

# MATHEMATICS EDUCATION IN VOCATIONAL AND INDUSTRIAL TRAINING

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## Introduction

- 1 The general objective of education and training is to prepare a child to take care of himself in later life through continuous learning and adaptation to the needs of the community. He would have inculcated a discipline of the mind, desirable habits, mental and emotional maturity and well balanced personality. He would also be trained to be an employed adult to contribute to the national development of the country.
- 2 The basic knowledge on which future learning and training of skills can take place is the mastering of the three Rs, i.e. reading, writing and arithmetic.
- 3 Many pupils have difficulties in mastering mathematics. Very often there is an over-emphasis in computation. Pupils learn to do mathematics mechanically without understanding the purpose and the application of mathematics in everyday life and for the job. Abstract examples are used rather than concrete ones. Teachers in a hurry to complete the syllabus and to prepare the pupils for the final examination often take the fun out of learning mathematics. Those who are unable to cope with the speed in which the subject is being treated eventually lose confidence. They develop a dislike for the subject.
- 4 There is not enough time for them to discover mathematical patterns, their relations in real life experiences, the understanding of space and number, measurement, mechanical devices and their natural forms. Thus learning often takes on a passive or receptive mode and it generates into merely acquiring information through rote learning. Many resort to learn the logical derivation and analysis of mathematical formulae by heart. Thus they miss the opportunity to develop their minds to think mathematically and to use them to solve problems.

## Mathematical Courses at VITB

- 5 Mathematics is an essential subject in most of the trade courses offered by the VITB. The ability to perform mathematical calculation is a pre-requisite to engineering training. Therefore mathematics is taught in almost all the trade courses offered by the VITB. VITB offers four levels of mathematics courses for engineering trades. They are:
  - 5.1 Foundation Mathematics for Workers
  - 5.2 Engineering Mathematics for Basic Engineering
  - 5.3 Mathematics for Trade Courses

## 5.4 Technical Mathematics for Industrial Technician Certificate Courses

For commercial training we have Commercial Arithmetic for trainees attending the Clerical Practice Course.

### Foundation Mathematics for Workers

- 6 This course is designed for workers in industries who have not completed their primary school education. In the annual Labour Force Survey conducted by the Ministry of Labour in 1979, it is found that about 59% of our workers above the age of 15 have not completed their primary education. In view of the new economic policy necessitating the restructuring of the industries, upgrading of technology and the introduction of more high value added industries, there is a need to provide upgrading and retraining of industrial workers. Since substantial numbers of the existing workers do not have a complete primary education, this will hinder the skill development of these workers. In order to prepare these workers to enter our skill development courses in the evenings under the continuing education programme, it is therefore necessary to introduce a foundation programme in English and Mathematics to bring them up to the level where they can have the language and mathematical ability to follow the skill development courses. The programme also prepares them to proceed to secondary education through evening classes under the continuing education programme.

### Course Structure

- 7 The mathematical programme in the foundation course is divided into four modules. Each module has a total of 60 training hours. Workers entering this programme have a choice to complete one module within 10 weeks on six-hour per week or 20 weeks on a three-hour per week. Workers can also select the appropriate module to suit their level. On entering the programme, workers are given a pre-test to enable them to gauge their level and to assist them in selecting the module to suit their level. For a beginner, he would have to complete all the four modules. If he attends two sessions a week, i.e. three hours per week, it takes him two years to complete the four modules. However, he has the choice to shorten the duration to one year if he attends four sessions a week, i.e. six hours per week.

### Course Content

- 8 The training objectives of the four modules are as follows:

#### *Module*

#### *Training Objectives*

Able to apply the four basic arithmetic operations using whole numbers, common fractions and decimals.

- 2 Able to solve simple arithmetical problems involving units of measurement, comparisons, averages, percentages and scale drawings.
- 3 Able to calculate perimeters, areas and volumes of regular objects and shapes commonly encountered in the workplace.

### Teaching System and Methods

- 9 The objectives of each module are specified in behavioural terms. Each module has 24 objectives which are known as module objectives. Each module objective constitutes a lesson. The module objectives are further broken down into specific objectives which are known as lesson objectives. Each module objective has 6 to 10 lesson objectives. An example of module objective and lesson objectives is as follows:

#### *Module Objective*

Trainees should be able to:

Construct lines, angles, triangles and tangents using a ruler and a pair of compasses.

