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Naval architecture as a subject for the proposed marine engineering course at the University of Moratuwa

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NAVAL ARCHITECTURE AS A SUBJECT FOR THE PROPOSED MARINE ENGINEERING DEGREE COURSE AT THE UNIVERSITY OF MORATUWA

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SRI LANKA

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The contents of this paper refelect my own personal views and are not necessarily endorsed by the university.

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ABSTRACT

The marine engineer who is concerned with the design or operation of machinery in ships requires some knowledge of certain aspects of naval architecture and it will be found that naval architecture is included in most courses leading to a degree or some other qualification in marine engineering.

The University of Moratuwa, Sri Lanka wishes to establish a degree course in marine engineering and to have it accredited by the Institute of Marine Engineers in the United Kingdom.

It is the feeling of the governing body of the University of Moratuwa to include naval architecture as one of the subjects in the proposed degree course.

The thesis studies the importance of the naval architecture in the proposed marine engineering degree course and its relevance to the maritime industry in Sri Lanka .

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CHAPTER 1

1.1 INTRODUCTION

If you are interested in creative work, and in the possibilities offered by the profession of engineering, you might like to consider working in the marine field, and in naval architecture in particular.

-Professor J B Caldwell

Considerable reductions in manning have been brought about by the reorganizing of shipboard operation, reduced maintenance arising from better design and improved materials, and changes in the 'hotel' arrangements on board ship. Fuel is now the major cost in the shipping operation, with manning cost being second. It is not proposed to consider fuel saving but the changes in manning and their effects will be examined in detail.

The manning of a ships has been considered in three areas; deck, engine, and catering. Any reductions in deck and engine room areas will also result in reduction in the catering staff. The introduction of self serving facilities, micro wave cooking of aeroplane type frozen meals, and similar innovation could significantly reduce or eliminate the catering department, which will not be considered further.

The deck and engine departments continue to be viewed by many as separate entities, with deck officers and engineers seemingly evolved from different species of human beings. The training scheme for each are vastly different; deck officer cadets learn something about enginering, while engineer cadets learn nothing about navigation, seamanship, or cargo work. It is nevertheless a fact that both deck and engineer officers are becoming increasingly reliant upon machines to do their work.

Does their basic training need to be much different? Specialization could occur much later in the career and dual-licensing could be practiced at least up to second engineer and second officer level. These are not new ideas. They have been tried and once again being considered and implemented. Dual licensed offers have reduced the manning of a ship to about 14. Some obstacles to further development are statutary requirements, concern about safety, the reliability of equipment and the changes needed in the education and training organisation.

The government of Sri Lanka has given a high priority for the general education and in particular for the higher education by allocating a significant budget. With the assistant of International Maritime Organisation (IMO), the Ministry of Shipping and Trading of Sri Lanka has already secured a project at the University of Moratuwa for deck and engineer officer training courses at diploma level. In addition, the university has initiated an individual plan for a marine engineering degree course, which is secheduled to commence on January 1990.

The purpose of this paper is to provide with a feasable study of Naval Architecture, as the one of the subjects in the proposed marine engineering degree course.

CHAPTER 2

2.1 General Education System in Sri Lanka

The youngsters in Sri Lanka begin their education at the age of six in grade one and progress through to grade five in primary schools. All the students are accepted into secondery schools in the sixth grade and progress through to grade ten. The instruction media is either Sinhalese or Tamil according to their domain, family situation and religion. On completion of the academic work in grade ten , the students are prepared for the Sri Lanka Generel Certificate of Education (GCE) Ordinary Level examination.

The sucessful candidates with a minimum of six passes including at least three credits at the GCE (Ordinary Level) examination are permitted further studies in colleges for a period of two years. Followed by that is the island's most compititive, (university entrance) the GCE (Advanced Level) examination.

Annually, there are about 140,000 candidates waiting to sit for the GCE (Advanced Level) examination. The minimum entry requirement for the unversities as stipulated by the University Grant Commission is four passes at the GCE (Advanced Level) examination. Of that, about 5000 students are selected on merit basis or on district basis to pursue studies in the disciplines of; engineering, madicine, accounting, law, art etc. at the follwing universites:

i) University of Peradeniya
ii) University of Colombo
iii) University of Moratuwa
iv) University of Kalaniya
v) University of Sri Jayawardanapura
vi) University of Ruhuna
vii) University of Jaffna
viii) University of Baticalow

Admissions to an university is through fierce competition. At least two A grade and two B grade passes are required at the GCE (Advanced Level) examination to be acceped as an egineering undergraduate or as a medical student.

75 <= Grade A
65 <= Grade B < 75
50 <= Grade C < 65
40 <= Grade S

In addition, the Open University of Sri Lanka offers variety of courses including certain deciplings of engineering. Formal entry qualifications are not required here and the employees of the government and the private sector are encouraged to pursue these courses.

2.2 The University of Moratuwa and Engineer Training

The University of Moratuwa , as it is now known, has its origins in the Ceylon Technical College, Maradana as early as 1893.

The Technician courses conducted at this college were transferred to the newly established Institute of Practical Technology (occuping the the present site of the University of Moratuwa) in 1960. This Institute was found with the aid of the Canadian Government to provide full-time courses for Architects, Junior Technical Officers, Surveyors and Levellers, and Draughtman Apprentices. In addition to these, a number of part-time courses were also provided.

The "Commission of Inquiry on Technical Education" (July 1963) recommended the expansion of facilities for professional engineering education. Since only the Faculty of Engineering of the University of Ceylon, Peradeniya provided such courses at the time, it was decided to establish the Ceylon College of Technology at Katubedda utilising the resourses of the Institute of Practical Technology. Assistance for this project was provided by the United Nations Development Programme through UNESCO.

Consequently, a new courses at professional level was started at this College of Technology in 1966. The exsisting courses (both full-time and part-time) at former Institute were also continued by the new College. The Engineering degree and Technician programmes were designed to have an industrial bias with the inclusion of a compulsoty period of in-plant training. The University of Ceylon was instituted on the 15th February 1972 by the University of Ceylon Act No. 1 of 1972' in corporating all the exsisting universities in Sri Lanka and the Ceylon College of Technology at Katubedda. The Ceylon College of Technology was named University of Ceylon, Katubedda Campus.

With Ceylon becoming a Republic, later in 1972, the University was redesignated the University of Sri Lanka. The Katubedda Campus of the University of Sri lanka provided undergraduates courses in Engineering, Architecture and Applied Science. Facilities for Post-graduate studies are provided in Town and Country Planning, Engineering, Architecture. In addition, the Campus conducts full-time and part-time courses for middle grade engineering personnel.

Further expansion took place in the 70's and in 1978 the Katubedda Campus became independent as the University of Moratuwa with three faculties:

i) Faculty of Engineering
ii) Faculty of Architecture and Town and Country Planning
iii) Faculty of Physical and Applied Science

2.2.1 Faculty of Engineering

In 1981 the Faculty of Physical and Applied Science merged with the Faculty of Engineering, whose ten departments now offer four years' duration B.Sc engineering degree courses in:

i) Civil Engineering
ii) Electrical Engineering
iii) Electronics and Telecomunication Engineering
iv) Mechanical Engineering
v) Chemical Engineering
vi) Materials and Mining Engineering
vii) Mineral Engineering
viii) Computer Engineering
ix) Textile and Clothing Technology

Admission to the Engineering courses is based on the results of the GCE (Advanced Level) examination, where passes in Chemistry, Physics, Pure Mathematics and Applied Mathematics are required, together with pre-requistes. They are a minimum of **six passes** including at least **three** credit passes, obtained at GCE (Ordinary Level) Examination.

