EE-406-E **ADVANCED CONTROL SYSTEMS**

L	T	P
3	1	-

Theory	:	100 marks
Class work	:	50 marks
Total	:	150 marks
Duration of exam.	:	3 hours

UNIT 1. STATE VARIABLE TECHNIQUES: State variable representation of systems by various methods. Solution of state equations-state transition matrix. Transfer function from state variable model. Controllability & observability of state variable model.

UNIT 2. SECOND ORDER SYSTEMS & STATE PLANE: Phase portrait of linear second systems. Method of isoclines, phase portrait of second order system with non-linearities, limit cycle, singular points.

UNIT 3. DESCRIBING FUNCTION ANALYSIS: Definition, limitations, use of describing function for stability analysis , describing function of ideal relay, relay with hysteresis & dead zone, saturation/coulomb friction & backlash,

UNIT 4. LINEAR APPROXIMATION OF NONLINEAR SYSTEMS: Taylor series, Liapunov's 2^{nd} method.

UNIT 5. SAMPLED DATA SYSTEMS: Sampling process, impulse modulation, mathematical analysis of sampling process, application of Laplace transform, Shannon's theorem, reconstruction of sampled signal zero order & first order hold, Z-transform, definition, evaluation of Z-transform, Inverse Z-transform, pulse transfer function, limitations of Z-transform, state variable formulation of discrete time systems. Solution of discrete time state equations, stability, definition, the Schur-Cohn stability criterion, Jury's test of stability of extension of Routh-Hurwitz criterion to discrete time systems.

TEXT BOOKS:

1. 1. Digital Control & State Variable Methods : M.Gopal ; TMH.

REFERENCE BOOKS :

1. Modern Control Theory : M.Gopal ; Wiley International.
2. Discrete time control system : K.Ogate ; PHI
3. Digital Control Systems : B.C.Kuo
4. Applied non-linear control : J.E.Slotine & W.P.Li; Prentice Hall, USA,
5. Nonlinear Control Systems: Isidari ; Springer-Verlag.

NOTE : 8 questions are to be set –one from each unit. Students have to attempt five questions.

EE-408-E **COMPUTER APPLICATION TO POWER SYSTEM**

L T P		
3 1 -	Theory	:100 marks
	Class work	:50 marks
	Total	:150 marks
	Duration of exam.	:3 hours

PART-A: LOAD FLOW STUDIES: Introduction, Bus Admittance Matrix, Formation of Y Bus, Tree graph, Cotree, Primitive network, Bus Incidence matrix, Formulation of Y Bus using singular transformation, Load flow equations Approximate Load flow study, Cious-Seidel method for Load flow Study, Algorithm and flow, Chart for Computer application to Load flow studies, using G-I method, Newton-Rophson method for Load flow studies, Algerthm and flow chart for Computer Application to Load flow studies using N.R. Method. Decenpted Load flow Studies, Fast Decenpted Load flow. Comparison between G-S & N.R. Methods. Load flow Study of Distribution System.

PART-B: DIGITAL TECHNIQUES IN FAULT CALCULATIONS: Review of symmetrical components, Sequence networks for synchronous machines, transforms and transmission Lines. Bus Impedene matrix, Altorithn for formulation of Bus. All types of modifications Short circuit Studies : Single line to ground fault, Line to Line fault, Double line to Ground fault and symmetrical fault. Consideration of Prefault currents.

PART-C: COMPUTER CONTROL & AUTOMATION: Introduction to energy control centres, various states of a power system, SCADA Systems and RTU. Introduction to the MATLAB Power System block Set. Introduction of the features of EMTP.

TEXT BOOKS:

1. Power System Engg.: B.R.Gupta.
2. Computer methods in power system: G. W. Stagg and A. H. El-Abiad, M.G.H.

REFERENCE BOOKS:

1. Advance power system analysis and dynamics: L.P. Singh, Wiley Eastern ltd.
2. 2. Electrical Energy system theory: An introduction by O.I.Elgerd, TMH.
3. 3. Elements of power system analysis: W. D. Stevenson, M.G.H.
4. 4. Power System Engineering, : I.J.Nagrath & D.P.Kothari(TMH).
5. 5. Power System Analysis : Hadi Saadat, TMH, New Delhi.