#### *Lesson Objectives*

Trainees should be able to:

- . Draw a perpendicular line from any point to a given line using a ruler and a pair of compasses.
- . Bisect a given line using a ruler and a pair of compasses.
- . Construct any given angle using a ruler and a pair of compasses.
- . Bisect any given angle using a ruler and a pair of compasses.
- . Construct a triangle given two of the angles and the length of one side, using a ruler and a pair of compasses.
- . Construct a tangent to a given point on a circle using a ruler and a pair of compasses.

- 10 For each lesson objective, exercises are developed for the trainees to work on. As far as possible, trainees are given meaningful exercises which are compiled into a work-book. Trainees are required to purchase a copy and work through them during the course.

### Teaching Staff

- 11 The course is highly structured and purposeful. Trainees are guided to reach the objectives as set out in the lesson. As the mathematical content is basic, no specialist instructors in mathematics are required to teach these modules.

Instructors should preferably be those who have knowledge of the engineering trades so that they can relate the application of mathematics to engineering problems.

- 12 These modules were first offered in July 1980. A total of 140 trainees enrolled for the courses. The class size is between 20 to 35. More publicity is required to encourage workers to attend these modules so that they are adequately prepared for retraining and upgrading in the skill development courses.

### Engineering Mathematics for Basic Engineering Course

- 13 Pupils in secondary schools, who are less academically inclined, choose to take up a trade course before completing their secondary education. Most of them choose engineering trades. VITB offers a range of engineering trades such as :

- 13.1 Air-conditioning & Refrigeration Mechanics
- 13.2 Arc Welding
- 13.3 Boiler/Pipe Fitting
- 13.4 Building Drafting
- 13.5 Electrical Fitting & Installation
- 13.6 Electronics Servicing
- 13.7 Heavy Duty Diesel Mechanics
- 13.8 Hull Fabrication
- 13.9 Maintenance Fitting
- 13.10 Marine Fitting
- 13.11 Metal Machining
- 13.12 Motor Vehicle Mechanics
- 13.13 Plumbing/Pipe Fitting
- 13.14 Sheetmetal Fabrication

These courses lead to the award of the National Trade Certificate Grade 3.

- 14 For pupils who complete Secondary III and IV in the schools they will enter into the one year trade courses. For those who complete Secondary I and II, they are required to do the same course in two years. Since January 1980 the two year trade courses have been restructured into two components. The first year engineering trade trainees study a common Basic Engineering Course. The curriculum for the course is as follows:

	<i>Hrs/wk</i>	<i>Hrs/Yr</i>
Bench Fitting	12	504
Sheetmetal Fabrication	06	252

	<i>Hrs/Wk</i>	<i>Hrs/Yr</i>
Electrical Fitting	04	168
Arc Welding	02	084
Gas Welding	02	084
Engineering Drawing	04	168
Engineering Mathematics	04	168
Related Studies (English, Industrial Safety & Attitudinal Training)	06	252
	40	1680

### Course Curriculum For Engineering Mathematics

15 The Engineering Mathematics module covers all the fundamental aspects of applied workshop calculations that a trainee requires in order to pursue a NTC-3 trade course. The topics covered include the following: whole numbers, fractions, decimals, other arithmetic operations, metric units of measurement, algebra, mensuration, geometry and trigonometry, use of calculators.

16 The content is specified in objective form as follows:

*Instruct-  
ional Hrs*

#### *A Whole Numbers*

- Write any whole number up to one million. 1
- Perform addition and subtraction of whole numbers up to one million. 5
- Perform multiplication and division of whole numbers up to three-digit multiplier and three-digit divisor. 8

#### *B Fractions*

- Perform addition and subtraction of fractions commonly used in the workshop. 4
- Compute multiplication and division of fractions commonly used in the workshop. 4

<i>C Decimals</i>	<i>Instruct- ional Hrs</i>
Compute workshop measurements of decimal numbers using addition and subtraction process.	4
Solve workshop problems involving multiplication and division of decimal numbers.	10
Convert fractions to decimal numbers and vice versa.	2
Round off a decimal number to a specified number of decimal places or given number of significant figures in workshop calculations.	2
 <i>D Other Arithmetic Operations</i>	
Use charts to obtain the required data.	2
Solve workshop calculations involving percentages.	4
Determine the average value from a given set of data collected from workshop projects, experiments and samples.	4
Determine the ratio of two or more quantities relating to Workshop Practice.	4
Calculate the unknown value of a variable using direct proportion or indirect (inverse) proportion.	6
Find the square and square roots of small numbers commonly used in Workshop Practice.	4
Perform addition, subtraction, multiplication and division of positive and negative numbers	4
Obtain the relevant information or data from graphs used in the workshop.	8
 <i>E Metric Units of Measurement</i>	
Use the metric units of measurements for length, weight and capacity used in the workshop.	8
 <i>F Algebra</i>	
Solve simple algebraic problems involving addition and subtraction.	4
Solve simple workshop problems using algebraic expression or terms involving multiplication and division.	6

