

POST GRADUATE DEPARTMENT
UNITED STATES NAVAL ACADEMY
Annapolis, Maryland,

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C A T A L O G U E
of
CURRICULA
and
COURSES OF STUDY

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T A B L E O F C O N T E N T S

Page

Introduction..... 1-2

Curricula:

Mechanical Engineering..... 2-3
Electrical Engineering..... 4-6
Ordnance..... 6-17
Naval Construction..... 18-19
Civil Engineering..... 20-21

Description of Courses:

At Naval Academy..... 22-33
At Columbia University..... 33-43
At Massachusetts Institute of Technology..... 44-55
At Rensselaer Polytechnic Institute..... 55-59

Manner of Selecting Specialties..... 60

UNITED STATES NAVAL ACADEMY,

Annapolis, Md.,

POST GRADUATE DEPARTMENT,

May 1, 1915.

1. In accordance with Article 1543 of the U. S. Naval Regulations, curricula have been established in this department follows:

- (A) Mechanical Engineering;
- (B) Electrical Engineering;
- (C) Ordnance;
- (D) Naval Construction;
- (E) Civil Engineering.

2. In the following statement of curricula, courses are designated by name and by number, which refer to descriptions of courses, given later. The courses given at the Naval Academy are grouped according to subject matter,- 100 to 199 dealing with Mathematics and Mechanics; 200 to 299 dealing with Mechanical Engineering subjects; 300 to 399 dealing with Electrical Engineering subjects; 400 to 499 dealing with Physics; 500 to 599 dealing with Chemistry; and 600 to 699 dealing with Ballistics.

3. Courses 100-199 are conducted by the Professor of Mathematics and Engineering Mathematics; Courses 200-299 by the Professor of Marine Engineering; Courses 300-399 by the Professor of Electrical Engineering; Courses 400-499 by the Professor of Electrical Engineering and other professors in the Academy specially assigned to this work; Courses 500-599 by the academic department in charge of Chemistry; Courses 600-699 by the Ordnance Department of the Naval Academy.

4. Courses pursued by naval officers at other institutions included in these curricula are designated here by the titles and numbers assigned them in the catalogues of the respective institutions. The courses at Troy, N.Y., not being numbered in the catalogue of the Rensselaer Polytechnic Institute, are here designated reference numbers above 2000.

5. At Annapolis, the day is divided into three periods, of two to two and a half hours each, two periods in the forenoon and one in the afternoon. The periods designated as class periods, mainly forenoon periods, are given to lectures, discussions and individual study or problem work, the apportionment of time being at the discretion of the instructor. Each naval officer is expected to devote from ten to fifteen hours per

to study, outside of working hours. This time is available for preparation for both laboratory and classroom exercises.

6. At Troy, N.Y., the day is divided into periods as at Troy, N.Y., while at New York and at Boston the time unit is the

C U R R I C U L U M (A).

MECHANICAL ENGINEERING.

1st Year. (At Naval Academy).

First Term.

Periods per week.
Class. Lab.

101)	Mathematics (a).....	2	0
111)	Mechanics (a).....	1	0
121)	Applied Mechanics (a).....	1	0
201)	Strength of Materials & Machine Design.....	1	0
203)	Thermodynamics.....	2	0
205)	Mechanical Engineering Laboratory.....	0	2
207)	Steam Power Plant Machinery.....	1	0
301)	Theory of Electricity.....	1	
401)	Physics of Heat.....	1	2
403)	Physics of Light and Sound.....	1	
501)	Chemistry.....	1	1

Second Term.

102)	Mathematics (b).....	2	0
112)	Mechanics (b).....	1	0
122)	Applied Mechanics (b).....	1	0
202)	Strength of Materials & Machine Design.....	1.5	0
204)	Thermodynamics.....	1	0
206)	Mechanical Engineering Laboratory.....	0	2
208)	Steam Power Plant Machinery.....	1	0
312)	Valve Gears.....	.5	0
402)	Direct Current Electrical Engineering.....	2	2
403)	Physics of Heat.....	1	
504)	Alternating Current Electricity.....	2	0

Summer Term.

- 52) Advanced Mechanics.
- 51) Practical Work at Experiment Station and Machine Shop.

Second Year. (At Columbia University, New York City.)

Shop Practices Option.

First Term.

		<u>Periods per week.</u>	
		<u>Class.</u>	<u>Lab.</u>
M.E.	155 Shop Processes & Machine Tools.....	1	3
Met.	131 Metallurgy of Iron and Steel.....	1	0
M.E.	117 Engineering Thermodynamics.....	2	3
M.E.	131 Standard Tests & Experimental Research.	2	3
M.E.	119-		
	139 Machine Analysis & Design.....	6	6

Second Term.

M.E.	152 Organization & Management.....	3	0
Met.	156 Metallographic Laboratory.....	0	3
M.E.	118 Engineering Thermodynamics.....	2	3
M.E.	132 Standard Tests & Experimental Research.	2	3
M.E.	150 Steam Turbines.....	3	0
M.E.	122 Gas Power.....	4	3
M.E.	120-		
	140 Machine Analysis & Design.....	2	3

Design Option.

First Term.

E.E.	101-		
	171 D. C. Electrical Apparatus.....	2	3
Met.	131 Metallurgy of Iron and Steel.....	1	0
M.E.	117 Engineering Thermodynamics.....	2	3
M.E.	131 Standard Tests & Experimental Research.	2	3
M.E.	119-		
	139 Machine Analysis & Design.....	6	6

Second Term.

E.E.	102 Selection & Application of Elec. Motors.	2	0
Met.	156 Metallographic Laboratory.....	0	3
M.E.	118 Engineering Thermodynamics.....	2	3
M.E.	132 Standard Tests & Experimental Research.	2	3
M.E.	150 Steam Turbines.....	3	0
M.E.	122 Gas & Oil Engines.....	4	3
M.E.	120-		
	140 Machine Analysis & Design.....	2	3

Summer Term, Mechanical Engineers.

Practical work at the Navy Yard, New York, N.Y.

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C U R R I C U L U M (B).

ELECTRICAL ENGINEERING.

First Year. (At Naval Academy.)

First Term.

	<u>Periods per week.</u>	
	<u>Class.</u>	<u>Lab.</u>
(101) Mathematics (a).....	2	0
(111) Mechanics (a).....	1	0
(121) Applied Mechanics (a).....	1	0
(201) Strength of Materials & Machine Design.....	1	0
(203) Thermodynamics.....	2	0
(205) Mechanical Engineering Laboratory.....	0	2
(207) Steam Power Plant Machinery.....	1	0
(301) Theory of Electricity.....	1	2
(401) Physics of Heat.....	1	
(403) Physics of Light and Sound.....	1	
(501) Chemistry.....	1	1

Second Term.

(102) Mathematics (b).....	2	0
(112) Mechanics (b).....	1	0
(122) Applied Mechanics (b).....	1	0
(202) Strength of Materials & Machine Design.....	1.5	0
(204) Thermodynamics.....	1	0
(206) Mechanical Engineering Laboratory.....	0	2
(208) Steam Power Plant Machinery.....	1	0
(212) Valve Gears.....	.5	0
(302) Direct Current Electrical Engineering.....	2	2
(402) Physics of Heat.....	1	
(304) Alternating Current Electricity.....	2	0

Summer Term.

(151) Differential Equations of Electricity.....		
(351) Practical Work in Electrical Engineering Laboratory.		

Second Year. (At Columbia University, New York City.)

Electrical Group.

First Term.

E.E. 101 Management of Electrical Machinery.....	2	0
E.E. 103 Electric Motors.....	2	0
E.E. 105 A. C. Engineering.....	3	0
E.E. 109 Telegraph Engineering.....	1	0

(First Term, Elec. Group, contd.)

		<u>Periods per week.</u>	
		<u>Class.</u>	<u>Lab.</u>
E.E. 153	Design of D. C. Machinery.....	0	3
E.E. 173	D. C. Machine Laboratory.....	1	6
E.E. 201	Seminar, Electricity on Ships.....	3	3
Met. 131	Metallurgy of Iron and Steel.....	1	0
Met. 155	Metallographic Laboratory.....	0	3

Second Term.

E.E. 103	Electric Motors.....	2	0
E.E. 106	Electric Plants.....	2	0
E.E. 108	Plant Visitation (optional).....	0	3
E.E. 110	Telephone Engineering.....	1	0
E.E. 154	Design of A. C. Machinery.....	0	3
E.E. 176	A. C. Machine Laboratory.....	1	6
E.E. 178	Instrument Laboratory.....	1	3
E.E. 202	Seminar, Electricity on Ships.....	3	3
E.E. 214	Radio-telegraphy Laboratory.....	1	3
Phy. 52	Conduction of Electricity in Gases.....	1	0

Radio Engineering Group.

First Term.

E.E. 101	Management of Electrical Machinery.....	2	0
E.E. 105	A. C. Engineering.....	3	0
E.E. 109	Telegraph Engineering.....	1	0
E.E. 153	Design of D. C. Machinery.....	0	3
E.E. 173	D. C. Machine Laboratory.....	1	6
E.E. 211	Radio Engineering Laboratory.....	1	6
Ch. 109	Theory of Electric Circuits.....	3	0
Met. 131	Metallurgy of Iron and Steel.....	1	0
Met. 155	Metallographic Laboratory.....	1	3

Second Term.

E.E. 102	Electric Motors.....	2	0
E.E. 106	Electric Plants.....	2	0
E.E. 108	Plant Visitation (optional).....	0	3
E.E. 110	Telephone Engineering.....	1	0
E.E. 154	Design of A. C. Machinery.....	0	3
E.E. 176	A. C. Machine Laboratory.....	1	6
E.E. 178	Instrument Laboratory.....	1	3
E.E. 212	Radio Engineering Laboratory.....	1	6
Ch. 110	Theory of A. C. Machines.....	3	0
Phy. 52	Conduction of Electricity in Gases.....	1	0

Summer Term. (Electrical & Radio Groups.)

Practical work at Navy Yard, New York, N.Y., American Telephone & Telegraph Co., New York City, and at the Works of the General Electric Co., Schenectady, N.Y.

C U R R I C U L U M (C)

ORDNANCE.

Part I, General Course, (18 Months).

Periods per week.
Class. Lab.

First Term. (At Naval Academy.)

(101)	Mathematics (a).....	2	0
(111)	Mechanics (a).....	1	0
(123)	Applied Mechanics for Ordnance Students.....	1	0
(205)	Mechanical Engineering Laboratory.....	0	2
(301)	Theory of Electricity.....	1	} 2
(401)	Physics of Heat.....	1	
(403)	Physics of Light and Sound.....	1	
(501)	Chemistry.....	1	1
(601)	Interior Ballistics.....	2	0
(602)	Exterior Ballistics.....	2	0

ir.

Ordinance.

Station - (Bethlehem
&
(Midvale.

Detail - 3 months.

(Inspection Methods
(
((Armor
((Projectiles
(Manufacture of (Gun steel
Subjects ((Castings, steel and composition
(
(Tests of material
(Specifications
(Metallurgy
(Metallography.

(Frankford Arsenal
Inspection (Watertown
(Carnegie
Trips. (Carpenter Steel Co.
(Steel Casting Plants
(J. B. Semple Co.

Lectures - Inspectors and Assistants, and Company's Experts.

(Harboard
Text (Campbell
Books & (Howe
Refer- (Stoughton
ences (Sauver
(Lake

T H E S I S.

Ordnance.

Station - Schenestady.

Detail - 3 months.

Subjects ((Motors
((Controllers
(Electricity (Rheostats
((Shop tests
((Meters
((Telephones
(Storage batteries
(Fire control.

