
 - 1.4 Continuing education
2.
 - 2.1 Introduction
 - 2.2 Time Management
 - 2.3 Stress and emotions
 - 2.4 Health and hygiene
3. Task Management
 - 3.1 Task planning and organizing
 - 3.2 Task execution
 - 3.3 Task evaluation
 - 3.4 Event management
4. Action Research
 - 4.1 Importance and Scope
 - 4.2 Steps in action research
 - 4.3 Analysis of data
 - 4.4 Conclusions and report writing