Express workshop problems in algebraic equations. 4

Solve linear equations used in the workshop. 6

*G Mensuration*

Determine the area of regular shapes such as square, rectangle, triangle, parallelogram and trapezoid. 4

Determine the area and circumference of circular objects. 6

Determine the surface area and volume of regular solids found in the workshop. 6

Determine the mass, density and volume of the common types of engineering materials. 4

*H Geometry & Trigonometry*

Determine the angles of common workshop components. 4

Determine the required dimension of a component using Pythagoras Theorem. 6

Determine the unknown dimension of a workshop component using the trigonometrical ratios of a right angled triangle. 8

Determine the dimension of given workshop component using sine rule and cosine rule. 8

*I Use of Calculators*

Use calculator to solve problems listed in sections A to H. 10

17 Each of the above objectives forms a lesson. They are then further broken down to specific objectives. Trainees are required to reach all the objectives as specified in each lesson. For example, the objective: "Determine the area and circumference of circular objects" can be broken down into the following specific objectives.

- Estimate the area of a circle as a little more than three times the square of its radius.

- Express the area of a circle in terms of pi ( $\pi$ ) and radius (r).

- Find the area of a circle when the radius (r) or diameter (d) is given using the formula  $A = \pi r^2$  or  $A = \frac{\pi d^2}{4}$

- Find the radius of the circle when the area is given.
- Estimate that the circumference is approximately three times the diameter of the circle.
- Express the circumference of the circle in terms of pi ( $\pi$ ) and radius ( $r$ ).
- Find either the radius ( $r$ ) or circumference ( $c$ ) if either the circumference or radius is given using the formula  $c = 2 \pi r$ .
- Apply the formulae  $A = \pi r^2$ , and  $C = 2 \pi r$ , in solving workshop problems.

18 As in the Foundation Mathematics Course for Workers, trainees going through the Engineering Mathematics modules are closely guided through the use of work-book. A sample lesson of the work-book is as follows:

#### Information

*Rule:* The area of a circle is equal to the product of pi ( $\pi$ ) and the radius squared, or the product of  $\pi/4$  and the diameter squared.

*Formula:*  $A = \pi r^2$  or  $A = \frac{\pi d^2}{4}$

*Symbols:*  $A =$  Area  
 $r =$  radius  
 $d =$  diameter  
 $\pi = 3.14$  or  $\frac{22}{7}$

*Example:* Find the area of a circle whose diameter is 20 millimetres (mm) (use  $\pi = 3.14$ ).

*Formula:* Area ( $A$ ) =  $\frac{d^2}{4}$

*Substitution:*  $A = \frac{3.14 \times 20^2}{4}$

*Evaluation:*  $A = \frac{3.14 \times 20 \times 20}{4}$

$A = 314 \text{ sq. mm}$

- II Rule: The circumference of a circle is found by multiplying the diameter by pi.  
 (The value of pi ( $\pi$ ) is  $\frac{22}{7}$ )

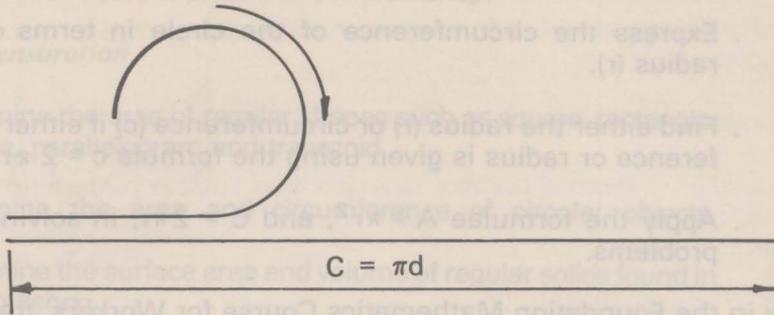


Figure 1

*Formula:*  $C = \pi d$  or  $C = 2\pi r$

*Symbols:*

- $C$  = Circumference
- $\pi = 3.14$  (approximate) or  $\frac{22}{7}$
- $d$  = diameter
- $r$  = radius

*Example:* If the diameter of a circle is 5.75 mm, find the circumference to the nearest whole number. (Take  $\pi$  as 3.14)

*Formula:*  $C = \pi d$

*Evaluation:*  $C = 3.14 \times 5.75$   
 $= 18.0550$

Thus, the circumference of the circle is 18 mm

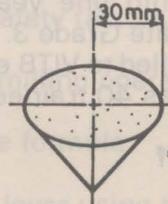
## Applications

- I Calculate the area of the shaded end of the cylindrical tank in Figure 2.