Inspection (Watervliet
(Westinghouse
(Edison - electrical and optical features
(of moving-picture machines.
(Exide (Phila)
(Diehl
(Sperry Gyroscope Co., New York.

Lectures - Inspector and Company's Experts.

Text (Bullard
(Army Ord. Dept.-pamphlet of instruction #2336
Books & (Franklin & Eddy
Refer- (Thomson, Vols. 1 and 2
ences. (Foster's Electrical Engineer's Pocket Book
(Bureau Pamphlets.

T H E S I S.

ur.

Ordnance.

V. Station - Rochester.

Detail - 1 month.

Subjects (Optics
(Range finders
(Spotting glasses
(Telescopes
(Periscopes
(Fire control in general
(Photo apparatus

Inspection (Keuffel & Esser Co.
(Brashear, Pittsburgh
Trips. (Warner & Swasey
(Sub-Target Gun Co.
(Coast Fortifications.

Lectures - Inspector and Company's Experts.

Text Books (Edser
and (Heath
References (Nulton's Fire Control
(Bureau's pamphlets.

T H E S I S .

Ordnance.

Station - Proving Ground.

Detail - 4 months.

(Proof of ordnance material - guns, powder, armor,
(projectiles, fuses, mechanisms, etc.
(Exterior ballistics
Subjects (Interior ballistics
(Manufacture of powder
(Explosives
(Ballistics of penetration.

(Sandy Hook
Inspection (Dupont's
(Pickatinny
Trips. (Iona Island
(Ft. Mifflin

Lectures - Inspectors and Assistants - Chemists.

(Exterior Ballistics - Alger
(Ballistic Tables - Ingalls (Art. Circular M.)
ext ((Brynk
ooks & (Interior Ballistics (Ingalls
efer- ((Bureau Pamphlet
nces. (Guttman
(Brunswig
(Weaver

T H E S I S.

Cur.

Ordnance.

VI. Washington Navy Yard and Bureau of Ordnance.

Detail - 3 months.

(Bureau organization and files; pamphlets and specifications.
(Washington Navy Yard organization.
(Drafting and designing, organization
(Bureau of Standards - equipment
(Elastic strength guns - strength and powder curves
(Guns
(Breech mechanism
(Turret mounts, hoists, rammers.
Subjects (Manufacture of Ordnance (Broadside mounts
(Sights, turret and broadside
(Drill equipment
(Submerged tubes
(Fuses, primers, cart-ridge cases
(Machines and Tools - uses, nomenclature, costs, etc.
(Bureau Officers, on subjects under Desks
Lectures (W. N. Y. Officers on " " "
(Ordnance Engineers, on subjects assigned.
(Ordnance and Gunnery - U. S. Naval Academy
Text (" " " - Lissak
Books (Treatise on Service Ordnance (British)
and (Elastic strength guns - Alger, Nulton, Storey,
Refer- (Pashkievitsch
ences. (Bureau pamphlets
(Army Ordnance publications.

T H E S I S.

Cur.

Ordnance.

Part II. Special Course, (6 Months).

- (1) Powder and Explosives.
- (2) Ordnance Engineering and Gun Design.
- (3) Metallurgy.
- (4) Optics and Fire Control Instruments.

Specialty - Powder and Explosives.

Station - (Washington
(Indian Head
(Pittsburgh

Subjects (Chemistry - G.W. University (6 months) Courses
(#23, #24,
(Explosive experiments - suggested by Prof. Monroe
(
(Bureau of Mines (1 month)
(
(Manufacture of nitrocellulose powder and acids -
(tests - assignments, etc.
(Nitroglycerine powders
(Interior ballistics
((applied to torpedoes, mines, projectiles
(Explosives - (
((effects of - submerged and otherwise.

Inspection (Dupont's
Trips. (Picatinny
(Magazines.

Lectures - Inspector, Indian Head, and Chemists; Desk "F", Bureau.

(Treatise on explosives - British
(Abbot - Engineer's Prof. papers, #23, 1881-Bernadon
(Guttman - Weaver - Brynk - Nobel
(Berthelot - Gody (French) - Brunswig - Munroe
(Report of experiments with explosives, Newport, 1907.
Text Books (Easy organic chemistry - Appleton
and (Short Qualitative Analysis - Hoyer
Refer- (" Quantitative " - Talbot
ences. (Chemistry of Explosives and oils - War Department
(Instr. Pamphlets #2334.
(Force of Explosives - Bureau drawing #39757
(" " " - Gody (Trans. by Major T.C.
(Dicken, U.S.A.)
(Nitro explosives - Sangford.
(Dictionary of explosives - Cundhill
(Cellulose - Cross & Devan

Cur.

Ordnance.

Specialty - Ordnance Engineering and Gun Design.

Station - Washington Navy Yard.

(Powder chambers for nitrocellulose and nitro-glycerine powders.
(Rifling
(Gas-checking devices
(Breech mechanism - locks, firing mechanisms, and metal for same
Subjects (Erosion
(Steel and its alloys for gun construction - defects and flaws in it
(Liners and methods of lining
(Shrinkages, assignment of
(Heat cracks
(Elastic strength - cross stresses
(Forcing of rotating bands, design of, and material for
(Design of gun mounts, recoil, etc.

(Watervliet
Inspection (Watertown
(Frankford Arsenal
Trips. (Colt's Company
(U. M. C. Co.

(Desk "D" - Bureau
Lectures (Officer in charge Drafting Room, W. N. Y.
(Attend Lectures By Bu. Standards, on Advanced Physics and Mechanics.

(Ingalls Interior Ballistics
(Army Ordnance Pamphlet #2337
Text (Bureau Pamphlet on Gun Design
Books (Notes on Construction of Ordnance (Army Ordnance)
and (Resistances et Construction des Bouches a Feu - Jacob
Refer- (Resistances of Guns to Tangential Rupture - Pashkovitsch.
(Naval Institute and Journal U. S. Artillery.
(Rausenberger - recoil of guns.

T H E S I S.

Cur.

Ordinance.

Specialty - Metallurgy

Station - Bethlehem

(
(Manufacture (gun steel forgings
(and (armor
(Treatment of (projectiles
(steel castings
(various compositions

Subjects ((chemical
(Tests of (physical (including hardness)
(Material (torsional
((vibratory
(
(Photo-micrographs and metallography
(Flaws and defects in metals
(Bureau specifications - study and criticism

(Midvale
(Carpenter
(Carnegie
Inspection (Illinois Steel Co.
Trips. (American Steel Foundries
(Federal Steel Castings
(Watertown

Lectures - Inspector and Company's Experts.

(Harboard
Text Books (Howe
and (Campbell
References (Stoughton
(Sauver
(Lake

T H E S I S.

Cur.

Ordnance.

Specialty - Optics.

Station - Rochester.

Subjects (Telescopes
(Range finders
(Binoculars
(Periscopes
(Spotting glass.

Inspection (Keuffel & Esser Co.
(Brashear, Pittsburgh
Trips. (Warner & Swasey.

Lectures - Inspector and Company's Experts.

Text Books (Edser
and (Heath
References (Nulton's fire control
(Bureau pamphlets.

T H E S I S .

Cur.

Ordnance.

REFERENCES - PERIODICALS.

General Ordnance Publications.

1. Journal of U. S. Artillery (with Index)
2. Proceedings of U. S. Naval Institute
3. Jane
4. Brassey
5. Scientific American
6. " " (Supplement)
7. Journal de la Marine (le Yacht)
8. Arms and Explosives
9. Revue d'Artillerie
10. Journal of the Royal Artillery
11. Kriegstechnische Zeitschrift
12. Zeitschrift fur das Gesamte Schiess - und Sprengstoffw.
Powder and Explosives.

1. Annual Report of H. M. Inspectors of Explosives
2. Memorial des Powders et Saltpetres
3. Journal of the Chemical Society (English)
4. Zeitschrift fur Angewandte Chemie (German)
5. Society of Chemical Industry
6. Chemical Abstracts
7. Journal of Industrial and Engineering Chemistry.
8. Chemical Engineer.

Metallurgy.

1. Iron Age.
2. Brass World and Platers Guide
3. Metal Industry
4. Iron and Steel Institute (London)
5. Foundry.
6. Castings
7. American Society for Testing Materials
8. Metallurgical and Chemical Engineering
9. Stahl und Eisen

Electricity.

1. Electrical World (New York)
2. The Electrical Engineer (London)

Cur.

Ordnance.

CONDENSED SCHEDULE

OF

SPECIAL COURSE IN ORDNANCE.

<u>Title of Course.</u>	<u>Headquarters.</u>	<u>Number of Students.</u>	<u>Months</u>	
			<u>Name.</u>	<u>No.</u>
General	Naval Academy	4	Oct-Jan	4
Inspection	Steel Plants	4	Feb-May	
			Feb-Apr	3
Electrical	Schenectady	4	Jun-Aug	
			May-July	3
Optics & Fire Control	Rochester	4	Sept-Nov	
			August	1
Proof & Experiments	Proving Ground	4	December	
			Sept-Dec	4
Ordnance Manufacture	Gun Factory	4	Jan-Apr.	
			Jan-Mar.	3
			May-July	

Metallurgy	Bethlehem	1 or 2	Apr-Sept	6
Engineering	Gun Factory	1 " 2	Aug-Jan.	
			do	6
Powder & Explosives	G. Wash. Uni.	1 " 2	do	6
Optics & Fire Control	Rochester	1 " 2	do	<u>6</u>

24

Cur.

C U R R I C U L U M (D)

NAVAL CONSTRUCTION.

First Year. (At Naval Academy).

Second Term.

	<u>Periods per</u>	
	<u>Class.</u>	<u>La</u>
(104) Mathematics.....	3	C
(114) Mechanics.....	3	C
(21C) Elementary Thermodynamics.....	1	C
(301) Theory of Electricity.....	2	2
(401, 402) Physics of Heat.....	2	1
(403) Physics of Light and Sound.....	1	0
(504) Chemistry.....	1	1

Summer Term.

- (155) Mathematics...
- (156) Mechanics.
- (353) Electricity.
- (452) Physics Laboratory Problems.
- (252) Shop work.

Second, Third and Fourth Years. (At Mass. Inst. of Tech.)

Junior Year.

First Term.

	<u>Hours per</u>		<u>te:</u>
	<u>Exer.</u>	<u>Pr</u>	
(1301) Naval Architecture.....	30	60	
(1311) Theory of Warship Design.....	30	30	
(1321) Warship Design, preliminary work.....		105	
(246) Heat Engineering.....	30	60	
(216) Applied Mechanics.....	45	90	
(M37) Mathematics.....	60	120	
(534) Analytical and Technical Chemistry.....	45	45	

Second Term.

(1301) Naval Architecture.....	30	60	
(1311) Theory of Warship Design.....	30	30	
(1321) Warship Design.....		120	
(246) Heat Engineering.....	15	30	
(251) Internal Combustion Engines.....	20	20	
(226) Applied Mechanics.....	30	60	
(M38) Mathematics.....	30	60	
(803) Precision of Measurements.....	10	10	
(534) Chemical Laboratory.....	90	0	
(332) Metallurgy.....	45		

Senior Year.First Term.Hours per Term
Exer. Prep.

(1302)	Naval Architecture.....	30	60
(1312)	Theory of Warship Design.....	30	60
(1322)	Warship Design.....	90	0
(1395)	Model Making.....	30	0
(229)	Applied Mechanics.....	45	90
(235)	Testing Materials Laboratory.....	20	10
(611)	Principles of Electrical Engineering.....	75	85
(667)	Standardizing Laboratory.....	30	30
(Ec31)	Political Economy.....	45	45

Second Term.