There are only 250 vacancies for engineering undergraduates at the University of Moratuwa each year. Prior to their engineering course, attendance to a three month, orientation programme and an intensive English programme are compulsory to all accepted candidates. All degree courses have a common first year programme and the instruction media is English from the first year for all courses offered by the University of Moratuwa.

The undergraduate courses in Engineering are honours courses. Students are selected for the different fields of specialisation after the first yesr examination. From second year onwards the undergraduates are mainly following lectures in the major streams. They are expected to complete specified number of laboratory classess streamlined with lectures, and to undertake a total of six months in-plant training with local industry. The award of the degree is upon satisfactory completion of all the examinations, a six month in-plant training with the local industry and the final year project, which is also industrially biased.

2.2.2 Engineering Technician Division

The Enginering Technician division is also under the ausipies of the Faculty of Engineering of the University of Moratuwa. It conducts the following courses for the National Diploma in Technology which is in line with the Higher National Diploma (HND) in the UK;

i) Chemical Engineering
ii) Civil Engineering
iii) Electrical Engineering
iv) Electronics and Telecommunication Engineering
v) Mechanical Engineering (both Automobile and Production)
vi) Marine Engineering
vii) Nautical Studies
viii) Polymer Technology
ix) Textile Technology

The entry requirements to the diploma programme is three passes in the GCE (Advanced level) examination and the applicants are required to appear for an entrance examination.

The NDT Course is a three-year full-time course comprsing two years of academic work in the University of Moratuwa and one year inplant training. for middle-grade technical personnel. The National Diploma in Technology certificate is awarded on successful completion of the course. The third year is devoted to in-plant training, in government as well as in private industrial establishments, and is managed by the National Apprentice Board.

2.2.3 The Computer Centre

The University of Moratuwa Computer Certre provides a general computing service to all students irrespective of their courses at any time of the office hours. The centre provides computing facilities for about 100 students at a time on Comorde 64, IBM PC, Radio-shack etc.. And also provides occasional courses in computer appreciation, programming and systems analysis. Further, it extends its service to other universities, and to few organizations.

2.2.4 The University Library

The university library aims to provide reading material on a wide basis as feasible. It contains some 27,000 volumes mainly relating to Science, Technology and Management. In addition, a representative selection of reading material suitable for general education and recreation is also available.

More than 200 periodicals are being currently subscribed to, including major abstracting journels. Books, Periodicals, etc., not available within the university library can be borrowed through the medium of various inter-library loan service; Such as the British library, including its overseas photocopy service.

2.2.5 Training and Employment Centre

The Training and Employment Centre of the University of Moratuwa, is responsible for organisation, supervision and assessment of in-plant training of National Diploma in Technology students and Engineering undergraduates, along with the National Apprentice Board. It also extends it service to find employments, whereever possible.

The training standards for both NDT students and engineering undergraduates are being prepared by committees with representatives from the industry, the NAB and the Ministry of Education. The Institute of Engineers, Sri Lanka gives recognision for the in-plant training provided to engineering undergraduates when they apply for Corporate Membership as part of the employment experience.

2.2.6 The UNDP Project "Merchant Marine Training" SRL/84/039/A/01/19

The University of Moratuwa with the assistance of International Maritime Organisation (IMO) and the Ministry of Trade and Shipping established the above two year project in January, 1987. The primary objective of the project is to establish the merchant marine training facilities in theoretical and practical training for deck officers, and its secondary objective is to upgrade the facilities for the exsisting marine engineering diploma course. The overall aim is to conform the standards of the courses to comply with the International Conventions of Standard Training, Certification and Watch Keeping for Seafarers (STCW 1978), and to improve productivity in national merchant marine sector by providing high quality skilled manpower.

Support is in two parts: US$ 1,040,000 from United Nations Development Programme (UNDP) to provide nautical and marine engineering training advisers, fellowship for the Sri Lankans to study abroad and training equipment for use in the deck officer and marine engineering officer training. The second part is a contribution by the Givernment of Sri Lanka and the University of Rs 14.6 million to provide new buildings, service, consumables, equipment maintanence, operating costs and the supply of technician staff.

2.3 MARINE ENGINEERING EDUCATION AND TRAINING COURSES IN SRI LANKA

The present official training system for seamen in Sri Lanka is under the administration of the National Apprentice Board (NAB) and the University of Moratuwa (UM).

Seamen

Apprentice Courses (NAB) | Diploma Courses (UM)

2.3.1 NAB Apprentice Course

The apprentices are accepted by the NAB in the following two major streams; the craft apprentices are trained as ratings, where as the special apprentices are trained as officers. Other training facilities are provided by some shipping companies for their own purposes and requirements but these are not mainly recognised by the Ministry of Trade and Shipping.

The admission requirements are six passes in General Certificate of Education (GCE) ordinary level examination. These include science, mathematics and Sinhalese language at grade C level or above and English at grade D level or above. Only male Sri Lankan residents are considered.

Grade A >= 75

75 > Grade B >= 65

65 > Grade C >= 50

50 > Grade D >= 35

English is the language used in both training and examination. Since most of the applicants to the marine apprentice course are from general education standards with inadiquate knowledge of English, the students may sometimes encounter difficulties.

The NAB special apprentice course is a four year sandwitch programme. The first two years of it consist of full time attendence at heavy engineering workshops assigned by the NAB. In the third and fourth years the special apprentice have both full time tution, advanced workshop training, and some amount of managerial training. Followed by this is the NAB final examination. Over the four year period, an apprentice must complete a guided study programme and enter the tasks undertaken in a book of the history of employment.

A cadet, after completion of the scheme, may embark upon a career at sea and progress through various levels of Certificate of Competency. This involves periods at sea, periods ashore undertaking perparatory courses, and subsequently end up with at Chief Engineer level.

2.3.2 The Marine Engineering Diploma Course at the University of Moratuwa

The department of Marine Engineering of the University of Moratuwa was found in 1977 to conduct Diploma courses in marine engineering. It is a sub-department of mechanical engineering, and provides most of the nations marine engineers. Candidates from the diploma course receive a diploma in marine engineering and progress their career in a variety of ways.

On completion of the National Diploma in Technology (NDT) course in marine engineering, candidates wishing to go to sea undergo nine months sea training as engineering cadets usually on board vessels owned by the Ceylon Shipping Coporation. Thereafter, they take prescribed courses, accumulate sea experience and progress from Fifth Engineer to Chief Engineer. This sea training programme is recognised by Department of Transport, UK.

Chief Engineer	18 Months
2nd Engineer	18 Months
Sea Training	9 Months
NDT diploma course	3 Years
GCE Advanced level	12 Years
GCE ordinary level	
Primary School	

TYPICAL ROUTE TO CHIEF ENGINEER
WITH THE NDT COURSE

2.4 Mechanical Engineering Degree Course

The undergraduates assigned to the mechanical engineering department on the performance of the first year examination,and they are permitted to pursue in from second year in the major field of mechanical engineering. Thereafter, they are supposed to attend classes according to the cirriculum as in the Appendix i. It is envisaged that from the second year to the forth year the subjects offered are more covergent towards in mechanical engineering.

It is envisaged in appendix i that the mechanical engineering undergraduates are exposed to some amount of managerial experience by taking the subjects in Industrial Economics & Managements, and Industrial Engineering. On choosing the career the graduates have the opportunity of employing not only as Engineers for industries but also as Managers for enterprises, due to the overall background.