NOTE: 8 questions are to be set –atleast 3 questions from Part -A & Part-B each and 2 questions from Part-C. Students have to attempt any five questions.

EE-410-E COMPUTER APPLICATIONS TO POWER SYSTEMS ANALYSIS LAB

L	T	P
-	-	2

Practical	:50 marks
Class work	:50 marks
Total	:100 marks
Duration of exam.	: 3 hours

1. 1. Draw the flow chart and develop the computer program for the formation of the Y Bus of a generalized network.
2. 2. Draw the flow chart and develop the computer program for the formation of the Z Bus of a generalized network.
3. 3. To plot the swing curve and observe the stability.
4. 4. To perform load flow study using Gaus Shiedel method.
5. 5. Perform short circuit study for any type of fault.
6. 6. To observe transmission losses and efficiency with variations in power for the given example.
7. 7. Design of distribution system
8. 8. To study the features of EMTP
9. 9. To study the MATLAB Power System block set features.

NOTE: At least 10 experiments have to be performed with at least 7 from above list, remaining 3 may either be performed from above list or designed & set by concerned institution as per the scope of syllabus.

DEPT. ELECTIVE – I

EE-432E	EHV AC/DC
EE-434E	Advanced Instrumentation
IC-404E	Fuzzy Control System (IC, EL, EE)
EE-438E	Recent Trends in De-regulated Power Systems
EE-466E	Utilization of Electric Power & Traction

DEPT. ELECTIVE – II

EE-442E	High Voltage Engineering
EE-444E	Electrical Power Quality
EE-446E	Artificial Intelligence
IC -405E	Computer Based Instrumentation & Control
EE-450E	Power Management

EE-432-E EXTRA HIGH VOLTAGE AC/ DC

L	T	P
3	1	-

Exam.	: 100
Sessionals	: 50
Total	: 150
Duration of exam.	: 3 hrs.

1. **1. Break Down Mechanism of Gaseous Materials :**
Mechanism of Breakdown of gases, Townsend's first Ionization Co-efficient, Townsend's second Ionization Co-efficient, Townsend's Breakdown Mechanism, Streamer Theory of Breakdown in gases, Paschen's law.

2. **2. Breakdown in Liquid and Solid Dielectrics:**
Suspended Particle Theory, Cavity Breakdown, Electro-convection Breakdown, Breakdown in solid Dielectrics, Intrinsic Breakdown, Electromechanical Breakdown, Breakdown due to Treeing and Tracking, Thermal Breakdown, Electrochemical Breakdown

3. **3. Generation of High Voltage AC. and D.C**
Half wave and Full wave Rectifier, Cockroft Walton Voltage Multiplier Circuit, Ripple in Multiplier Circuit, Electrostatic Vandegraff Generator, Generation of High Alternative Voltage, Cascade Transformer, Resonant Transformer, Generation of High Frequency A.C. High Voltage

4. 4. **Generation of Impulse Voltages and Currents**:
Standard Impulse Wave Shapes, Impulse Generator Circuit, Multistage Impulse Generator, Marx's Circuit, Generation of Switching Surges, Impulse Current Generation, Tripping and Control of Impulse Generator

5. **5. Measurement of High Voltage and Current:**
Sphere-Gap, Uniform field Spark gap, Rod Gap, Electrostatic Voltmeter, Generating Voltmeter, Impulse Voltage Measurement using Voltage divider, Measurement of high DC, AC and Impulse Current.

6. 6. **High Voltage Testing of Electrical Equipments**:
Testing of line Insulator, Testing of Cable, Testing of Bushings, Testing of Power Capacitor, Testing of Power Transformers, Testing of Circuit Breaker.

7. 7. **Transients & Insulation Co-ordination in Power System**:
Over Voltage due to disturbances in D.C & A.C. System, Lightening surges, Switching Surges, Insulation Co-ordination in Power System, Surge Arrestor, Application of surge Arrestor.