(1302)	Naval Architecture.....	15	30
(1312)	Theory of Warship Design.....	30	30
(1322)	Warship Design.....	90	0
(1365)	Marine Steam Turbines.....	30	60
(756)	Sanitation of Ships.....	15	15
(M57)	Hydrodynamics.....	20	40
(1372)	Aeronautics.....	30	60
(261, 814)	Engineering Laboratory.....	60	30
(612)	Principles of Electrical Engineering.....	45	45
(684)	Electrical Engineering Laboratory.....	45	45

Graduate Year.First Term.

(1313)	Theory of Warship Design.....	30	30
(1323)	Warship Design.....	90	0
(1355)	Marine Engineering.....	30	30
(1361)	Marine Engine Design.....	90	45
(261)	Engineering Laboratory.....	60	30
(623)	Alternating Current Machinery.....	45	45
(685)	Electrical Engineering Laboratory.....	45	45
(Ec41)	Economics of Corporations.....	30	30
(E39)	Public Speaking.....	30	15

Second Term.

(1313)	Theory of Warship Design.....	30	30
(1323)	Warship Design.....	90	0
(1372)	Aeronautics, Advanced.....	30	60
(635)	Mechanical Applications of Electric Power..	30	60
(145)	Theory of Structures.....	105	90
(274)	Industrial Management.....	15	15
(Ec60)	Business Law.....	15	15
(1305)	Memoirs.....	15	45
	Thesis.....		120

During the summer months the officers specializing in Naval Construction are assigned to Navy Yards and Ship-Building yards for practical work.

Cur.

C U R R I C U L U M (E)

CIVIL ENGINEERING.

First Year. (At Naval Academy.)

		<u>Second Term.</u>		<u>Periods per week</u>	
				<u>Class.</u>	<u>Lab.</u>
	(104)	Mathematics.....		3	0
	(114)	Mechanics.....		3	0
	(210)	Elementary Thermodynamics.....		1	0
	(301)	Theory of Electricity.....		2	2
401	402	Physics of Heat.....		2	1
	403	Physics of Light and Sound.....		1	0
	(504)	Chemistry.....		1	1

Summer Term.

- (155) Mathematics.
- (156) Mechanics.
- (353) Electricity.
- (452) Physics Laboratory Problems.
- (252) Shop work.

Second Year. (At Rensselaer Polytechnic Institute).

First Term.

(2001)	Thermodynamics.....	}	5	0
(2003)	Heating, Ventilation, & Refrigeration.....			
(2005)	Electrodynamics.....			
(2007)	Botany.....	}	5	0
(2009)	Stone Cutting Theory.....			
(2011)	Architecture.....			
(2013)	Mechanics.....	}	0	5
(2015)	Electrical Measurements.....			
(2017)	Stone Cutting Drawing.....			
(2019)	Map Drawing.....			
(2021)	Testing Laboratory.....			

Second Term.

(2014)	Mechanics.....	}	5	0
(2004)	Structures.....			
(2006)	Resistances.....			
(2008)	Geology.....	}	5	0
(2010)	Mineralogy.....			
(2012)	Mechanical Laboratory.....			
(2002)	Fire Proofing and Protection.....	}	0	5
(2016)	Metallurgy.....			
(2018)	D. C. - A. C. Machines, Laboratory.....			

Cur.

Civ. Eng.

Third Year. (At Rensselaer Polytechnic Institute).

		<u>Periods per</u>	
		<u>Class.</u>	<u>La</u>
<u>First Term.</u>			
(2023)	R. R. Curves.....	}	5 0
(2025)	Electrical Engineering Course.....		
(2027)	Internal Combustion Engine Design.....		
(2029)	Electrical Transmission & Distribution....		
(2031)	Electric Cranes, Elevators.....		
(2033)	Bridges.....	}	5 0
(2035)	Highways.....		
(2037)	Heating and Ventilating Laboratory.....		
(2039)	Railroad Engineering.....	}	0 .5
(2041)	Hydraulics.....		

Second Term.

(2020)	Electric Lighting.....	}	5 0
(2022)	Central Station Elec. Equipment.....		
(2024)	Central Station Mech. Equipment.....		
(2026)	Compressed Air.....		
(2028)	Pumping Machinery.....	}	5 0
(2030)	Lighting, Transmission & Distribution Lab.		
(2032)	Central Station Architecture.....		
(2034)	Water Supply and Sewers.....	}	.5 0
(2036)	Law of Contracts.....		
(2038)	Bridge Design.....	}	0 5
(2040)	Architectural Design.....		
(2042)	Lighting, Transmission & Distribution De- sign.....		
(2044)	Thesis.....		

During the summer months the officers specializing in Civil Engineering are assigned to practical work as the Bureau of Yards & Docks may direct.

D E S C R I P T I O N O F C O U R S E S .

Courses pursued at the Naval Academy.

101. Mathematics (a):

The course is partly review, and the order of topics is governed largely by the needs of other courses taken at the same time. One term, two periods per week.

Graphs of elementary functions by combinations of ordinates of simple curves. Meaning of derivative. Differentiation of elementary functions from explicit, implicit and parametric equations. Differential notation, meaning of integral as inverse derivative and as limit of a sum. Integration of polynomials and of transcendental functions. Solution of equations, algebraic, trigonometric, inverse trigonometric, and mixed functions, using graphical approximations when exact methods fail. Determinants and their uses in elimination. Analytic geometry of the straight line and conic sections; transformation of coordinates. Application of derivatives to curves and to maxima and minima. Polar coordinates, length of arc, curvature. Technique of integration; use of tables of integrals. Improper integrals, successive and multiple integrals, with applications.

Text books: The Calculus, Davis & Brenke, and A Short Table of Integrals, B. O. Pierce, supplemented by multigraphed notes on review topics.

102. Mathematics (b):

Continuation of Mathematics (a), One term, two periods per week.

Empirical equations, logarithmic plotting. Method of least squares, precision of measurements. The law of the mean, Taylor's theorem, indeterminate forms, power series. Demoivre's theorem; geometrical interpretation of complex quantities. Trigonometric series. Partial and total derivatives of functions of several variables, with applications. Fundamental notions of differential equations. Differential equations of first order, of first degree and of higher degree. Linear differential equations of higher order than the first with applications in mechanics and electricity. Special types of differential equations of higher order, solvable by elementary methods. Simultaneous differential equations in two or more independent variables, with applications to plane motion and electricity.

Text books: The Calculus, Davis & Brenke, with reference to tables and hand books, and supplemented by multigraphed notes on advanced topics.

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Lectures, references and problems. Principal reference book, Applied Mechanics, D. A. Low.

122. Applied Mechanics (b):

The course is a continuation of Applied Mechanics (a), one term, one period per week.

Flat plates; conical pistons. Stresses in curved members under eccentric loading. Resilience under tension, compression, shear, torsion and bending. Sudden loads, impact. Effort, acceleration and velocity diagrams; velocity and acceleration of reciprocating parts of direct acting engine. Piston and crank effort diagrams. Turning effort for multi-cylinder engines. Balancing reciprocating and rotating masses for single and multi-cylinder engines.

Lectures and references: The principal reference book is, Applied Mechanics, D. A. Low. Numerous problems and exercises are assigned.

123. Applied Mechanics for Ordnance Students:

This work is arranged to supplement the courses in Mathematics and Mechanics, with a view to the special needs of students in Ordnance. It covers one term, one period per week.

Theory of elasticity, Poisson's ratio, true stress. Analysis and distribution of stresses in thick cylinders under different conditions of external and internal pressure. Stresses in compound cylinders, determination of shrinkages, etc. Differential equations of first order and first degree, and of first order and higher degree, differential equations of an order higher than the first, with application to dynamics, special attention being given to preparation for study of exterior ballistics.

Use is made of Alger's Elastic Strength of Guns, of pamphlets by Winston and Nulton, and of multigraphed notes on differential equations.

151. Differential Equations of Electricity.

Summer work for Electrical Engineers. The work consists of lectures, assigned reading and problems, arranged to meet the needs of the electrical engineering group. Additional work in differential equations is given, with applications to alternating current electricity, and to radio telegraphy. Study of conditions for maximum resonance, and for sharpness of resonance in coupled circuits.

152. Advanced Mechanics; Summer Work for Mechanical Engineers.

Lectures, assigned reading and problems, arranged to meet the needs of Mechanical Engineers. Additional work in differential equations, with applications to dynamics of machinery. Theory of internal work, with application to deflections of framed structures and to determination of stresses in cases not statically determinate.

155. Mathematics:

This summer course for Naval Constructors and Civil Engineers is planned with careful attention to the preparation required for subsequent courses at the Massachusetts Institute of Technology and at Rensselaer Polytechnic Institute. It is largely concerned with functions of two or more variables, and their interpretation in solid geometry. Systems of coordinates in three dimensions; rectangular, polar and cylindrical. Solid analytic geometry of the plane, the straight line and simple surfaces and space curves, use being made of partial derivatives and their geometrical applications. Total differentials, with application to small errors or functions of several variables. Maxima and minima of functions of several variables. Multiple integration in rectangular, polar and cylindrical coordinates, with applications.

156. Mechanics:

The work of this summer course reinforces and supplements Mechanics 114, and completes the preparation required for courses in Applied Mechanics at the Massachusetts Institute of Technology. Graphical and other approximate methods of integration applied to areas, pressures, moments, work diagrams, etc. Fundamental force, momentum-impulse and work-energy equations applied to problems involving rotation and combined rotation and translation of rigid bodies. Harmonic motion; composition and resolution of harmonic motions. Fourier's theorem with applications.

201-202. Strength of Materials and Machine Design:

First term, one period per week; second term, one and one-half periods per week.

Analysis of the ultimate and working strengths of the ferrous and non-ferrous engineering materials, with special reference to Navy Department leaflet specifications. Analysis of stresses in machine parts of standard form under varying conditions of service and proportions of elements to resist resulting stresses.

In the study of machine parts, examples are taken from the latest available engine designs of the Bureau of Steam Engineering. Examinations are made of the strength and proportions of boilers, engine shafts, couplings and the action of reciprocating parts.

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Lecture course with accompanying drawing room periods.

Text used: Navy Department leaflet specifications, multi-graphed notes and Bureau of Steam Engineering Design and Data sheets.

203-204. Thermodynamics.

First term, two periods per week; second term, one period per week.

Study of the thermal properties of substances in general; of gases and of saturated and superheated vapors; analysis of the cycles for engines and turbines; flow of fluids and economy of engines.

Text books: Goodenough's Principle of Thermodynamics, and Marks and Davis Steam Tables.

205-206. Mechanical Engineering Laboratory:

Two terms, two periods per week.

Work covering the strength of materials in tension, compression, bending, torsion and impact; fundamental engineering measurements of temperatures, pressures, speed and power; tests under variable load of gasoline and oil engines, triple expansion and compound marine engines, turbo-generator, steam turbines and direct-acting feed pumps.

Student officers work in groups of three under the supervision of an instructor and reports of experiments are required in accordance with forms of correspondence and reports prescribed by Navy Regulations.

Reference books: Carpenter & Diederichs Experimental Engineering; Holmes, Experimental Engineering; American Society for Testing Materials; Specifications and others.

207-208. Steam Power Plant Machinery:

Two terms; One lecture and problem work requiring three or four periods per month.

Functions of boilers and general relations between boiler structure and heat absorption; arrangement of boiler surface to promote heat absorption and water and gas circulation; boiler furnaces, mechanical stokers, oil furnaces; compound and liquid and gaseous fuels; heat transfer apparatus, consisting of economizers, superheaters, feed water heaters, condensers and evaporators; performance of reciprocating engines and steam turbines;

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Nav. Acad.

relation of form and adjustment to minimum fuel consumption; gas and oil engine arrangements for power generation as distinguished from steam; use of liquid and solid fuels in explosive engines; mechanical refrigeration.