Much more emphasis also given tq production engineering and automobile engineering which make our graduate to accept any mechanical engineering position irrespective of the opptional subjects studied in the final year. (Appendix i)

Perhaps one of the most important featers of the courses is the technical visits for about eight to ten local industries in the final year. As part of the curriculum, the students have to undertake a six month of in-plant training with the local industry after completion of their second and third years academic work. The purpose being to provide useful practical training for each individual in order to make sure that the theoretical studies at the university are properly coupled with practical training.

The third term of the fourth year of the course, is mainly devoted to the preparatin of a written report on a selected topic that is also industrialy bias, but interwova with the theoretical knowledge gained over the four years.

CHAPTER 3

3.1 NEEDS OF THE MARITIME EDUCATION IN SRI LANKA

Over the past decade, the government of Sri Lanka has invested heavily in port development, ship building and ship repair facilities. The port of Colombo has become one of the major trans-shipment ports in the region, and the government of Sri Lanka wishes to expand its maritime industry.

A Marine Engineer who complete his recognised pre-sea training either in Sri Lanka or elsewhere embarks upon a career at sea and progress through various level of certificates of competencies. Once holding a class 1 certificate and promoted as a Chief Engineer, this officer will enjoy resonable rewards for his efforts while remain at sea.

If however, a lifetime at sea is not that appealing, the move ashore usually results in a considerable drop in status and renumeration, and possibly even a period of unemployment. The traditional certificate of competency, while important at sea, receive little recognition of its academic and practical contents for the job ashore.

A qualified class 1 certificate holder is trained as a 'ship operator' which ensures his retention within the industry. This has resulted in mariners being ship operators with little knowledge of their industry and overemphasis on skills to the detriment of education in an academic scene.

Because the objective of the ship-officer training in Sri Lanka sea going personnel are train for the shipping companies only. There has been no formal or consistent training course in the shipping business in Sri Lanka since 1977, like charting, broking, insurance etc, which can be provided for the officers who wish to change to ashore job. The effect of the absence of these training courses will be felt in the long term rather than in the short term.

Changes have occured to improve the academic standard of certificates of competency. Much more needs to be done. A highly qualified well trained engineer need not be lost to his industry. He may be lost to the sea but his work in a suitable post ashore will no doubt benefit the industry and probably those at sea. If the career offered more opportunities for transfer ashore with status and appropriate renumeration, then many sea going officers might well remain at sea longer, secure in the knowledge that they can come ashore when circumstances suit them.

The question of professional registration has assumed, and will continue to assume, greater importance since the Finniston inquiry into the engineering profession in 1980. Following Finniston, the engineering council was created, with a charter which empowers it to establish and maintain qualifications appropriate to the three levels of;

i) Chartered Engineer
ii) Technician Engineer
iii) Engineering Technician

For each level, registration depends upon satisfying the appropriate academic requirements, training requirements, and a period of time in a position of responsibility.

On completion of the diploma course at the University of Moratuwa or the apprentice course conducted by the NAB, the engineers hopefully end up as a Chief Engineer with a First Class Certificate of Competency. The Certificate of Competency are not, however, academic qualifications. The academic requirements for chartered status is a degree which has been accredited by an Engineering Institution (acting on the behalf of the Engineering Council). The NAB apprentice course with the certificate of competency, or the NDT course, with or without certificate of competency, is only sufficient for registration at Technician Engineer level. This means that without a degree he cannot register at the full professional level of chartered engineer with a professional institute (in this case the Institute of Marine Engineers) which, quite apart from being the cause of intense frustration, limits his career prospects ashore. It also follows that there are relatively few graduate marine engineers compared with other branches of engineering.

At the same time there has been increased opportunies for seafarers in the ashore side of the industry. Indeed, one result of the technology advanced has been to induce a transfer of jobs from ship to ashore, eg, port control or vessels traffic services. It is true that chief engineer certificates and associated experience have traditionally been the pre-requistes for the many technical positions in the port and marine authorities; but more is now required in the way of specialist knowledge and this is also influencing the direction of maritime education.

3.2 PROPOSED MARINE ENGINEERING DEGREE COURSE

Primary reasons for the establishment of marine engineering undergraduate course is for the supply of highly academically trained personnel to fulfill the needs of the maritime industry as described in chapter 3.1. A mechanical engineering undergraduate will have the option to choose his career as a mechanical or as a marine engineer. On this proposed marine engineering degree course, the governing body of the University of Moratuwa decided to offer only one subject in the third year, and three subjects in the fourth year as optionals (in chapter 3.2.1) within the exsisting mechanical engineering programme, and the curriculum would be kept under review for the needs of the maritime industry.

The aim of the University of Moratuwa is to have accredited the proposed marine engineering degree course by the Institute of Marine Engineers, UK and to cater the highest qualified chartered status engineers to the maritime industry in Sri Lanka.

In the accreditation process the course must be satisfy the following;

- relevant to the needs of industry and contain inputs from it
- be taught with application bias
- be formulated after discussion with industry
- contain element of administration and management practice
- contain element, involving practical experience in the fabrication, properties and use of materials

3.2.1 COURSE STRUCTURE

WEEKLY LOADING HOURS; *An academic year has 35 weeks*

FIRST YEAR

Subject	*Dept*	*Lec*	*Tut*	*Lab*
Mathematics I	MA	2	1	-
Mathematics II	MA	2	1	-
Pysics	EE	3	1	1.5
Engineering Chemistry	CH	3	1	1.5
Building Construction	CE	1	-	2
Surveying	CE	1	-	1.5
Engineering Drawing	ME	1	-	5
Workshop Technology	ME	1	-	4
English	EN	2	-	-

SECOND YEAR (PART I)

Subject	*Dept*	*Lec*	*Tut*	*Lab*
Mathematics	MA	2	1	-
Strength of Materials	CE	2	1	1.5
Fluid Mechanics	CE	2	1	1.5
Theory of Electricity	EE	2	1	1.5
Applied Thermodynamics	ME	2	1	1.5
Engineering Mechanics	ME	2	1	1.5
Production Technology	ME	2	-	1.5
Machine Element and Design	ME	2	-	3

*Key to the department codes are in appendix i

THIRD YEAR (PART II)

Subject	*Dept*	*Lec*	*Tut*	*Lab*
Mathematics	MA	3	1	-
Industrial Economics and Management	ME	2	-	-
Strenth of Materials	CE	2	1	1.5
Fluid Mechanics	CE	2	1	1.5
Applied Thermodynamics	ME	2	0.5	1.5
Electrical Technology	EE	2	0.5	1.5
Machine of Machanics & Control Systems	ME	2	1	1.5
Naval Architecture I and Marine Engineering I	MR	2	1	1.5
Design of Machine Elements	ME	-	-	3

FOURTH YEAR (PART III)

Subjects	*Dept*	*Lec*	*Tut*	*Lab*
Industrial Economics and Management	ME	3	-	-
Industrial Engineering	ME	2	1	-
Marine Structures	MR	2	1	1.5
Naval Architecture II	MR	3	1	-
Marine Engineering II	MR	2	1	3
Project				

and ONE of the following options

Applied Thermodynamics	ME	2	1	3
Fluid and lubrication	ME	2	1	1.5

3.2.2 Justification of the Course

Ships are becoming more automated and computerised. They can not be operated and maintained with untrained personnel without proper understaning of technology. Therefore, It is a timely and far-sighted desicion to establish a marine engineering degree programme at the University of Moratuwa.

Shore based jobs are becomming more available. They have to be employed with personnel with suitable educational and technical background. Over the past mariners have been trained from the scratch called the hose piped system. It has become a burden to the maritime industry with the fast development of the technology. The exsisting mariners can not specify the situation. It is the hope of the Minisrty of Shipping, the indusries and the University of Moratuwa that the proposed marine engineering programme will cater the undergraduates with adequate qualification.