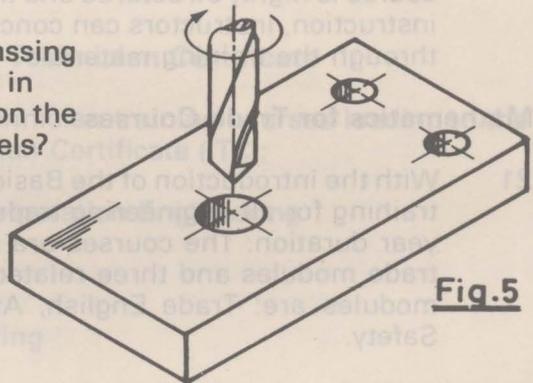
**Fig.2**

- II Calculate the area and circumference of the base end of the cone in Figure 3.



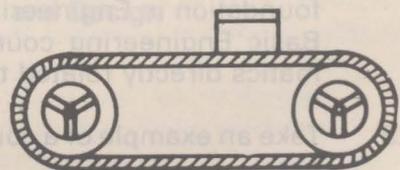
**Fig.3**

- III Figure 4 shows a conveyor belt passing over 2 wheels, each 300mm in diameter. How far will an object on the belt travel in 3 turns of the wheels?



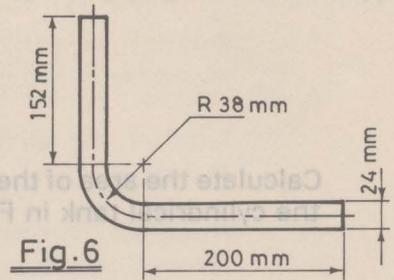
**Fig.5**

- IV In Figure 5, calculate the area and circumference of the hole produced by a drill of 14 mm in diameter.



**Fig.4**

- V Find the length of the material required as shown in Figure 6.



- 19 Basic Engineering Course is designed to prepare Secondary I and II pupils to go into one year of trade courses leading to the National trade Certificate Grade 3. About 3,000 to 4,000 Secondary I and II pupils are channelled to VITB each year to be trained in the respective trades. Each class has 40 trainees.

#### Teaching Staff

- 20 Instructors teaching the Engineering Mathematics should be familiar with the application of mathematics in the engineering trades. Since the course is highly structured and training materials are developed to guide instruction, instructors can concentrate on helping the trainees to work through the training materials.

#### Mathematics for Trade Courses

- 21 With the introduction of the Basic Engineering Course as the first year of training for all engineering trade trainees the trade courses are of one year duration. The courses are modularised. There are generally four trade modules and three related studies modules. The related studies modules are: Trade English, Attitudinal Development and Industrial Safety.
- 22 At trade course level mathematics is not taught as a separate subject or module. Mathematics is integrated into the trade modules. With the foundation in Engineering Mathematics acquired in the first year of the Basic Engineering course, trainees in the second year learn mathematics directly related to the trade training as and when required.
- 23 Take an example of a course in Metal Machining. The four trade modules are:

Milling I  
Grinding I  
Turning I  
Turning II

- 24 Each module contains all the knowledge and skills required to perform the job. They are all integrated into a self-contained package so that trade theory including mathematics, drawing and other related knowledge are taught to enable the trainees to perform the job to the required standard, understand the engineering problems and take all safety precautions and measures.
- 25 Some examples of application of mathematics in the trades are as follows:
- . Calculate the machine spindle speeds in revolutions per minute.
  - . Calculate gear specifications given the formulae.
  - . Determine the cooling load requirements of a specified space given the appropriate formulae and safety factors.
  - . Calculate the feed per revolution for milling operations.
  - . Determine the heat transfer given the formula.
  - . Calculate the effort/load applied to a lever using the Principle of Moments.

### **Technical Mathematics for Industrial Technician Certificate**

- 26 VITB conducts the following technician training courses leading to the award of the Industrial Technician Certificate (ITC):
- 26.1 Air-conditioning and Refrigeration Engineering
  - 26.2 Automotive Engineering
  - 26.3 Industrial Plant Engineering
  - 26.4 Mechanical Engineering
  - 26.5 Mechanical Engineering Drawing and Design
  - 26.6 Electrical Engineering
  - 26.7 Electronics Engineering
- 27 As mathematics is the basic tool in engineering, it is taught as a subject in all these courses. Basically the seven ITC courses can be classified into two broad disciplines, i.e. Mechanical and Electrical & Electronics. Therefore, the curriculum for mathematics is designed to meet the requirements for Mechanical

courses and Electrical & Electronics courses.