References: Gebhardt, Steam Power Plant Engineering, and multigraphed notes.

210. Elementary Thermodynamics, - Theory of heat engines.

The course is devoted to a study of the laws governing the transformation of heat into work, and the application of these laws to the processes in air, gas, steam, and other heat engines.

212. Valve Gears:

This work is intended to cover the following: Complete study of harmonic motion and piston motion graphically. Valve gears for simple non-reversing engines. Valve gears for variable load engines, including Corliss, Meyers, and other rider valve mechanisms. Valve gears for reversing engines, including link motions and Walschaert, Marshall & Joy radial gears. Cams for poppet valves for gas engines, etc. Slide valves for gas engines. Knight valve gear, etc. Crank effort diagrams.

Seven 2-hour periods, partly lectures and partly practical work at drawing board, are used. A 50 page pamphlet is issued on the subject, compiled from standard works on valve gears and original sources.

251. Practical Work at Experiment Station and Machine Shop:

For student officers pursuing design option, summer work consists in testing of machine apparatus and materials at the Engineering Experiment Station, including investigations on economy of boilers, fuels, auxiliary machinery, metallography, boiler room accessories, corrosion, boiler water treatment, lubricant testing and chemical investigations.

For student officers pursuing shop practices, this schedule is varied to allow additional time for machine shop, blacksmith shop and foundry practices and the study of practical systems employed in industrial establishments.

252. Shop Work:

Twelve afternoons during summer term.

Shopwork time will be available primarily for construction

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work in connection with the following courses: Electricity 353, and Physics Laboratory Problems 452; time not so used will be available for the study of the possibilities and limitations of machine tools under which head the following exercises are planned

1. Setting up of lathe and turning of one cylinder;
2. Turning flange, drilling,
3. Thread cutting,
4. Taper cutting,
5. Planer,
6. Shaper,
7. Vertical Drill,
8. Grinding,
9. Milling Machine (Facing
(Gear cutting.

The models worked on are not completed, but carried just far enough to illustrate the characteristics of the machine tool.

301. Theory of Electricity:

The course is designed to cover the elementary theory of direct current electricity. The course runs for one term, using one morning period and 1/2 afternoon period per week.

The subjects taken up in the morning hours are given below, the number in parenthesis indicating the number of periods devoted to them:

Definitions, Units, & Dimensional Equations (1); Coulomb's law (1); Terrestrial Magnetism (1); Magnetometer (2); La Place's Law (2); Magnetic Circuit (9).

A large number of problems are assigned in connection with the work of the morning periods. In the laboratory eight experiments are made by the officers working ordinarily in sections, two men to a section. These experiments deal with magnetometer, earth inductor, tangent, galvanometer, Ewing Hysteresis Tester, Koepsel Permeameter, Slide Wire Bridge, and Ballistic Method of Iron Testing.

Text books: Problems in Electrical Engineering by W. V. Lyon; Pender's American Handbook for Electrical Engineers.

302. Direct Current Electrical Engineering:

The course is designed to take up the engineering applications of electricity, particularly the direct current machines. The course runs for one term, using two morning periods and two afternoon periods.

The subjects taken up in the morning hours are given below the numbers in parenthesis indicating the number of periods devoted to them:

Magnetic Circuit and Magnetic Properties (4); Electrostatic Circuit (2); Electric Circuit (2); Kirchoff's Laws (6). Direct Current Machine Generation of E. M. F. (1); Armature Winding (4); Machine Characteristics (11); Commutation (2).

A large number of problems are assigned in connection with the work of the morning periods. In the Laboratory twelve experiments are made by the officers working ordinarily in sections, two men to a section. These experiments deal with Koepsel Permeameter, Carey Foster Bridge, Kelvin Double Bridge Conductivity Test, Insulation Resistance, Potentiometers, Electrodynamometer, Watt hour Meter, Armature Winding, Resistance Measurements on D. C. Machines, Magnetization Curves, external characteristics, brush shifting, compounding.

Text books: Problems in Electrical Engineering by W. V. Lyon; Pender's American Handbook for Electrical Engineers; Franklin & Esty, Vol. I, Direct Current.

Columbia University is prepared to continue this course from the point reached in the Post Graduate Department.

304. Alternating Current Electricity:

One term, two 2-1/2 hour morning periods per week. About one-fifth of these periods are devoted to laboratory demonstration of the subjects treated in the course.

This course deals with the transient state, the natural frequency state (radio) and the forced vibration state (ordinary commercial alternating current) of electric circuits; inductance and capacity; simple circuits; series circuits; parallel circuits; series parallel circuits; Kirchoff's Laws applied to A. C. circuits; polyphase circuits; "iron" circuits; and lastly, the transformer. A large number of problems illustrating the theoretical part of the course are assigned.

Text books: Same as for courses 301-302, except that Vol. II of Franklin & Esty is used.

351. Practical Work in Electrical Engineering Laboratory:

In the summer months laboratory and shop work problems are assigned from the following list:

Radio Station, practice in tuning and in code; Armature Winding Problems; Storage Battery Characteristics; A. C. Telegraph system as on the "MORENO"; Calibration of Bridge Boxes

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Nav. Acad.

for Department of Electrical Engineering & Physics; Repair of Galvanometers; Inductance Measurements, applied to tuning coils, setting up of recently purchased sechometer; Oscillograph practice, photography of rectified waves, arc method; Construction of a Radio Transformer; Further experiments with direct current machinery.

In addition there are trips to points of engineering interest in the vicinity.

353: Electricity:

This course is a continuation of course 301 and is carried far enough to furnish a preparation for courses 611, 667, 612, 684, given at Massachusetts Institute of Technology, and for courses 2015, 2018, at Rensselaer Polytechnic Institute. It will also include such parts of course 351 as may be suitable.

401. Physics of Heat:

This course gives a general survey of the theory of Heat. The course runs for one term and uses one morning period and one two-hour afternoon period per week.

In the morning periods the following subjects are treated, the numbers in the parenthesis indicating the number of periods devoted to them:

Units (2); Heat Transmission (4); Mechanical Equivalent of Heat (2); Expansion (6); Latent Heat (1); Miscellaneous Heat Effects (1).

Bearing on these subjects a set of problems is assigned once a week.

In the laboratory, experiments are made as follows:

Expansion of Water; Expansion of Glass; Mechanical Equivalent of Heat; Electrical Equivalent of Heat; Latent Heat; Conductivity of Copper; Resistance Thermometer, and Thermo-electric Couple.

Text Book: 1914 Edition of the Smithsonian Physical Tables.

402. Physics of Heat:

This is a continuation of course 401 and is allotted the same amount of time.

The additional subjects treated in the morning periods are: Miscellaneous Heat Effects (3); Vapor Theory (3); Partial Pressure (2); Radiation (2); Heating & Cooling Curves (2); Calorimetry (2); and Thermometry (2).

The additional experiments performed in the laboratory are: Variation of Boiling Point with concentration of solution; Specific Heat; Thermometer Stem Correction; Vapor Pressure of Water by two methods; Gas Thermometer; Hygrometry by three methods; and Radiation.

Text book: 1914 Edition of Smithsonian Physical Tables.

403. Physics of Sound and Light:

One term.

Twenty-six periods of the first term are assigned to the study of Sound and Light. Sixteen of these periods are used in the class room for theoretical instruction and recitation. Ten periods are devoted to experimental work in the laboratory. The subjects considered both in class room and laboratory are indicated below.

Sound: Wave motion; Production and propagation of sound waves in gases, liquids and solids; Bells, tuning forks, organ pipes, whistles and vibrating strings; Pitch and intensity of sound waves; Reflection, interference, resonance, echoes, voice tubes.

Light: Production and propagation of light waves; Analysis and differences of water waves, sound waves and light waves; Reflection of light from plane and curved surfaces; Formation of images by mirrors; Photometry; Standards of light; Use of different photometers; Best lamps for different purposes; Refraction of light; Measurement of index of refraction; Total reflection, critical angle; Use of totally reflecting prisms; Dispersion of light; Achromatic combination of prisms and lenses.

Optical Instruments: Spectrum Analysis; Interference and diffraction; Color phenomena; Polarization and double refraction; Saccharimetry; Florescence and phosphorescence; Cathode rays, X rays; Radio activity.

Text books: Text book of General Physics by Ames; Practical Physics by Glazebrook and Shaw; Practical Acoustics by Barnes; Light for Students by Edser.

452. Physics Laboratory Problems:

Twelve afternoons during summer term.

The officers will work in sections of two or three and will spend all their time on problems similar to the following:

Problem (1). Thermal conductivity by Angstrom's Method. One end of a bar is alternately heated and cooled and after a time waves of temperature disturbance travel regularly along the bar. The rate of progress at different points and the rate of diminution in the amplitude of the disturbance yield data for calculating the conductivity. See Phil. Trans., A., Part I, 1895, p. 165. Apparatus to carry out this method is to be constructed.

Problem (2). Construction of Thermo-Rectifiers for measuring high frequency electric currents of small magnitude. To follow work done at radio department of Bureau of Standards.

501. Chemistry:

Practical Work. Tests of common mineral acids; Qualitative Analysis, including preliminary experiments and examination of unknown mixtures for acids and for metals; Qualitative analysis of boiler scale; Qualitative analysis of alloys; Principal common tests applied to oils, e.g., flash point, boiling point, specific gravity, distillation test, viscosity, etc.; Preparation of normal and other standard solutions for use in analysis of feed water; Quantitative examination of feed water for total solids, per cent normal alkalinity, and chlorine contents; Quantitative proximate analysis of steaming coal for moisture, volatile combustible matter, fixed carbon, and ash, and determination of its calorific value; Quantitative analysis of flue gases, and use of the Orsat apparatus.

In addition to and in connection with the above, a brief course of parallel reading is prescribed.

Note books on laboratory work are kept and submitted.

Lectures on topics assigned are prepared by student officers, one lecture by each, and one lecture on each topic is delivered by its author before the other members of the class.

Text books and references: Stoddard's Qualitative Analysis; Cairns Quantitative Analysis; Newth's Manual of Chemical Analysis. Reading prescribed in Fresenius' Quantitative Analysis, Remsen's Elementary Chemistry, Remsen's Organic Chemistry, Oswald's

Fundamental Principals of Chemistry. Prescribed references to a large number of standard books on various lines of work in connection with practical work and with preparation of lectures by student officers. Sheets on qualitative analysis and on all other practical work prepared by the Professor in Chemistry (about 12 in number) and served out to each student officer, these of the nature of explanation and directions.

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Courses pursued at Columbia University.

Phys. 52. Conduction of Electricity in Gases:

Fundamental theory of electricity. Electronic theory of the conduction of electricity through metals and through gases. Discussion of the laws of the passage of electricity through gases. Action of electrons. A study of the vacuum tube, mercury vapor arc and corona effect, effect of temperature and pressure.

E. E. 101. Management of Electrical Machinery:

The selection and application of electrical machines for particular purposes from the view point of the Consulting Engineer. Methods of operation, testing; consideration of efficiency; regulation, specifications, standards, costs, weights and speeds; shunt and compound generators, shunt and series motors, motor generators, boosters, balancers, storage batteries.

Reference book: American Handbook for Electrical Engineers.

E. E. 102. Electric Motors:

Abbreviation of course E. E. 103 for Mechanical Naval Officers.