Looking at the foreciable future, it is contravertial statement among the mariners, wheather these graduates will fulfil the demands of the aritime industry, and whether all the successful graduates can be absorbed by the exsisting maritime based industries. As primary objectives, the governing body of the University of Moratuwa already agreed to offer a marine engineering programme bias with the exsisting mechanical engineering programme. The proposed programme will be updated according to the needs of the industry, and the marine enginering graduates will have the opportunity to choose their career as a mechnical engineer or as a marine engineer.

The guidance and advice are always obtained by recognised universities such as The University of New Castle, Uk. The University of Moratuwa is having close link wih the maritime industry. The assistance is received from the industry as visiting lectures. The permanent staff members have doctorial degrees from the University of New Castle, and are qualified enough to carry out the proposed course.

As the By-Laws of the University of Moratuwa, and to have in-line with other degree courses, the marine engineering undergraduates should undertake a six month in-plant training with the local industry given in chapter 4.5 . This traing period also will count as work experience (chapter 5.1.1) when they apply for the coporative membership at the Institute of Marine Engineers.

The mechanical engineering degree from the University of Moratuwa is well accepted by the local industry. The subjects, Industrial Engineering and Indusrtial Ecinomics and Managements will put our graduates at better position not only as engineers but also as managers. One of the requirements of the IMarE for coporative membership is to engage in managerial position, that will be supported by these subjects to carry-out their managerial work with a sound knowledge.

CHAPTER 4

4.1 IMPORTANCE OF NAVAL ARCHITECTURE IN THE PROPOSED DEGREE COURSE

Ships are used for the purpose of carrying men, material, and/or weapons upon the sea. In order to accomplish its mission, a ship must possess serveral basic characteristics. It must float in a stable upright position, move with sufficient speed, be able to manoeuver at sea and its restricted waters, and be strong enough to withstand the rigors of heavy weather and wave impact. To manoeuver a ship with these features, the marine engineer must have an understanding of a ship dynamics.

With a simple knowledge of hydrostatics a marine engineer can maneuver a ship that will float upright in calm waters. However, ships rarely sail in calm water. Waves, which are the main source of ship motions in a seaway, affects the performance of a ship considerably and the success of a voyage depends ultimately on its performance in seaway. Unfortunately, however, the prediction of a ship motions, resistance and power, and structural loads in an actual seaway is such a complex problem that the marine engineer is ususlly forced to select on the basis of calm water performance without much consideration of the sea and weather conditions prevailing over the route on which the ship is to operate.

In the maneuvering of ships, speed is an important factor. However, there is a loss of speed while a vessel is an under way in a sea, because of the increase in the motion resistance and loss of propellar efficiency. This results in higher fuel consumptions and there by reduce the crusing range. The heavier the seaway, the greater is the loss of speed. To overcome this loss it is often necessary to improve the resistance and propulsion characteristics of the vessels, as well as to select the machineary plant for adequate reserve power. The model tests can predict with reasonable accuracy the still water resistance and propulsion performance of a ship.

The relative importance of various aspects of ship performance in a sea way vary from ship to ship, depending on the what the operators require of the ship. The following general items must be investigated when manuvering the ship seaworthy.

a) Excessive motions, which are undesirable since they may impair stability and cause discomfort to the crew and passengers. Also in warships, most weapon systems require a stable platform for proper funtioning.
b) Additional stresses caused,by the ship's bending or by wave impact in a seaway.
c) Internal forces causing damages to the equipment, armament structurs, and so forth
d) Shipping and spraying of green water, causing equipment breakdown and degradation of the liability.
e) Slamming
f) Speed reduction and the conditions underwhich the propeller will start racing, thereby overloading the propeller machinery and hence increasing the fuel consumption or dropping off the crusing range.

The various problems encountered in regard to ship motion may be investigated in four different ways:

1. Analytically, that is on a theoritical basis
2. Experimentally, by means of model tests in controlled envoirnments
3. Emperically, through stastical observations
4. Directly, as with trials of ships after they are built

Both theoretical and experimental studies help the marine engineers to dertermine the influences of various ship features on seakeeping characteristic, knowledge that is extremely valuable in manoeuvering a ship. Therefore one of the most important study in naval architecture is the investigation of ship performance in rough water. Both merchant and naval vessels must maintain a high degree of seakeeping quality in many different types of weather and still attain their mission - the merchant ship in the commertial point of view, and the naval vessel with regard to the optimum operational ability. Theoretical studies, model results, and full scale data are all necessary to provide reliable criteria.

In recent years, research on ship motion has made considerable advances in the area of theoretical development, as well as in experimental facilities. However no quantitative index has yet been found to compare the seakeeping quantities of ship, as if possible in comparing the resistance or propulsion characteristics of hull form with another, by means of simple coefficient.

The introduction of advanced marine vehicles, such as planing crafts, hydrofoil boats, and air cushion vehicles has necessitated further studies in seakeeping in order to achieve the maximum results from the special vehicles. Intensive investigation are now underway to dertimine experimentally the effects of parameteric variations in motions, bottom pressures, and power requirements on models of planning boats, surface effects ships (SESs), and so on. In addition, scale effect studies on high performance vessels are being looked into to correlate test results from models of different scale and full scale trails.

With the knowledge of naval architecture a marine engineer would be able to engage in the development of technology for measuring, predicting, and improving the varaious quantities that governs ship dynamics. This also includes the application of this technology to specific design, the identifications of design faults, and correction and improvement of such designs. The specific will depend on the particular design, but it is essential that the marine engineer have some means of judging the expected formance.

4.1.1 Relavance to the Maritime Industry

The development of the industry is from sail boats to motor ship as other maritime nations. Presently the Port of Colombo has become the major trans-shipment port in the region, serving ports in India, Bangladesh, Burma, Thailand and Malasiya. The fleet strength of Sri Lanka is growing larger, and the private establishments are getting into the business at a good pace. The vessels approaching the Port of Colombo are versatile, from bulk carries to newly built reefer container ships.

The government of Sri Lanka has eight container ships under the administration of Ceylon Shipping Coporation that dominates the island owned vessels.

NAME OF VESSEL	DWT	YEAR BUILT
1. M V Lanka Siri	3831	1981
2. M V Lanka Seedevi	3831	1981
3. M V Lanka Srimathi	9700	1982
4. M V Lanka Srimani	9700	1982
5. M V Lanka Muditha	3000	1982
6. M V Lanka Mahapola	10325	1983
7. M V Lanka Athula	10600	1983
8. M V Lanka Ajitha	10600	1985

Apart from the vessels owned by the Sri Lankan entreprises, there are 62 foreign vessels under the Sri Lankan shipping registary. It is agreed with the foreign shipping owners to recruit fifty percent of the Sri Lanlan crew for their vessels. The proposed marine engineering course will able to satisfy the demands of the foreign vessels aside from the local need, offering a sound theoretical and technical knowledge to the graduates. This hopefully will pave the way to the our graduates to employ on foreign vessels with higher renumaration.

In view of the new container terminal at the Port of Colombo, it is enlightening that the expansion is taking place in berthing facilities as well as in warehouses. A neumerious offdeck container freight station are operated by various private sector organisation that handle all inland container transpotation.

Colombo Dockyard Limited, the island largest docking facility is capable of offering its service to any type of ship under 100,000 dwt that approaching the Port of Colombo. With the knowledge of naval architecture, the graduate will complement to enhace the facilities and efficiecy, and more of the small craft could be able to built at the Colombo Dock Yard.