- 28 ITC trainees attend a 35-hour per week curriculum. The duration of the course is two years making a total of 2,940 training hours. Technical Mathematics is taught in the first year. The curriculum for Technical Mathematics has a total of 126 training hours.
- 29 The objective of conducting Technical Mathematics in the first year of the two-year ITC course is to provide trainees the analytical and practical approach in applying mathematical principles and concepts to solving engineering problems.
- 30 The content of Technical Mathematics is based on the mathematical requirements of all the other engineering subjects. The scope of the content is similar for Mechanical and Electrical & Electronics courses. The difference is in the applications to their respective engineering problems. It can be broadly classified into six areas:

Algebra	– logarithm, equations, binomial expansions, continued fraction, arithmetic and geometric progression.
Statistics	– probabilities, distribution, dispersion, standard deviation, permutation and combination.
Graphs	– algebraic graphs, straight line graphs, logarithmic graphs.
Mensuration	– calculation of area, volume, mass for regular and irregular shapes.
Geometry and Trigonometry	– relationships of lines and angles, geometrical and trigonometrical properties.
Calculus	– differentiation, integration, partial differentiation.

### Teaching Staff for Technical Mathematics

- 31 Technical Mathematics is taught by instructors who are also responsible for teaching other engineering subjects. This is necessary so that the instructors can relate actual application of mathematics to the engineering problems, which the trainees will face in the other engineering subjects. The class is either 28 or 32 depending on workshop facilities. The total number of trainees for this subject is about 2,400.

## Commercial Arithmetic

- 32 Commercial Arithmetic is introduced as one of the modules in the Clerical Practical Course. Pupils who have completed Secondary III can apply for the Clerical Practice Course.
- 33 Pupils with Secondary III education require further consolidation of their arithmetical skills. The Commercial Arithmetic course is aimed at providing these pupils with application of arithmetic normally required of a clerk in performing his/her duties in the office.

## Course Curriculum

- 34 The content of the Commercial Arithmetic course covers the following :
- . Metric System
  - . Approximation and significant figures
  - . Mensuration
  - . Percentages
  - . Simple and compound interests
  - . Simple averages
  - . Weighted averages
  - . Ratios and proportions
  - . Simple transport calculations
  - . Trigonometry
  - . Stocks and shares
  - . Simple business statistics
  - . Statistical charts and diagrams

- 35 VITB has a total enrolment of 510 for Clerical Practice Course. The class size is 30.

## Teaching Staff

- 36 As the arithmetic content is basic and related to commercial practice, training officers teaching the Commercial Arithmetic are also responsible for teaching other commercial subjects.

## Conclusion

- 37 Since April 1979 VITB has embarked on a systematic development of curriculum specifying the training contents into objective form. The training objectives and materials described in this paper provide an insight of the curriculum design and development of the courses. Since this new development has only taken place over the last 18 months the materials are still in the draft form. More work is required to revise and improve on the training objectives and training materials.

38 The objective of mathematical education in the VITB is to enable the trainees to acquire the mathematical skills to help them to master the skills of the trades they have chosen. Thus the curriculum is so designed that the essential mathematical contents necessary for the trades are selected. They are clearly specified so that the instructor will prepare the trainees to reach the required standards. It is not intended that the course should differentiate the mathematical abilities between trainees or to set the standards as high as possible. It is expected that trainees who reach the required standards should have adequate mathematical skills to do their jobs in industry.

30 The content of Technical Mathematics is based on the mathematical requirements of the Commercial Arithmetic course covers the following:

- Algebra
  - Measurement
  - Formulas
  - Simple and compound interest
- Statistics
  - Simple averages
  - Weighted averages
  - Ratios and proportions
- Graphs
  - Simple interest calculations
  - Trigonometry
  - Stocks and shares
- Measurement
  - Simple business statistics
  - Statistical charts and diagrams

VITB has a total enrolment of 810 for Commercial Practice Course. The class size is 30.

**Teaching Staff**

38 As the arithmetic content is basic and related to commercial practice training officers teaching the Commercial Arithmetic are also responsible for teaching other commercial subjects.

31 Conclusion  
 Since April 1978 VITB has embarked on a systematic development of curriculum specifying the training content into objectives. The training objectives and materials described in this paper provide an insight of the curriculum design and development of the course. Since this new development has only taken place over the last 18 months the materials are still in the draft form. More work is required to revise and improve on the training objectives and training materials.