E. E. 103. Electric Motors, Control and Application:

Statement of forms and types of direct and alternating current motors encountered in practice. Shunt Motors - Characteristic curves, factors influencing speed. Methods of speed control, rheostatic, multiple - voltage, double armature, motor generator equipments; field control such as interpole and compensated types with typical numerical problems to bring out each feature. Series Motors - characteristic curves, speed control and regulation. Compound Wound Motors - characteristic curves, methods of regulation. Synchronous Motors - single phase and polyphase, theory of operation, methods of synchronizing, starting torque, action under load changes, characteristic

curves, operative-curves, phase curves, etc., hunting, etc.; with problems to bring out characteristic features. Induction Motors - Polyphase and single phase; development of rotating magnetic field, types of field or stator winding, types of rotors, theory of motor showing how voltage, rotor resistance, frequency etc. influence same; methods of starting for squirrel cage motors - such as compensator and Boucherot windings, slip ring or wound motor control. Circle Diagram predetermination; method of computing starting resistance, etc.; speed regulation of induction motors - analysis of pole changing, frequency changing, resistance control cascade connection, etc.; methods of starting single phase induction motors, comparison of same with polyphase. Single Phase Commutator Motors - discussion of series, repulsion and shunt induction types; modification of design to overcome inherent difficulties, compensating windings, resistance leads etc. Applications of Electric Motors - The general characteristics of speed and torque requirements met in practice and typified by line shaft drive, weaving, printing, ventilating, traction, propulsion, pumping, hoisting, drilling, punching, etc.; with statement of which type of motor best satisfies each form of requirement, method of motor control and connection to be recommended. The various topics considered are amplified by numerical problems.

Reference book: Electric Motors by Crocker & Arendt.

E. E. 105. Alternating Current Engineering:

The laws of alternating current circuits having resistance, inductance and capacity; calculation of A. C. distributing and transmission lines, single phase and polyphase; theoretical and commercial characteristics of generators; transformers; synchronous motors with problems in regulation and efficiency; measurement of voltage, current and power in polyphase systems.

Reference books: American handbook for Electrical Engineers, and Jackson's Alternating Current Engineering.

E. E. 106. Alternating Current Engineering: "Electric Plants":

The functions and relations of the various pieces forming part of a complete alternating current power plant, transmission and distribution system; prime movers, generators, switchboards, transformers, lighting protection, transmission line, substations, regulation and control of systems; costs, operating expenses, sources of income, methods of charging for energy - illustrated by visits to commercial installations and plants in the vicinity.

E. E. 108. Plant Visitation (Optional):

Visits of inspection to power plants, factories, telephone exchanges and other institutions where electrical apparatus is operated under conditions of commercial operation.

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E. E. 109. Telegraph Engineering:

Historical development of methods of signalling semaphore, flag, heliograph and electromagnetic. Code, The Morse telegraph: circuit, operation and apparatus, open circuit and closed circuit arrangements. Keys, automatic senders, sounders, relays, switchboards. Repeaters: semi-manual and automatic such as Milliken, Atkinson, etc. Duplex Telegraphy: - Theory, circuits and operation of single current and polarized arrangements. Duplex Telegraph: - Theory, circuits and operation. Quadruplex: - Theory, circuits and operation. Multiplex repeaters: Theory, circuits and operation. Submarine Telegraphy: automatic senders, mirror and siphon records, cables, artificial cables, etc.

Mech. 109-110. Theory of Electrical Circuits and Alternating Current Machines:

A discussion of the fundamental laws of variable currents and a mathematical treatment of the physical relations between potential current, the magnetic field and the electrostatic field in alternating current circuits. The application of these principles to the transformer, induction motor and other apparatus.

E. E. 110. Telephone Engineering:

Historical development of means for transmitting speech, Bourseal, Reis, Bell, Gray, Hughes, etc. Development of transmitters, receivers, etc. Musical notes and speech contrasted. Receivers: electromagnetic, considerations of designs, mechanical and magnetic adjustment, need of permanent magnets, bipolar types. Transmitters: action of transmitter, carbon type, single contact - Blake, multiple contact and granular type - White, packing, heating, etc. Induction coils - need of same for transmitter circuits. Signal Apparatus - magneto - A. C. and pulsating. Bell: A. C. and Biased. Connection of signal apparatus in series and in bridge or multiple. Automatic hook control of subscribers equipment. Subscribers Equipment - local battery sets, connection of parts and combined functions, connected for series and bridge or multiple circuits. Lines - grounded lines, metallic lines, electromagnetic disturbances from power lines, cross talk, etc., electrostatic disturbances, atmospheric etc. Transposition of lines, stranded pair cables, etc. Telephone Exchanges: Local battery systems, function of exchange, equipment of exchange, function of parts, multiple boards, answering jacks, multiple jacks, busy test, etc. Common battery system: advantages of same, typical cord circuits, Stone, Hayes, Dean, Kellogg, etc. Subscribers Equipment Common Battery System: Exchange Common Battery System - signals such as calling, ring off, supervisory, cord circuits, ringing keys, etc., function

of parts and procedure, multiple boards and transfer systems, comparison of methods. Party Line Signalling - non-selective and selective, such as harmonic, biased bell and step by step. Private Exchange Board - parts, function and operation. Combined telegraph and telephone lines. Intercommunicating systems. Ordinary house circuits, common battery system, selective arrangements, etc.

Reference books: Maver's American Telegraph Practice and Miller's American Telephone Practice.

M. E. 117-118. Engineering Thermodynamics:

Laws of heat generation by combustion; Heat transfer and transformation into work; Relation between temperatures and quantities of heat; Units of heat; Effect of heat on solids, liquids, gases and vapors. Laws of heat transfer. Laws of surface evaporation, ebullition and condensation. Properties of saturated and superheated vapors. Combustion of fuels, calorific power, quantities of air for combustion. Temperature of combustion. Boiler efficiency and conditions affecting. Principles of chimney draft. Laws of expansion and compression of gases. Work and heat diagrams to pressure volumes and temperature entropy coordinates. Air and wet vapor compression. Expansion of steam by hypothetical adiabatic and saturation laws and application to steam engine efficiency. Missing water in steam engines. Influence of cylinder condensation, re-evaporation, steam jackets, initial superheat, compounding and reheat- ing on steam engine efficiency. Relation of boiler and engine performance. Free expansion laws and application to injector and steam turbine nozzles. Heat transformation by perfect gases. Hot air, gas and oil engine efficiency. Mechanical re- frigeration. Effects of evaporation of ammonia and carbonic acid and expansion of air. Heat balances and combined ef- ficiency of complex systems.

M. E. 119-120. Machine Analysis and Design:

Determination of the forces acting on each member of a machine in motion, on the machine as a whole and on the most stressed part of each individual member. Relation of the various forces and motions to the function of the parts, their materials, dimensions, strength, rigidity and life. Effort is concentrated on the demonstration of broad inclusive principles and methods of determination rather than on accumulation of large numbers of isolated facts, and while these principles are applied to all sorts of machines the principal illustrations for drill are taken from power generating and auxiliary equipment. Both of the analytic and synthetic methods are used, but more importance is

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Columbia.

attached to analysis and interpretation of existing successful practice than to the development of skill in synthetic designing. The presentation of the subject matter is largely by lecture, though constant reference is made to selected parts of existing tests, professional papers, blue prints and data sheets of experienced machine designers, as illustrative or contemporaneous material, and as the basis for the numerical problems that occupy the bulk of the student's time. Examination of machines to determine the nature and distribution of the forces acting on, and the resulting stresses and strains in each element, due to kinetic and structural conditions. Selection of working stresses for parts subject to steady, repeated and reversed stresses. Selection of materials based on adaptability to service and to the shop. Proportions of parts subjected to tension, compression and shear; bending and torsion; combined bending and tension, torsion and compression, buckling action and stresses due to eccentric loading and complex supports. Illustrations from designs of complete machines and their details, crank and turbine shafts, machine frames, housings, connecting and reach rods; gear wheels, pulleys, flywheels, turbine discs and drums; rings, riveted joints, thin and thick cylinders, braces and stays, flat plate members, pressure joints, screws, belting, rope and chain drives for power transmission. Bearing surfaces, flat, cylindrical, pivot, ball, roller, thrust. Application of theory of elasticity to the more complicated elements. Determination of turning efforts for single and multi-cylinder engines and analysis of uniformity of speed by angular variations per cycle. Analysis of the static and dynamic force relations in engines with reference to the influence of reciprocating masses, and the determination of forces tending to shake and rock the engine and its bed. Balancing of engines by counterweight and by spacing of crank angles according to the methods of Taylor and Schlick.

M. E. 122. Gas Power.

Fundamental ideas of the gas power system of generating power; the gas cycle; the engine mechanism for executing the cycle, and the auxiliary mechanism for preparing fuel and controlling internal combustion. General analysis of status of the gas power as compared with the steam power system. Types, sizes and performance of standard gas power equipment on all fuels and general trend as evolved from historical review and analysis of present successes or failures. Gas cycles thermodynamically analyzed, and compared with indicator cards and test data, determination of efficiency factors and diagram factors and diagram factors, prediction of horsepower and fuel consumption, empirically and rationally, for all sizes, speeds and types on any fuel. Properties of fuels and combustible fuel mixtures, with special reference to explosive gaseous mixtures, apparatus for mixture making, mixture property limitations to engine performance. Preparation of liquid fuels, carburetion,

Des.

Columbia.

vaporization and spraying, with analysis of apparatus; gasoline, kerosene and heavy oil engines on explosive and non-explosive cycles. Preparation of solid fuels by gasification; review of roasting distillation and of fixed carbon gasification with air and steam. Fixed carbon reactions and the thermo-chemistry of the performance of coke producers, rational analysis of test data. Producer structure for coke, good and bad practice, special modifications for bituminous coal, the coking coal problem. Gas cleaning, dust and tar control and gas producer auxiliaries. Gas engine structures, general analysis of reasons for modern types, their good and bad features. Engine frames, cylinders, jackets, liners, heads, valves and valve location, valve gear and controls, rotating and oscillating cams, springs, cam shafts, and drives, pistons, piston rods, stuffing boxes, cross-heads, auxiliary jacket systems. Liquid fuel injection and electric ignition systems, engine starting, and exhaust muffling systems. Comparison of stationary vs marine use, large and small; the automobile and aero motors.

While a text, such as Guldner or Clerk & Burls, is used, it is not rigidly followed. The general order of treatment and point of view is that of the lecturer who corrects text errors, supplies omissions and assigns reading in other books, professional papers and trade literature. Approximately half the time is devoted to computations, aside from the afternoon work in the laboratory, which is devoted to experimental demonstrations of some of the basic principles.

Met. 131. Metallurgy of Iron and Steel:

Manufacture of iron and steel. Blast furnace. Puddling. Cementation. Crucible process. Bessemer process. Open hearth process. Statistics. Iron and steel casting. Effect of heat treatment. Effect of mechanical treatment. Malleable cast iron. Standard specifications. Constitution of iron and steel. Relation to physical properties. Change of structure with heat and mechanical treatment. Alloy steels. Corrosion.