Sri Lankan Navy has taken steps to enhance the naval strength. To make it reality, expansion in the petroal craft ought to be done, and technicaly qualified personnel have to be recruited. all the academic and technical reuirements for the navy could be satisfied by the proposed course.

The governtment of Sri Lanka has given a high priority to the fishing industry. The Ministry of Fishing is taking care of the local fishmen who are dominating the costal area. The fishing boat building is one of the small scale developing industies in Sri Lanka. Unfortunately, this industry is heavly depend on the foreign advice due to the very fact of unqualified personnel.

It is the intention of the University of Moratuwa, with the inclution of naval architecture to the proposed course to cater the industry by supplying well qualified personnel to this fastly developing fishing world.

4.2 PROPOSED SYLLABUS OF THE MARINE ENGINEERING UNDERGRADUATE COURSE

4.2.1 PROPOSED SYLLABUS FOR THE THIRD YEAR

1. Basics of Naval Architecture
   - 1.1 Ship and Naval Architecture
   - 1.2 Hull form, lines, fairing

2. Hydrostatics
   - 2.1 Coefficients
   - 2.2 Flotation, stability, metacentre
   - 2.3 GM, GZ, righting moments
   - 2.4 KG, weight transactions
   - 2.5 Small angle heel, inclining experiment
   - 2.6 Suspended weights, free surface
   - 2.7 Form and initial stability

3. Stability
   - 3.1 Stability at largre angle of heel
   - 3.2 Cross curves, statical stability curve
   - 3.3 Heeling moments, weights, wind, turning
   - 3.4 Criteria of adequate stability
   - 3.5 Longitudinal stability and trim
     - 3.5.1 Movement of small masses
     - 3.5.2 Use of MCTC
   - 3.6 Cargo handling effects on trim
   - 3.7 large weight trim effects
   - 3.8 Stability curves and trim

4. Floding
   - 4.1 Floding and subdivision

4.2 Calculation of draught after damage

4.2.1 Lost buoyancy method

4.2.2 added weight method

4.3 Damaged stability

4.4 Probability of survival

4.5 Curves of floodable length

4.6 Permeability

4.2.2 PROPOSED SYLLABUS FOR THE FOURTH YEAR

1. RESISTANCE
   - 1.1 Introduction
   - 1.2 Composition of Resistance
   - 1.3 Frictional Resistance
     - 1.3.1 Frictional resistance formula for a flat plate
     - 1.3.2 Density and kinematic viscosity
     - 1.3.3 Wetted surface area
     - 1.3.4 Equivalent flat plate
     - 1.3.5 Comment on frictional resistance
   - 1.4 Residual Resistance
     - 1.4.1 The Froude's similarity law
     - 1.4.2 Viscous pressure resistance
   - 1.5 Tank Test
     - 1.5.1 Analysis of the test
     - 1.5.2 frictional resistance
     - 1.5.3 Roughness correction
   - 1.6 Estimation of Residual Resistance
     - 1.6.1 Taylor charts
     - 1.6.2 Yamagata charts
   - 1.7 Effective Horse Power EHP

2. PROPULSION
   - 2.1 Propeller
     - 2.1.1 Structur and geometry
   - 2.2 Performance Characteristics
     - 2.2.1 Generation of force by propeller
     - 2.2.2 Propeller characteristics
   - 2.3 Intraction of Propeller with Hull
     - 2.3.1 Wake
     - 2.3.2 Thrust deduction

4.2.3 Justification of the Syllabus

The work of the proposed marine engineering degree programme with Naval architecture as one of the subjects will be directed towards the preparation of undergraduates for a career involving ships and shipping, or other marine activities. The common theme in all this work are the sea and the ways in which naval architecture can be used for the marine purposes. The proposed undergraduate course recognises that this general area of interest embraces a variety of professional work:

1. **design** of ships or other marine vehicles
2. **construction** involving modern management and production methods
3. **operation** both of fleets and individuals units
4. **Research** involving scientific investigation of problems in all these areas.

With the inclusion of naval architecture as a subject in the proposed degree course, the undergraduates will be able to achive the following;

i) A knowledge that is concernes with the design and operation of machinery in ships

ii) A knowledge about ship resistance and propulsion which is the main interest of marine engineering

iii) A knowledge about ship design and calculation of stability and trim, ship motion and structural strength with emphasis on computrized application of such applicable

4.3 LIBRARY FACILITIES

4.3.1 List of Recommonded Periedicals

1.	Journal of Ship Research	USA
2.	Royal Institute of Naval Architects	UK
3.	Marine Engineers Review	UK
4.	Holland Ship Buliding	Netherlands
5.	Institution of Engineers and Shipbuilders	Scotland
6.	International Shipbuilding Progress	USA
7.	Socity of Naval Architecture	Korea
8.	Journal of Sound and Vibration	UK
9.	North East Coast Institute of Engineers & Shipbulders	UK
10.	Socity of Naval Architecture	Japan
11.	Naval Engineers	USA
12.	Shipyard Bulletin	USA
13.	Shipyard Weekly	USA
14.	Naval Engineers	UK
15.	New Construction (shipbuilding)	UK
16.	Ship & Boat Builders	UK

4.3.2 List of Recommended Books

Principles of Naval Architecture	J P Comstock
Naval Architecture for Marine Engineers	W Muckle
Practical Solution of Torsional Vibration Problems, 5 vols	W Ker Wilson
Speed and Power of Ships	D W Taylor
Open Water Tests Seires with Modern Propoller forms	L Troost
Three Bladed Propellers	L Troost
Two and Five Bladed Propellers	L Troost
Development in Propeller Design and manufacture for merchant ships	L C Burrill
The effect of cavitation on the intera. propeller and ship's hull	J D Van Manen
Resistance of flat surfaces moving through a fluid	K E Schoenhee
Ship wave resistance	W C S Wigley
Theory of ship waves and resistance	T H Havelock
Dynamics of Marine Engineering Vehicles	R Bhattacharyya
Hydro Elasticity	R E D Bishop
What is a Classification Socity	Bureau Veritas
Mechanics of marine Vehicles	B R Clayton
Introduction to Naval Architecture	T C Gillmer
Element of Ship Design	R Munro-Smith
Basic Ship Theory	K J Rawson
Ship Design and Construction	The Soc. Nav Arch & Mar Eng.
Know your own ship	W Thomas
Dictionary of Ship types	A Dudszus

4.4 PROPOSED ASSIGNMENTS, EXPERIMENTS AND PROJECTS

4.4.1 ASSIGNMENTS *(Complementary programmes are in Appendix ii)*

1. Storing of Ship Data on a file
2. Calculations of Water Plane Area and Cetre of Flotation
3. Calculation of Cross Section Area and Immersed Volume
4. Plotting on the Computer Screen
    i) Water Planes
    ii) Cross Sections
5. Usage of Plotter for
    i) Water Planes
    ii) Cross Sections

4.4.2 Laborotary Experiments

1. Theory of model testing
2. Hull form and standard series
3. Resistants experiments comparing actual tests with standards series(60)
4. Selections of Propellers

4.4.3 Final Year Project

For the fulfilment of the course it is necesary to write a thesis with colaboration with a local industry to their requirements.

4.5 INDUSTRAIAL TRAINING

As the policies of the University of Moratuwa, it is a requirement to undergo a six month in-plant traing at a recognised heavy engineering workshop. It is followed by at the end of second and third years' academic work.