Text Book:
1. High Voltage Engineering By M.S. Naidu & V. Kamaraju -TMH Publication

Reference Books:
1. J. Arrillaga, *High Voltage Direct Current Transmission.* Pub: Peter Peregrinus Ltd. on behalf of I.E.E Power Engg. Series.
2. Rakos Das Begamudre, *Extra EHV A.C Transmission.* PHI Publication.
3. C.L Wadhwa , *High Voltage Engineering*. Pub.: New Age International Ltd.

EE-434-E ADVANCED INSTRUMENTATION

L	T	P
3	1	-

Exam.	: 100
Sessionals	: 50
Total	: 150
Duration of exam.	: 3 hrs.

1. INTRODUCTION: Functional block diagram of generalized Instrumentation system. Input-output configuration, specifications under steady & transient state & their performance characteristics.
2. REVIEW OF SENSORS AND TRANSDUCERS: Temperature, pressure, displacement, velocity, acceleration, strain and torque type.
3. SIGNAL CONDITIONING: Current & voltage sensitive bridges, Blumlein Bridges, Shielding & grounding, Instrumentation Amplifier & its Characteristics, Linearizing circuits, Wave form and frequency conversion, Acitve filters, A/D & D/A converters; Balanced modulators & demodulators.
4. NOISE: Characteristics & Measurements of signal in the presence of noise.
5. MICROCONTROLLER BASED INSTRUMENTATION SYSTEM: Interfacing of 8051 Microcontroller with (a) ADC and DAC, (b) Alphanumeric Devices (Sixteen-segment Display, Dot Matrix Displays, LCD Display).

REFERENCES:

1. E.O. Doeblin, *Measurement System – Application & Design.* TMH
2. A.K. Sawhney, *A Course in Electrical & Electronics Measurement & Instrumentation.* Pub.: Dhanpat Rai & Sons.
3. C.S. Rangan, G.R. Sarma, V.S.V. Mani, *Instrumentation Devices & Systems.* New Delhi: Tata McGraw-Hill Pub. Co. Ltd.
4. Oliver & Cage, *Electronic Measurement & Instrumentation.*
5. Raj Kamal, *Microcontrollers: Architecture, Programming, Interfacing and System Design.* Delhi: Pearson Education (Singpaore) Pte. Ltd., Indian Branch.
6. Kenneth. J. Ayala, *The 8051 Microcontrollers – Architecture, Programming & Applications.* Mumbai: Penram International Publishing (India) Pvt. Ltd..
7. Scott Mackenzie, *The 8051 Microcontrollers.* Englewood Cliffs: Prentice Hall Pub. Co.

IC-404-E **FUZZZY CONTROL SYSTEM**

L	T	P
3	1	0

CLASS WORK	:	50
EXAM	:	100
TOTAL	:	150
DURATION OF EXAM	:	3 HRS

UNIT 1 INTRODUCTION:
Fuzzy control from an industrial perspective, knowledge-based controllers, knowledge representation in KBC's.

UNIT 2 THE MATHEMATICS OF FUZZY CONTROL:
Vagueness, fuzzy logic versus probability theory, fuzzy sets, their properties & operations on fuzzy sets, fuzzy relations & operations on fuzzy relations, the Extension Principle, Fuzzy propositions, The Compositional Rule of Inference, Different implications, Representing a set of rules.

UNIT 3 FKBC DESIGN PARAMETERS:
The PKBC architecture, choice of variables & content of rules, Derivation of rules, choice of membership functions, choice of scaling factors, choice of fuzzification procedure, choice of defuzzification procedure, comparison and evaluation of defuzzification methods.

UNIT 4 NONLINEAR FUZZY CONTROL:
The Control Problem, The FKBC as a Non-Linear Transfer Element, Types of FKBC such as PID-like FKBC, Sliding Mode FKBC, Sugeno FKBC.

UNIT 5 ADAPTIVE FUZZY CONTROL:
Design & Performance Evaluation, Approaches to Design such as membership function tuning using gradient descent, membership function tuning using performance criteria, the self-organizing controller, model based controller.