M. E. 131-132. Standard Tests & Experimental Research Methods:

Methods of approach for the solution of new problems concerning the performance of power generating and auxiliary machinery, requiring experimental determination. While the work is done wholly with existing standard apparatus, the operating characteristics of which are determined by test and then analyzed by the aid of the basic thermodynamic or hydraulic laws, the stress is laid on the interpretation of results rather than on their determination, and the methods employed are such as to lead to experimental development of improvements and new equipment. As all experimental conclusions rest primarily on the accuracy of the observations and on the soundness of the reasoning by

When conclusions and interpretations are reached, the initial effort is concentrated on an analysis of existing instruments and direct methods of measurement by lectures and laboratory drill, based on the material of text "Experimental Engineering" by Carpenter & Diederichs, instrument makers' bulletins and the experimental papers of the professional societies. Special attention is devoted to indirect determination of important quantities that cannot be directly measured and in this way the judgment in interpretation is developed. The research method is followed throughout, which provides drill in interpretation. Each problem is undertaken as if its solution were entirely unknown, and the first step is a required preliminary report, which shall analyze the problem into its elements, reviewing whatever information can be found relating to each and proposing in detail a plan for the conduct of tests to find the missing elements. After the test the final report begins with the log of observations, followed by the calculations of derived quantities, an estimate of probable precision, and ends with the answer sought and the interpretation. The principal topics include, flow of liquids, gases and vapors in pipes, flues, valves, nozzles; efficiency and capacity of steam boilers, piston steam engines, pumps, fans, compressors and ice machines with analysis of all losses.

I. E. 139-140. Machine Analysis and Design:

Same as outlined in courses 119-120.

I. E. 150. Steam Turbines:

Effect on the turbine performance of general arrangements, proportions of parts, and service conditions, for all classes. Review of Rankine cycle and use of temperature entropy and Mollier diagram methods of determining jet velocities. Nozzle reheat and efficiency factors; flow weight laws, rational and empiric, and nozzle energies for all conditions. Essential relations between jet velocity and wheel speeds for all shapes and arrangements. The problem of economy and size vs rotative speeds; the geared system, the various multi-stage systems and the turbo-electric system, general comparative survey, followed by detailed analysis of each in turn for both large main units and small auxiliaries. Impulse turbines, single stage, compartment compounded and multi-pressure-velocity compounded types. Reaction and combined reaction and impulse turbines, disc or drum, single or double flow, all types of construction. Analysis of principal dimensions and performance of each class, evaluation of all energy losses by direct and indirect methods, nozzle and vane friction, windage, bucket spilling, leakages. Nozzle and vane constructions, bearings, packing, end thrusts and rotor clearance,

Des.

Columbia.

controls, wheels, shafts, bearings, casings; governors, by-passes, chamber drainage. Low pressure turbines, bleeder turbines, reversing turbines and other specials. The general position of the turbine in comparison with the reciprocating engine. To a considerable extent a text such as Martin or Stodola is followed, but frequent departures are made and a considerable part of the time is devoted to numerical problems and all the afternoon work is of this character.

M. E. 152. Organization and Management:

Fundamental relations between the human and the physical factors in production, and between the elements of organization and those of management. Organization for reproduction of output or function, typified by manufacturing, compared with each other and with organizations for new or emergency conditions. Efficiency of industrial organizations, measured by costs. Nature of costs, analysis of cost elements and possibilities of reduction or inflation of both the quantity and the price factor of each cost element. Accounting principles and cost data collecting systems. Capital, labor and material classifications. Relation of capital charges to efficiency of processes, physical equipment and other factors. Relation of material charges to design, purchase and control of wastage. Relation of labor charges to efficiency of the individual and the physical equipment. Analysis of human efficiency. Efficiency systems and the labor problem. Systems of organization and management analyzed and compared with typical specific examples.

Lecture presentation is mainly relied upon because of the absence of a suitable text, but several books are referred to for specific topics which are then critically analyzed by the lecturer, and many professional papers are assigned for reading and subsequent appraisal.

E. E. 153. Design of Direct Electrical Machinery:

Application of theory and practical data to the design of generators and motors.

Reference book: American Handbook for Electrical Engineers.

E. E. 154. Design of A. C. Machinery:

Application of alternating current theory and practical data to the design and calculation of alternators, transformers, induction motors, etc.

Reference book: American Handbook for Electrical Engineers.

Des.

Columbia.

M. E. 155. Shop Processes & Machine Tools:

Review of the methods and equipment of the shop with special reference to the comparative economic value of alternatic methods of doing the same job, and with some reference to ordinary and emergency repairs. Some familiarity with the common appliances, tools and practices of the pattern shop, foundry, forge, plate or structural and machine shops is assumed, but this is made a subject of review, followed by a critical analysis of the value of each. The subject matter is presented largely by lecture because of the absence of adequate texts, but reference is made to the publications of the tool manufacturers, to papers in professional journals and transactions of the Engineering Societies, and afternoon visits are made to successful shops where each of the important things discussed may be inspected in operation. The principal topics include the following:- pattern shop material and tool equipment; wood turning lathe, band, swing and circular saw, jointer, surface planer, core box machine and hand tools. Pattern types, drafts, shrinkage and finish allowances, wood and metal patterns, cores, core boxes and core ovens. Foundry practices, sands, sand mixtures and facing materials, molding tools and molding machines; types of molds. Foundry cupolas, melting furnaces and crucibles; iron, steel, brass and soft metal casting, special precautions for sound castings. Malleablizing and case hardening of castings. Wire, tube and sheet metal drawing. Forge shop practices; furnaces for heating, annealing, tempering and welding, fired by coal, oil, gas and electrically heated. Blacksmith's hand tools and typical hand forging. Limits of forging material, irons, carbon and alloy steels. Steam hammer and anvils, drop hammer, forging dies, bulldozers, bolt and nut forging machines. Flanging presses. Pipe bending. Welding, common, autogeneous and electric. Tool making and tool room practice. Grades of tool steel. Riveting, hot and cold, hand, hydraulic, and air tools. Machine shop laying out and measuring tools, precision gauges. Hand cutting tools. Machine tools for cutting, all classes. Feeds, speeds and cuts, power requirements and typical drives, line shaft, group and individual. General principles of cutting metals and characteristics of each class of tools. General round work inside and outside, straight and taper, in lathes, drills, boring mills and grinders; flat work in millers, shapers, planers and grinders, machine tools for cutting gears, slots, threads, cams and other shapes. Semi and complete automatic tools and jigs for rapid reproduction. General arrangement of shops for jobbing or repair work and for manufacturing, with examples. Typical and special auxiliary shop requirement and building construction.

Des.

Columbia.

Met. 155. Metallographic Laboratory. Iron & Steel and Industrial
" 156. Alloys.

Methods of examination. Comparison of good and bad material; wrought iron, low carbon steel, structural steel, rail and steel, tool steel, etc. Examination of brasses, bronzes, bearing metals and other industrial alloys. Relation between chemical composition, physical properties and microstructure.

E. E. 171. D. C. Electrical Apparatus:

A course given to Mechanical Engineers, similar to E.E. 101.

E. E. 173. Direct Current Machine Laboratory:

Operation and testing of shunt, series and compound wound generators; distribution of potential around commutator and study of distortion of field; function and operation of starting boxes; operation and testing of shunt, series, compound and differentially wound motors; determination of speed and efficiency curves by various methods; operation of shunt and compound wound generators in parallel; methods of distributing load and effects of individual differences; heat runs to determine capacity by various methods; characteristics of series boosters and balancer sets.

Text book: Mimeograph Instructions.

E. E. 176. Alternating Current Machine Laboratory:

Determination of inductance, capacity, impedance, phase relations, true and apparent power and power factor in single phase and polyphase alternating current circuits; investigation of wave shapes and phase relations of voltage and current by instantaneous contact ondograph and oscillograph. Tests for the characteristics of alternators, synchronous motors, synchronous converters, transformers, induction motors, single phase commutator motors.

Reference book: Laboratory Manual of Alternating Currents by Morecroft.

E. E. 178. Standardizing Laboratory:

Determination of inductance and electrostatic capacity by the Absolute and Bridge Methods. Testing of iron for permeability and the separation of eddy and hysteresis losses. Insulation and dielectric strength tests. Study of insulating materials. Study and test of commercial types of storage batteries under conditions of practice. Study of commercial methods

Des.

Columbia.

of metering voltage, current, power and energy in D. C. and A. C. circuits. Characteristics of commercial meters, their weaknesses and probable error. Calibration of D. C. and A. C. meters in accordance with commercial methods.

Mimeograph Notes.

E. E. 201-202. Seminar, Electricity on Ships:

A detailed study of the electric circuits and apparatus of all kinds on board naval vessels, illustrated by official drawings of certain definite vessels; the various classes of electrical machinery are taken up separately and a complete report written up on each class or type. This report includes a description of the apparatus, a discussion of its method of operation, diagrams of the method of connection and a discussion of the possible troubles and methods of correcting the same. In addition to the minor apparatus on ship-board, the subject of electric steering gear, gyroscopic compass and electric propulsion are studied. A complete design of the generators, motors and control apparatus for electric propulsion of a battleship is included.

E. E. 211-212. Radio Engineering Laboratory:

The aim of this course is to make the student, specializing in radio work, thoroughly familiar with the theory and operation of the various types of sending and receiving apparatus used in radio communication, with the adjustments and tests necessary in making comparisons of various systems and with the special instruments used in radio work. The theory and laboratory work covers derivation and experimental proof of the formulae used in calculation of inductance, capacity, resistance, resonance in simple and coupled circuits, including effects of resistance, coupling, mistuning, etc.; measurement of wave length and decrement by various methods, including the oscillograph; adjustment of quenched spark sets and continuous wave sets; comparison of various detectors, with special work on continuous wave receiving systems, recently developed in this laboratory.

E. E. 214. Radio Engineering Laboratory:

Abbreviated course, for students not specializing in radio work, consists of a course of experiments designed to familiarize the student with the adjustment and operation of sending and receiving apparatus. The work covers the phenomena of resonance in simple and coupled circuits, measurements of wave length and decrement, various connection schemes used in sending and receiving apparatus, comparison of detectors, adjustments of quenched spark and continuous wave sending sets, etc.

Des.

Courses pursued at Massachusetts Institute of Technology.

Ec. 31. Political Economy:

A course of three hours a week in the first term of the senior year, involving lectures, discussions, and written work. The course is elementary, with special emphasis upon descriptive economics.

M. 37. Mathematics: (Advanced Calculus & Differential Equations):

A course of four hours a week during the first term, covering the following subjects: Taylor's Formula with applications to approximations in calculation and analysis, complex numbers, vectors, differential equations of the first order, linear differential equations, total and partial differential equations, with numerous applications to geometry and physics.

M. 38. Mathematics: (Advanced Calculus & Differential Equations).

This course of thirty exercises in the second term treats the following subjects: Line and surface integrals, vectors, functions defined by integrals, the elements of the calculus of variations, differential equations of physics.

E. 39. Public Speaking:

The course in Public Speaking consists of thirty exercises and fifteen hours of preparation in the first term. It takes the form largely of individual training, and aims to cover the use of literature and reference books, and the preparation and delivery of at least one original address.

Ec. 41. Economics and Corporations:

A course of two lectures a week in the first term of the graduate year. It treats of the nature of corporations and their legal development, accounting, valuation of bonds, holding companies, lighting companies, street railway franchises, and the taxation of corporations.

M. 57. Hydrodynamics:

This course consists of twenty lectures during the second term in which the fundamental equations of Hydrodynamics are developed and applied to the solution of particular problems.

Des.

M. I. T.

ec. 60. Business Law:

Fifteen lectures, given in the second term of the graduate year. The course consists of a general treatment of the subject of business law, such topics as the definition of law, its sources, the distinction between law and equity, and the application of law to business contracts being considered. To the last of these topics the most thorough treatment is given, that being the form of business law with which the students will have most to do in their professional work.

145. Theory of Structures:

This is a specialized course arranged for the Naval Constructors, and consists of forty-five lectures during the second term of the graduate year, together with about sixty hours in the drawing room. It is intended to give an outline of the methods of computing and designing structures, with the object of enabling the students to meet the simpler structural problems arising in the design of ships.

216. Applied Mechanics (Strength of Materials):

A course of forty-five lectures (or recitation), during the first term of the junior year.