The following workshops are already agreed to give their support and facilities to train our undergraduates.

a. **Ceylon Shipping Coperation** now already provides the training facilities for the NDT diplomates and the mechanical engineering undergraduates, supported to extend their facilities to the proposed marine engineering course.

b. **Ports Authority of Sri Lanka** is under the expansion in their container handling facilities for the two years. It is also agreed to provide the training facilities and to support our undergraduates to train in their own staff training institute which is meant for training at all levels in port operation and managements.

c. **Ceylon Dock Yard Ltd.** is also already agreed to offer the training facilities to our graduates with much more emphasis on heavy engineering workshops.

4.6 STAFF TRAINING REQUIREMENTS

The Marine Engineering division is a sub-department within the present Mechanical Engineering Department at the University of Moratuwa.

The staff members are required to hold a postgraduate degree achieved by at least two years of research for promotion from the assistant lecturer to the lecturer grade. Assistance lecturers are provided the facility to pursue their postgraduates work mostly in overseas universities.

Presently, marine engineering division is under the supervision of two lecturers who hold doctorial degrees from the University of Newcastle and three assistant lecturers who are now at the following universities, expecting to complete their stuidies;

i. Oregan State Univ., USA	Oct, 88
ii. World Maritime Univ., Sweden	Dec, 88
iii. Univ. of Newcastle,, UK	Sep, 89

Marine engineering division is offering diploma courses in marine engineering and nautical sciences. In certain areas expertise will not be available in Moratuwa for some years pending the return of seconded staff. To avoid this suituation, the university is presently employed a few visiting lectures from Ceylon Shipping Coperation and other marine oriented establishments.

It is envisaged that marine engineering division is sufficient with marine engineering lectures though it does not have a qualified staff member in Naval Architecture. It is also proposed that at least one staff member should attain a doctorial degree in Naval Architecture.

The course is constantly being reviewed and revalidated in-line with the university policy and the needs of the maritime industry. Staff maintain close link with industry and many undertake industrial attachaments to remain abreast of changes. Staff are either former sea-going officers who hold First Class certificates, or acadamics who hold doctorial degrees. The subject material is costantly updated, laboratary work deals with the latest equiptment, projects are sometimes research related and often embrace the industry rather than simply theoretical orienterd. The development in the other countries is observed and drawn upon to improve what is done in Sri Lanka.

4.7 ROLE OF THE GRADUATE IN INDUSTRY

The maritime industry is developing as fast as electronics. It is appreciated that in order to remain competitive, new technolog must be used to modernise the design and to manufacture the process and has sustained a healthy demand for well-qualified and innovative mariners.

It is already time for Agents, acting on the behalf of the the Classification Socities to recuirt directly from universities because their traditional sourse of industry trained surveyors has dried up. There is chronic shortage of well qualified personnels in the maritime industry with a sound educational backgraoud and with a few years of relevant experience.

With the inclution of naval architecture as one of the subjects in the proposed degree course, our graduates will have the opportunity to embark upon a well paid interesting jobs. For example; `

1. The Colombo Dock Yard Ltd. will employs graduates on design(as naval architects), or in production or management.

2. The matime related industries associated with the design, construction and operation of marine craft and structures.

3. Shipping companies for technical and operational departments.

4. There are good opportunities for surveyors or reserch work with Agents for Classification Socities or the Ministry of Trade and Shipping that are concerned with the safety and intergrity of ships and other marine systems.

5. Ministry of Defence is already willing to employ graduates for their design, technical and management work.

6. A small number of graduates will take teaching as their career with the intention to further education and research work.

CHAPTER 5

5.1 CONCLUSIONS AND RECOMMENDATIONS

The initiative by the University of Moratuwa to establish a degree course in marine engineering is timely and far-sighted. The focus of ship building and marine engineering is moving to the developing world in the Far East and the establishment of this course will provide professional calibre engineers in a field in which the Government of Sri Lanka anticipates expansion to become a regional centre.

As the need for the subject of the naval Architecture in the proposed marine engineering course in the University of Moratuwa is clearly defined in this research on the chapter 4.1.1, 4.2.1 and 4.7. The author can therefore conclude that there is a strong need for it and its inclusion in the syllabus. Such inclusion will further enrich the course content for the benefit of the high quality of instruction, wich in turn benefit the students in particular, and the Sri LanKan industry.

5.1.1 Follow up by the University of Moratuwa

a. The Author recommends that the inclusion of the subject Naval Architecture to be approved and supported by the policy making body of the University of Moratuwa.

b. A letter of intent to prepare a course for submission through I.Mar.E. to satisfy stage 1 requirement for registration at the Charted level should be sent to

Professor J C Levy, OBE, Director of Engineering Profession, The Engineering Council, 10 Maltravers St, London, WC 2R 3Er, UK.

c. Continue the necessary action with IMarE to give recognition for the in-plant training undertaken by the engineering undergraduates, when they apply for coporative membership.

d. Proceed with the syllabus design and submission for accreditation along guidelines as discussed, with a target date of January 1990 for the course to be offered as a trird year option.

e. Certain areas of expertise will not be available in Moratuwa for some years pending the return of seconded staff, in which case the secondment of Newcastle staff for teaching or as cosultants in the installation and commissioning of the ship model towing tank, would be disirable.

f. It is also required that the staff member should attain a Ph.D in Naval Architecture, as other staff members having their doctorial in marine engineering.

g. Make necessary arrengements with the University of Peradeniya to use their towing tank for experiments of our undergraduates.

Appendix i

MECHANICAL ENGINEERING PROGRAMME; WEEKLY LOADING HOURS

Each academic year consists of 35 working weeks

FIRST YEAR

Subject	*Dept*	*Lec*	*Tut*	*Lab*
Mathematics I	MA	2	1	-
Mathematics II	MA	2	1	-
Pysics	EE	3	1	1.5
Engineering Chemistry	CH	3	1	1.5
Building Construction	CE	1	-	2
Surveying	CE	1	-	1.5
Engineering Drawing	ME	1	-	5
Workshop Technology	ME	1	-	4
English	EN	2	-	-

SECOND YEAR (PART I)

Subject	*Dept*	*Lec*	*Tut*	*Lab*
Mathematics	MA	2	1	-
Strength of Materials	CE	2	1	1.5
Fluid Mechanics	CE	2	1	1.5
Theory of Electricity	EE	2	1	1.5
Applied Thermodynamics	ME	2	1	1.5
Engineering Mechanics	ME	2	1	1.5
Production Technology	ME	2	-	1.5
Machine Element and Design	ME	2	-	3

THIRD YEAR (PART II)

Subject	*Dept*	*Lec*	*Tut*	*Lab*
Mathematics	MA	3	1	-
Industrial Economics and Management	ME	2	-	-
Strenth of Materials	CE	2	1	1.5
Fluid Mechanics	CE	2	1	1.5
Applied Thermodynamics	ME	2	0.5	1.5
Electrical Thecnology	EE	2	0.5	1.5
Machine of Machanics & Control Systems	ME	2	1	1.5
Production Engineering	ME	2	1	1.5
Design of Machine Elements	ME	-	-	3

FOURTH YEAR (PART III)

Subjects	*Dept*	*Lec*	*Tut*	*Lab*
Industrial Economics and Management	ME	3	-	-
Industrial Engineering	ME	2	1	-
Mechanics of Solids	ME	2	1	1.5
Project				

and THREE of the following options

Mathematics	ME	3	1	-
Applied Thermodynamics	ME	2	1	3
Automobile Engineering	ME	2	1	3
Fluid and lubrication	ME	2	1	1.5