This course comprises a study of the strength of materials, including the stresses and deformations in bodies subjected to tension, to compression, to shearing; common theory of beams with thorough discussion of the distribution of stresses, shearing forces, bending moments, longitudinal shear, slopes, and deflections; stresses in hooks, in columns, and in beams subjected to tension or compression as well as bending; torsional stresses and stresses in springs.

226. Applied Mechanics (Strength of Materials - Graphic Statics).

A course of thirty lectures, or recitation, in the second term of the junior year.

The course includes the study of the methods of the design of riveted joints; a mathematical treatment of the continuous girder, planned to apply to parts of machinery and structures where continuity exists; a study of the methods of treatment of non-homogeneous beams and particularly of the theories underlying the design of reinforced concrete structures. The student is required to solve a considerable number of problems illustrating the application of the fundamental principles dealt with in this portion of the work. The course also includes a study of the general methods of Graphic Statics with applications to

Des.

M. I. T.

the determination of stresses in roof trusses and other framed structures, and to the determination of the stability of masonry arches and abutments. A number of problems illustrating these principles are worked out by the student on the drawing board during this part of the course.

229. Applied Mechanics (Stability of Structures - Strength of Materials.):

A course of forty-five lectures, or recitations, in the first term of the senior year.

The course comprises a study of experimental data on the strength of materials with especial reference to tests on full sized beams, columns, shafting and other pieces under practical conditions; of experiments to determine the effect on physical properties of different materials of varying conditions of stress, of temperature, and of treatment; and of standard specifications for the composition and physical properties of the different materials used in construction; also of the study of the methods of testing the friction reducing power and other properties of lubricants and data in regard to coefficients of friction and losses due to friction.

The course also includes a study of the construction of simple forms of roof trusses, girders, and arches; the stresses in suspension cords; the theory of curved beams and applications; and the derivation and use of the formulas for the stresses and strains in shafting subjected to combined bending and torsion, thick cylinders and spheres, and flat plates. A considerable number of problems, illustrating applications of these principles in practice, are solved by the students in this course.

235. Testing Materials Laboratory:

A course of thirty hours, laboratory and preparation, in the first term of the senior year.

The tests made by the students in the Test Materials Laboratory vary somewhat from year to year but include tests to determine the modulus of elasticity, limit of elasticity, yield point and tensile strength of steel bars, commercial tests on steel bars; tests of the deflection and of the transverse strength of a full-sized iron or steel I-beam, or of a wooden beam subjected to a transverse load; transverse tests on cast iron; tests to determine the modulus of elasticity and the tensile strength of wire; torsional tests of wire; tests to determine the shearing modulus of elasticity and torsional strength of 2-inch steel bars; tests on cement mortars including sizes of ropes and of different knots used in fastening ropes; tests to

Des.

M. I. T.

determine the ratio of the modulus of rupture to the tensile strength in cast iron and steel; the crushing of timber.

246. Heat Engineering:

A course of sixty lectures extending through the year on Thermodynamics and the mechanism of the steam-engine, especially adapted to the needs of Naval Constructors.

This course includes a detailed study of the principles of thermodynamics; a discussion of the properties of gases, saturated and superheated vapors, especially of air and steam; of the flow of fluids through orifices, nozzles, pipes and meters, a discussion of the action of the steam injector; a study of the various cycles of the hot air, internal combustion, and steam engines, of the turbine, air compressor, and refrigeration systems. These engineering applications are treated from the physical, analytical and graphical points of view, so as to give the student a good foundation in the principles of thermodynamics, not only as applied to the discussion of ideal cases, but also in the solution of actual heat engineering problems. The course also includes a study of the simple, compound and multiple expansion steam engine, of the different types of gas engines, of the gas producer, of compressed air and refrigerating machines, and the methods of testing such machines. A careful study of the mechanical and various thermal efficiencies is made from data based upon reliable tests made on steam engines and turbines, gas engines, compressors and refrigerating systems. The mastery of principles and the discussion of data are much simplified by an extensive use of both the pressure-volume and the temperature-entropy diagrams. The theoretical work of the course is paralleled by a suitably graded set of drill and engineering problems to be solved independently by the student. The subjects of steam boilers and gas engines are treated at considerable length. Several lectures are given on condensers, air pumps, and the various accessories of a steam plant.

251. Internal Combustion Engines:

This course of twenty lectures, or recitations, is given in the second term.

Internal combustion engines of all kinds are discussed with reference to mechanical details of design required by the various fuels and conditions of operation. About a third of the course is devoted to oil and gasoline engines, including the types applied to marine propulsion. The lectures are illustrated by lantern slides, photographs and drawings.

Several text books are used for reference, but most of the reading is assigned from current articles in the technical press and transactions of engineering societies.

261. Engineering Laboratory:

This is a course of four hours a week throughout the year.

The work can be best illustrated by the following list of tests made by the students during the past few years: Test to determine the efficiency of chain drives; Tests of the transmission of power by belting; Tests of the performance of a surface condenser; Tests of a duplex steam pump 16, 10-1/2 x 12; Tests to determine the accuracy of planimeters; Tests of a 36-horse power gas engine; Tests to determine the efficiency of pulley blocks; Tests of the flow of steam; Valve setting (plain slide valve); Tests of a pulsometer; Calibration of orifices for the flow of water; Determination of the clearance of an engine; The use of the Emerson power scale; Valve setting (double valve); Tests of gauges, steam and vacuum; Tests of the steam injector; The use of three different kinds of calorimeters; Tests of a Humphrey turbine; Tests of a rotary pump of a capacity of 1,000 gallons per minute; Measurements of the flow of air; Tests of the water injector; Tests of 36-inch American impulse wheel; Tests of an air pump; Tests on coefficient of friction; Moment of inertia of connecting rod; Tests of three-stage air compressor, 2,500 lbs; High temperature measurements; Heat of combustion of coal; Measurements of the flow of water by means of orifices and weirs; Test of a 48-inch Pelton water wheel; Tests of a Rider hot-air engine; Valve setting (Harris-Corliss engine); Analysis of chimney gas; Explosive force and time of reaching maximum pressure of different mixtures of gas and air; Tests of a hydraulic ram; A 120-hour plant test on engines and boilers at the Institute; Tests on a centrifugal pump 40-horse power input; Tests on an Emerson pulsometer pump; Tests on a dry-air pump; Tests on a 500-kw. Parsons turbine so arranged as to give the pressure at each barrel of each stage; Tests on one or more types of gasoline engine; Tests on a 25-car train of Westinghouse air-brakes; Tests on a 150-kw. Curtis turbine; A 120-hour continuous test on a battery of Babcock & Wilcox boilers of 1,000 boiler horse power, together with a plant test on the engine used in the Institute power plant.

The method of conducting the laboratory tests is as follows: Tests are made under the direction of seven instructors, three students generally working together on one test. As the students are applying in their laboratory work knowledge they have already gained in the class room it is necessary only for the instructors to explain the arrangements of piping and connections for any piece of apparatus before beginning work. This makes it possible for a great deal of valuable laboratory work to be done in a period of two hours. Each student in his turn is put in charge of the tests made by that group. Whenever it is safe, the students are made to start the apparatus and do all the work of getting ready for the test. Each student writes a complete report of the test, giving the arrangements, methods of testing, with details of computation. The observations taken on every test are returned to the instructor, who works up the test and critically

tion with his own.

274. Industrial Management:

This course of fifteen lectures in the second term of the graduate year includes a study of the organization and relations of the various departments of an industrial establishment; the location, arrangement, construction and equipment of industrial works for efficiency and economy in manufacturing, efficacious conditions for labor, process mapping and routing, scheduling of work, classification of metal working plants and the machine shop problem, the office and engineering department, forms of industrial organization and differentiation of responsibility, reports, methods of superintendence, employment and cost of labor, systems of compensating labor, and a discussion of the effect on cost of different systems of distributing indirect expenses, and current methods of "efficiency engineering".

332. Metallurgy of Engineering Materials:

This is a course of forty-five exercises in the second term of the junior year.

Its aim is to make the engineer familiar with the industrial use of fuels, with the production of the metals and alloys used in construction, and the effects foreign constituents have upon them. The instruction is given by lectures and laboratory and microscopical examination of the leading metals and alloys.

534. Analytical and Technical Chemistry:

This course comprises forty-five lectures during the first term, and six hours per week of laboratory exercises during the second term, covering the principles of Organic, Analytical and Technical Chemistry, with particular reference to the needs of Naval Constructors.

611, 612. Principles of Electrical Engineering:

(a) Sixty lectures and recitations, and fifteen hours of problem work given in the first term of the senior year (611), is devoted to the laws and properties of electric and magnetic circuits and a treatment of the principles of direct current machinery.

(b) Forty-five lectures and recitations, given in the second term of the senior year (612) are concerned with the principles of electro-statics and variable currents, the general theory of alternating-current circuits, and the application of these principles to various engineering problems.

In connection with the work much importance is attached to the solution of problems selected with reference to their engineering application.

Text books: Franklin & Esty's Elements of Electrical Engineering, Vol. I, and Pender's Principles of Electrical Engineering.

623. Alternating Current Machinery:

This course of lectures, recitations and problems, extending through the first term, is devoted to a careful discussion of alternating current machinery. Certain

details of the action and operation of machinery which are not essential for students not intending to become electrical engineers are omitted.

635. Mechanical Applications of Electric Power:

A course of lectures, recitations, and reading, two hours per week during the second term, in which the various types of direct and alternating current machinery are discussed with special reference to their uses in power work and industrial processes.

667. Standardizing Laboratory:

A course of thirty hours of laboratory exercise in the first term of the senior year, in which special attention is given to the calibration of instruments and to the tests concerned in the acceptance of electrical material.

684, 685. Electrical Engineering Laboratory:

The work in this course occupies forty-five hours in the senior year and the same in the graduate year, and is arranged each year in accordance with the requirements of the individual students.

756. Sanitation of Ships:

A short course of fifteen lectures is offered, in the second term, in the Elements of Sanitation.

One half of the course consists of instruction in the general principles of sanitation; disease and its causes; the germ theory; infection and contagion and the methods of their dissemination, etc.; while the other half deals directly with sanitary aspects of the heating and ventilation of shops, their sanitary requisites, lighting, water supply, drainage, sewage disposal, and the like.

803. Precision of Measurements:

A course of two exercises a week for five weeks in the second term in connection with the laboratory course in General Physical Measurements. The work includes a discussion of the nature and methods of elimination of errors and the application of the Calculus to the solution of precision problems in direct and indirect measurements. These problems are selected from cases which arise in connection with the laboratory work, a fact which adds to their practical interest. Graphical methods of treating observations are also discussed.

Text book: Goodenough's Elements of the Precision of Measurements and Graphical Methods.

814. Heat Measurements:

A course given in the second term of the fourth year in connection with course 261.

This course consists of eight or more laboratory exercises in the measurement of high temperatures, precise thermometry, the efficiency of fuels, and determinations of thermal properties of engineering materials. Especial attention is given to the study of such temperature and heat measurements as are of technical importance - for instance, the calorific efficiency of coal and the determination of the temperature of kilns and furnaces.

1301. Naval Architecture:

A continuous series of lectures and recitations, thirty each term of the junior year, on the statics and dynamics of Naval Architecture.

The course opens with methods of computation and use of integrating instruments, and proceeds with the methods of computing displacement and stability of ships, and includes a discussion of surface of buoyancy and of waterlines, also a consideration of the effects of adding weights, flooding compartments, grounding, docking and landing. A simple form of modern hydrodynamics is developed and applied to the study of waves and their influence on the rolling of ships, and also to the investigation of stream line about ships.

1302. Naval Architecture:

This course of forty-five lectures, thirty in the first term of the senior year and fifteen in the second term, is a continuation of the course of the preceding year.

A discussion is given of the resistance of ships and of propulsion by paddle wheels, screw propeller, and by sails; also methods of making power and speed trials, and of steering and manoeuvring. Methods are given of determining the strength of ships in quiet water and among waves; also in consideration of the strength of bulkheads. Instruction is given in compass adjustment.

1305. Memoirs:

Given second term of graduate year, by Professor Peabody.

1311. Theory of Warship Design:

A series of sixty lectures, thirty in each term of the juni

year.

The work of the first term gives a historical account of the development of warships, dealing separately with each of the more important classes; seagoing battleships, coast defense ship cruisers, gunboats, torpedo vessels and submarine boats.

The attention of the student is particularly directed to an appreciation of the causes which have led to the various steps in the development, the chief object of these lectures being to broaden the view of the students and to afford a basis for the full understanding of the following lectures of this course.

The lectures during the second term are the first part of a course of practical and theoretical nature relating directly to the design and construction of warships. The course of this term comprises a discussion of the principles which govern the choice of the elements of the design of the hull and the general arrangements of its main features; principal dimensions, distribution of weights, stability, seaworthiness, watertight subdivision and strength. It contains also practical rules for working out a preliminary design and for the performance of weight calculations.

These lectures, as well as the following lectures on this subject, are accompanied by numerous compilations, directly useful in naval design work.

1312. Theory of Warship Design:

A course of sixty lectures, extending throughout the senior year.

The work of this year is a continuation of the lectures described under 1311 and comprises a discussion of the structural arrangements of warships, including strength calculations and the theory of riveted joints as applied to shipbuilding. Special attention is given to methods of construction used in the United States Navy and comparisons are made with methods used in other navies.

The lectures during the second term comprise the design and installation of boilers, engines, and propellers as far as these problems concern the naval architect; coaling and coal stowage; liquid fuel; rudders and steering gear.

1313. Theory of Warship Design:

A course of sixty lectures extending throughout the graduate year.

This course comprises, - drainage, ventilation, heating and anchor gear; disposition and installation of artillery; ammunition, ammunition transport and stowage; design of ammunition rooms; torpedo installations; effects of gunfire, resistance of armor, principles of armor protection; protection against submarine attack; conning towers.

The lectures during the entire three years are accompanied by description of methods and installations used in the United States Navy and other navies, together with explanations and study of plans and working drawings, by which the students are also made familiar with the interpretation of such drawings.

1321. Warship Design:

The time allotted to the subject of warship design is seven hours per week during the first term of the junior year, eight hours per week during the second term, and this is followed by two three-hour exercises per week throughout the senior and graduate years.

The first term of the junior year is occupied by introductory work consisting of fairing of lines, tracing, and ship calculations. The object of this work is to provide exercises for the students in drawing and calculation. In the second term of the junior year the students commence the design of a warship. In working out the general arrangement plan, particular attention is given to the disposition of ordnance, ammunition, and armor; and the problems of ammunition transport, coal stowage and transport, drainage, and ventilation are studied. Special plans are worked out, showing structural arrangements, drainage and ventilation and sketches of structural details are prepared. Detailed calculations are performed for the determination of displacement, weight distribution, stability, and strength, and the usual diagrams accompanying such calculations are prepared. The methods of calculations are those used by the Bureau of Construction and Repair.

The horse power and coal capacity are determined, the principal dimensions of boilers, engines, and propellers are fixed, and the general arrangement of the machinery is studied.

A half-block model of the design is made by each student, and on this model the plating, longitudinal, etc., are laid off.

1322. Warship Design:

The course is given in the senior year, and is a continuation of the subject described under course 1321.

1323. Warship Design:

This course is given throughout the graduate year and forms a continuation of course 1322.

1355. Marine Engineering:

A course of thirty lectures in the first term of the graduate year, giving attention especially to naval engines.

This course gives a description of marine engines and their adjuncts, together with methods of determining dimensions and proportions of parts and strain in them due to steam pressure and dynamical actions. A discussion is given to vibrations of ships and balancing engines. Each student makes a preliminary design of a marine engine adapted to the ship which he is designing in course 1321.

1361. Marine Engine Design:

A course of ninety hours in the first term of the graduate year in the design and drawing of a reciprocating naval engine, including the determination of power, proportion of parts, and stresses. Detailed drawings are made and the construction and assemblage of a naval engine and auxiliary machinery, including the propeller, are discussed.

1365. Marine Steam Turbines:

A course of thirty lectures in the second term of the senior year giving a discussion of arrangements and construction of various types of steam turbines, and methods of determining sizes and proportions required for the development and distribution of power especially as applied to marine propulsion.

1372. Aeronautics:

A course of thirty lectures in the second term giving the essential principles of experimental and theoretical aerodynamics, theory of aeroplane design, theory of dirigible design, history of flight, and description of modern air craft.

1395. Model Making:

Each student in Naval Architecture after having designed a set of lines for a ship is given twenty-five hours instruction in cutting a model to those lines, in order that a proper conception of the form of the ship may be had.

To aid in shaping the model two sets of lines are transferred to the model. In the first place the lifts or boards

from which the model is made, are sawed to the form of horizontal sections or water lines. These lifts are then glued together to form a block, which is profiled to the forms of transverse sections or stations, in a special machine. The student then proceeds to cut away redundant material and to fair and smooth up the model guided by the double system of lines which were transferred from his design. The model is afterward used for laying off shell plating.

Courses pursued at Rensselaer Polytechnic
Institute.

2001. Thermodynamics:

Text books and lectures; the laws of thermodynamics and their application to perfect gases, saturated vapors, superheated vapors and the flow of fluids; cycles and application to engines.

2002. Fire Proofing and Protection.

2003. Heating, Ventilation, & Refrigeration.

The principles of ventilation; the arrangement of heating systems; methods of refrigeration; computations for specific plants.

2004. Structures:

Equilibrium and stability of structures - dams, chimneys, buttresses, abutments, retaining walls, piers, arches; analytical and graphical analysis of framed structures, - beams, columns, trusses; specifications for masonry constructions and for bridge foundations of structures; reviews of special structures.

2005. Electrodynamics:

Electricity.- Theory; methods of producing electricity; its various effects; fundamental laws of magnetism, electrostatics and electrodynamics; electrical measurements. Laboratory work; measurements of magnetic fields, magnetic permeability and hysteresis, resistance, current, potential, capacity and induction.

2006. Resistances:

Materials of Construction.- Strength of materials - metals building stones, cements, timber; tests and inspection of materials; manufacture and use of materials - metals, cements, concrete, masonry, timber.

Des.

Rensselaer.

2007. Botany:

Engineering botany. The growth, characteristics and method of preservative treatment of woods used in engineering practice.

2008. Geology:

Structural; historical; applied.

2009. Stone Cutting Theory:

Stereotomy. Stone cutting, theory and plates.

2010. Mineralogy:

Crystallography; descriptive and determinative mineralogy.

2011. Architecture:

2012. Mechanical Laboratory:

Calibration of gauges and indicators; indication and tests of simple and compound steam engines; tests of gas engines.

2013. Mechanics:

Rational Mechanics. Mechanics of solids; mechanics of fluids; mechanical problems.

2014. Mechanics:

A continuation of Course 2013.

2015. Electrical Measurements.

Calibration of instruments; comparison of standards; temperature coefficients.

2016. Metallurgy.

Metallurgy of iron and steel.

2017. Stone Cutting Drawing:

Practical work of course 2009.

2018. D. C. - A. C. Machines, Laboratory:

Direct Current Machines: Theory; generators; motors; controlling appliances; switchboard instruments. Laboratory work;

operation, characteristic curves, efficiency, heat runs of generators and motors; tests of D. C. appliances.

Alternating Current Machines: Theory, mathematical theory of alternating currents; alternators; synchronous and induction motors; transformers; controlling appliances; switchboard, instruments, Laboratory work; operation, characteristic curves, efficiency and heat runs of single and polyphase generators and motors.

2019. Mar Drawing:

Topographical Drawing. Contour map; map of hydrographical survey.

2020. Electric Lighting:

Theory; arc and incandescent lamps; interior and street lighting.

2021. Testing Laboratory:

Materials of Construction;- A continuation of Course 2006.

2022. Central Station Electrical Equipment:

Theory; equipment and operation of central power plants.

2023. Railroad Curves:

Railroad Engineering. The discussion of simple and compound curves, vertical curves, spirals and earthwork and the construction of earthwork tables and diagrams. The use of the slide rule in railroad problems.

2024. Central Station Mechanical Equipment:

Theory; equipment and operation of central power plant.

2025. Electrical Engineering Course:

Text books, lectures and laboratory work; the principles of alternating currents; direct and alternating current generators and motors; rotary converters and transformers; storage batteries; the transmission and distribution of electrical energy and its application in railway and power work, lighting and electro-chemical processes.

2026. Compressed Air:

Text books, lectures and calculations on power required to compress air in different types of machinery; utilization of compressed air for power purposes.

Des.

Rensselaer.

2027. Internal Combustion Engine Design:

Gas and oil engines. The peculiarities of the design of gas and oil engines; forms of engines; fuels; governing; ignition; design of an engine.

2028. Pumping Machinery:

Text books, lectures, and design calculations; historical development of pumping machinery; design of pumps for specific duty; analysis of tests of pumps and pumping engines.

2029. Electrical Transmission & Distribution:

Transmission and distribution of electrical energy. Theory; direct and alternating current systems; long distance transmission lines; overhead and underground distribution; cost of production and distribution; depreciation; establishment of rates.

2030. Lighting, Transmission & Distribution Apparatus:

Laboratory work; efficiency distribution and life tests of arc and incandescent lamps; cable testing; insulation; conductivity; standardization of meters.

2031. Electric Cranes, Elevators:

2032. Central Station Architecture:

2033. Bridges:

Calculation of stresses in and details of bridges and roofs - plate girders, truss bridges, suspension bridges, cantilever bridges, draw bridges, roofs.

2034. Water Supply and Sewers:

Water Supply Engineering. Sources of supply; quality of water; drinking water and disease; river and stream water; natural purification of water; lake and reservoir water; ground water; artificial purification of water; structures, - basins and filters; aqueducts; pipe lines; distributing systems; dams; reservoirs; stand pipes; pumping machinery.

Sewers: House sewage and rainfall; formulae for flow; separate and combined systems; general design of plants; disposal and treatment.

2035. Highways:

The design, construction and economics of common roads and city pavements.

Des.

Rensselaer.

2036. Law of Contracts:

2037. Heating and Ventilating Laboratory:

Experimental determinations of the heating surface efficiencies of different types of radiators, heating and cooling coils; tests of humidifying apparatus.

2038. Bridge Design:

Designs; detailed shop drawings and estimates of cost of bridges, examination of existing bridges and shop work.

2039. Railroad Engineering:

Materials used in railroad construction; the locomotive; train and other resistances; speed problems; velocity profiles; the economics of railroad location; railroad signaling; railroad surveys - theory and practice.

2040. Architectural Design:

2041. Hydraulics:

Flow of water in pipes, mains, ditches, canals, sewers; streams, rivers; measurement of the flow of water by orifices, weirs, current meters; measurement, estimates of, and cost of water power; hydraulic motors; hydraulic plants. Laboratory: Duty tests of pumping engines; tests for efficiency of turbines and other water wheels; flow of water over weirs and through orifices and pipes.

2042. Lighting, Transmission, & Distribution Design:

Design; plans, specifications and bills of material of transmission lines and distribution systems.

2044. Thesis:

Preparation of graduation thesis.