KEY TO THE DEPARTMENT CODES

MA - Mathematics

EN - English

CH - Chemical Engineering

EE - Electrical Engineering

CE - Civil Engineering

ME - Mechanical Engineering

MR - Marine Engineering

```
5 CLS
10 REM EXAMPLE 01
20 REM STORING OFFSETS
30 DIM H(7,13)
40 OPEN "E01.DAT" FOR OUTPUT AS #1
50 FOR I=1 TO 7
60 FOR J=1 TO 13
70 READ H(I,J)
80 PRINT #1,H(I,J)
90 PRINT
100 NEXT  J
110 NEXT I
120 CLOSE
125 CLS
130 OPEN "E01.DAT" FOR INPUT AS #1
140 FOR I=1 TO 7
150 FOR J=1 TO 13
160 INPUT #1,H(I,J)
165 PRINT USING "##.###";H(I,J);
170 NEXT J
175 PRINT :PRINT
180 NEXT I
190 CLOSE
270 DATA     0,     0,     0,1.111,3.392,6.224,7.110,5.331,
        2.291,0.580,     0,     0,   0
280 DATA     0,0.691,1.520,3.762,6.782,8.672,9.062,8.311,
        6.022,3.411,1.711,1.111,0.760
290 DATA     0,0.842,1.942,4.823,7.814,9.271,9.463,8.922,
        6.902,4.192,1.990,1.200,0.671
300 DATA     0,1.071,2.802,6.544,8.923,9.500,9.500,9.291,
        7.711,4.942,2.122,1.000,0.250
310 DATA     0,2.172,4.523,7.945,9.364,9.500,9.500,9.412,
        8.172,5.460,2.311,1.000,0.060
320 DATA 2.132,4.464,6.434,8.911,9.491,9.500,9.500,9.462,
        8.510,6.040,2.762,1.200,0.111
330 DATA 4.250,6.321,7.822,9.333,9.500,9.500,9.500,9.500,
        8.811,6.741,3.580,1.900,0.432
```

1. STORING SHIP DATA ON A FILE

```
10 REM EXAMPLE 02
20 REM CALCULATION OF WATER PLANE AREA
30 REM                  CENTRE OF FLOTATION
40 REM                  Cw
50 CLS
60 DIM H(7,13)
70 FOR I=1 TO 7
80 FOR J=1 TO 13
90 READ H(I,J)
100 NEXT J
110 NEXT I
120 INPUT "Water Line Number";N
130 INPUT "LENGTH OF SHIP";L
140 FOR I=1 TO 7
150 LET WA(I)=2*L/30*(.5*(H(I,1)+H(I,13))+2*(H(I,2)+
    H(I.5)+H(I,7)+H(I,9)+H(I,12))+1.5*(H(I,3)+H(I,11))+
    4*(H(I,4)+H(I,6)+H(I,8)+H(I,10)))
160 LET M(I)=2*(L/10)^2/3*(2.5*(H(I,1)-H(I,13))+
    9*(H(I,2)-H(I,12))+6*(H(I,3)-H(I,11))+12*(H(I,4)-H(I,10))+
    4*(H(I,5)+H(I,6)-H(I,8)-H(I,9)))
170 NEXT I
180 IF N>2 THEN X=1.5 ELSE X=.5
190 IF N>6 THEN Y=2 ELSE Y=1
200 PRINT
210 FOR I=1 TO N STEP 2
220 IF I=0 OR I=1 THEN W=I+1 ELSE W=I/2+2
230 PRINT USING "WA(##) = ";I;
240 PRINT USING "####";WA(W);
250 PRINT TAB(22)
260 LET CF(W)=M(W)/WA(W)
270 PRINT USING "CF(##) = ";I;
280 PRINT USING "#.###";CF(W);
290 PRINT  TAB(44)
300 PRINT USING "CW(##) = ";I;
310 PRINT USING "#.###";WA(W)/2/L/H(7,6)
320 IF I=0 OR I=1 THEN I=I+1:GOTO 220
330 NEXT
340 DATA     0,     0,     0,1.111,3.392,6.224,7.110,5.331,
        2.291,0.580,     0,     0,    0
350 DATA     0,0.691,1.520,3.762,6.782,8.672,9.062,8.311,
        6.022,3.411,1.711,1.111,0.760
360 DATA     0,0.842,1.942,4.823,7.814,9.271,9.463,8.922,
        6.902,4.192,1.990,1.200,0.671
370 DATA     0,1.071,2.802,6.544,8.923,9.500,9.500,9.291,
        7.711,4.942,2.122,1.000,0.250
380 DATA     0,2.172,4.523,7.945,9.364,9.500,9.500,9.412,
        8.172,5.460,2.311,1.000,0.060
390 DATA 2.132,4.464,6.434,8.911,9.491,9.500,9.500,9.462,
        8.510,6.040,2.762,1.200,0.111
400 DATA 4.250,6.321,7.822,9.333,9.500,9.500,9.500,9.500,
        8.811,6.741,3.580,1.900,0.432
```

2. CALCULATION OF WATER PLANE AREA AND CENTRE OF FLOTATION

```
10 REM example 03
20 REM CALCULATION OF CROSS SECTION AREA
25 REM                    IMMERSED VOLUME
30 DIM H(7,13)
40 DIM S(13)
50 L=150
60 OPEN "E01.DAT" FOR INPUT AS #1
70 FOR I=1 TO 7
80 FOR J=1 TO 13
90 INPUT #1,H(I,J)
100 NEXT J
110 NEXT I
120 CLOSE
130 FOR J=1 TO 13
140 LET S(J)=4/3*(.5*H(1,J)+2*H(2,J)+Y*H(5,J)+
        X*H(3,J)+4*(H(4,J)+H(6,J))+H(7,J))
150 NEXT J
160 LET MA=(L/10)^2/3*(2.5*(S(1)-S(13))+9*(S(2)-S(12))+
        6*(S(3)-S(11))+12*(S(4)-S(10))+4*(S(5)+S(6)-S(8)-S(9)))
170 LET V=2*L/30*(.5*(S(1)+S(13))+2*(S(2)+S(5)+S(7)+S(9)+S(12))+
        1.5*(S(3)+S(12))+4*(S(4)+S(6)+S(8)+S(10)))
180 CLS
190 PRINT
200 FOR J=1 TO 13
210 B=J
220 IF J=1 THEN B=0
230 IF J=2 THEN B=.5
240 IF J=12 THEN B=9.5
250 IF J=13 THEN B=10
260 PRINT USING "SA(##.#) = ";B;
270 PRINT USING "###.##";S(J)
280 NEXT
290 PRINT
300 PRINT "VOLUME = ";INT(V);
310 PRINT TAB(30)
320 PRINT USING "L C B =  #.###";MA/V
```

3. CALCULATION OF CROSS SECTION AREA AND IMMERSED VOLUME

```
10 REM EXAMPLE EX05
20 REM WATER PLANE CURVES ON THE SCREEN
30 DIM H(7,13)
40 OPEN "E01.DAT" FOR INPUT AS #1
50 FOR I=1 TO 7
60 FOR J=1 TO 13
70 INPUT #1,H(I,J)
80 NEXT J
90 NEXT I
95 CLOSE
100 CLS
110 SCREEN 9,0
120 LINE (320,0)-(320,320)
130 FOR J=1 TO 13
140 FOR I=1 TO 5 STEP 2
150 IF I=1 THEN F=1 ELSE F=2
160 P=(H(I+2,J)-2*H(I+1,J)+H(I,J))/2/F/F
170 Q=(H(I+2,J)-H(I,J))/2/F
180 R=H(I+1,J)
190 IF I=5 THEN I=7
200 IF I=1 THEN B=I-1 ELSE E=I+3
210 IF I>1 THEN B=E-4 ELSE E=I+1
220 C=(B+E)/2
230 FOR Y=B TO E STEP .1
240 Z=Y+.1
250 J1=P*(Y-C)^2+Q*(Y-C)+R
260 J2=P*(Z-C)^2+Q*(Z-C)+R
270 IF J>7 GOTO  290
280 LINE (320+20*J1,300-20*Y)-(320+20*J2,300-20*Z):GOTO  300
290 LINE (320-20*J1,300-20*Y)-(320-20*J2,300-20*Z)
300 NEXT
310 NEXT
320 NEXT
```

4.1 WATER PLANE CURVES ON THE SCREEN

```
0 REM EX06
0 REM CROSS SECTION CURVES ON THE SCREEN
0 DIM H(7,13)
0 OPEN "E01.DAT" FOR INPUT AS #1
0 FOR I= 1 TO 7
0 FOR J= 1 TO 13
0 INPUT #1,H(I,J)
0 NEXT J
0 NEXT I
00 CLOSE
10 CLS
20 SCREEN 9,0
30 FOR I=1 TO 7
40 FOR J=1 TO 11 STEP 2
50 IF J=1 OR J=11 THEN F=.5 ELSE F=1
60 IF J=11 THEN A=9:E=A+1:GOTO 190
70 IF J=1 THEN A=0:E=A+1:GOTO 190
80 A=J-2:E=A+2
90 P=(H(I,J+2)-2*H(I,J+1)+H(I,J))/2/F/F
00 Q=(H(I,J+2)-H(I,J))/2/F
10 R=H(I,J+1)
20 C=(A+E)/2
30 FOR X= A TO E STEP .1
40 Z=X+.1
50 J1=P*(X-C)^2+Q*(X-C)+R
60 J2=P*(Z-C)^2+Q*(Z-C)+R
70 LINE (50*X,200-10*J1)-(50*Z,200-10*J2)
80 NEXT
90 NEXT
00 NEXT
```

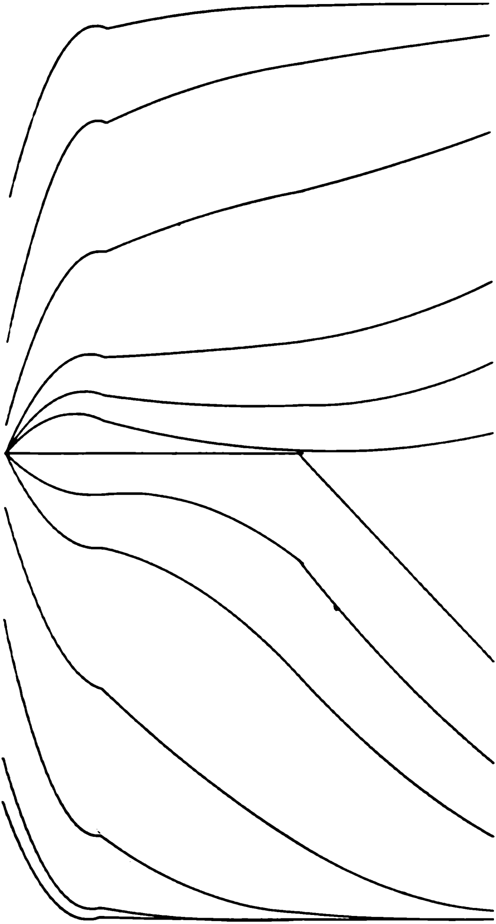
4.ii CROSS SECTION CURVES ON THE SCREEN

```
10 REM EXAMPLE p110
20 REM USAGE OF PLOTTER FOR THE WATER PLANES
30 DIM H(7,13)
40 OPEN "E01.DAT" FOR INPUT AS #1
50 GOSUB 400
60 FOR I=1 TO 7
70 FOR J=1 TO 13
80 INPUT #1,H(I,J)
90 NEXT J
100 NEXT I
110 CLOSE #1
120 CLS
130 SCREEN 9,0
140 LINE (320,0)-(320,320)
150 FOR J=1 TO 13
160 FOR I=1 TO 5 STEP 2
170 IF I=1 THEN F=1 ELSE F=2
180 P=(H(I+2,J)-2*H(I+1,J)+H(I,J))/2/F/F
190 Q=(H(I+2,J)-H(I,J))/2/F
200 R=H(I+1,J)
210 IF I=5 THEN I=7
220 IF I=1 THEN B=I-1 ELSE E=I+3
230 IF I>1 THEN B=E-4 ELSE E=I+1
240 C=(B+E)/2
250 FOR Y=B TO E STEP .1
260 Z=Y+.1
270 J1=P*(Y-C)^2+Q*(Y-C)+R
280 J2=P*(Z-C)^2+Q*(Z-C)+R
290 IF J>7 THEN X1=5500-500*J1 ELSE X1=5500+500*J1
300 Y1=1000+500*Y
310 IF J>7 THEN X2=5500-500*J2 ELSE X2=5500+500*J2
320 Y2=1000+500*Z
330 IF J>7 GOTO  350
340 LINE (320+20*J1,300-20*Y)-(320+20*J2,300-20*Z):GOTO  360
350 LINE (320-20*J1,300-20*Y)-(320-20*J2,300-20*Z)
360 GOSUB 460
370 NEXT
380 NEXT
390 NEXT
400 REM pltest4
410 OPEN "COM1:2400,S,7,1,RS,CS65535,DS,CD" AS #2
420 PRINT #2,"IN;SP1;PA0,0,"
430 RETURN
440 END
450 REM PLOT SUB.
460 PRINT #2,"PU",X1,Y1,"PD",X2,Y2,"PU;"
470 RETURN
```

5.i USAGE OF PLOTTER FOR THE WATER PLANES

```
10 REM EXAMPLE p106
20 REM USAGE OF PLOTTER FOR THE CROSS SCETIONS
30 DIM H(7,13)
40 OPEN "E01.DAT" FOR INPUT AS #1
50 GOSUB 380:REM House keeping
60 FOR I=1 TO 7
70 FOR J=1 TO 13
80 INPUT #1,H(I,J)
90 NEXT J
100 NEXT I
110 CLOSE #1
120 CLS
130 SCREEN 9,0
140 FOR I=1 TO 7
150 FOR J=1 TO 11 STEP 2
160 IF J=1 OR J=11 THEN F=.5 ELSE F=1
170 IF J=11 THEN A=9:E=A+1: GOTO 200
180 IF J=1 THEN A=0:E=A+1: GOTO 200
190 A=J-2:E=A+2
200 P=(H(I,J+2)-2*H(I,J+1)+H(I,J))/2/F/F
210 Q=(H(I,J+2)-H(I,J))/2/F
220 R=H(I,J+1)
230 C=(A+E)/2
240 FOR X=A TO E STEP .1
250 Z=X+.1
260 J1=P*(X-C)^2+Q*(X-C)+R
270 J2=P*(Z-C)^2+Q*(Z-C)+R
280 X1=100+1000*X
290 Y1=3000+140*J1
300 X2=100+1000*Z
310 Y2=3000+140*J2
320 GOSUB 420
330 LINE (50*X,200-10*J1)-(50*Z,200-10*J2)
340 NEXT
350 NEXT
360 NEXT
370 REM pltest4
380 OPEN "COM1:2400,S,7,1,RS,CS65535,DS,CD" AS #2
390 PRINT #2,"IN;SP1;PA0,0,"
400 RETURN
410 END
420 REM PLOT SUB.
430 PRINT #2,"PU",X1,Y1,"PD",X2,Y2,"PU;"
440 RETURN
```

5.ii USAGE OF PLOTTER FOR THE CROSSECTIONS



Appendix iii

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