UNIT 6 STABILITY OF FUZZY CONTROL SYSTEMS:
The State space approach, Stability and robustness indices, input-output stability, circle criterion, the conicity criterion.

TEXT BOOK:
An Introduction to Fuzzy Control: D.,Driankov, H.Hellendoorn and M.Reinfrank.; Narosa.

REFERENCE BOOKS:
Fuzzy Control Systems : Abraham Kandel and Gideon Imngholz; Narosa

NOTE : Eight question are to be set at least one from each unit. Students have to attempt five questions in all.

EE-438-E RECENT TRENDS IN DEREGULATED POWER SYSTEMS

L	T	P
3	1	-

Exam.	: 100
Sessionals	: 50
Total	: 150
Duration of exam.	: 3 hrs.

1. **Deregulation of the Electricity Supply Industry**:
   Background of deregulation and the current situation, Benefits from a competitive Electricity Market, After effects of Deregulation.
2. **Power System Operation in Competitive Environment**
   Role of Independent System operator, Operational Planning activities of ISO, operational planning activities of Genco.
3. **Transmission open Access and Pricing Issues**
   Power Wheeling, Transmission Open Access, Cost component in Transmission, Pricing of Power Transmissions, Security Management in Deregulated environment, Congestion management in Deregulation.
4. **Reliability and Deregulation**
   Reliability Analysis, Optimal Power Flow as a Basic Tool, Unit Commitment, Formation of Power Pools.

REFERENCES:

1. 1. Lei Lee Lal, *Power System Restructuring and Deregulation*. UK: John Wiley and Sons, 2001.
2. 2. Kankar Bhattacharya, Math H.J.Bollen and Jaap E. Daalder, *Operation of Restructured Power Systems.* USA: Kluwer Academic Publishers, 2001.
3. 3. Md Shahidehpour and Muwaffaq Alomoush, *Restructured Electrical Power Systems.* Marcel Dekker, Inc.
4. 4. S.S. Rao, *Switch Gear Protection and Power System Analysis.* Khanna Publications.

EE- 466-E UTILIZATION OF ELECTRIC POWER AND TRACTION

L	T	P
4	-	-

Theory marks	:	100 marks
Class work	:	50 marks
Total marks	:	150marks
Duration of exam.	:	3 hours

UNIT 1. ILLUMINATION:
Basic laws of illumination, light sources and their characteristics, sources of light, design of lighting schemes, incandescent lamp, sodium lamp, mercury lamp and fluorescent lamp, comparison of various lamps.

UNIT 2. ELECTRIC HEATING :
Principle and application of resistance, induction and dielectric heating.

UNIT 3. ELECTRIC WELDING :
Resistance welding, arc welding, welding generator and welding transformer, properties of arcing electrode.

UNIT 4. ELECTROLYTIC PROCESS:
Principles and applications of electrolysis. Faraday's law of electrolysis, electroplating, charging and discharging. Capacity and efficiency of battery, defects in battery.

UNIT 5. ELECTRIC TRACTION:
Advantages of electric traction, requirements of an ideal traction system, train movement, mechanism of train movement, traction motors, traction motor control, multi unit control, braking of electric motors, thyristor control of electric traction.

REFERENCE BOOKS :
1. Utilization of Electrical Energy : Open Shaw Taylor ; ELBS
2. Art and Science of Utilization of Electrical Energy : H. Pratab ; Dhanpat Rai & Sons, Delhi.
3. Generation, Distribution and Utilization of Electrical Power : C.L. Wadhwa ; Khanna Pub.

NOTE: 8 questions are to be set – at least one from each unit. Students have to attempt any five questions.

EE- 442-E High Voltage Engineering

L	T	P
4	-	-

Theory	:100 marks
Class work	: 50 marks
Total	:150 marks
Duration of exam.	: 3 hours

1. 1. **Introduction:** Recent trends in high voltage transmission.
2. 2. **Conduction and breakdown:** Conduction & breakdown in gases, liquids and solid dielectrics, insulator breakdown, insulation characteristics of long air gaps.
3. 3. **Voltage gradients on conductors:** Electrostatic fields of sphere gaps, fields of line charges and their properties, charge-potential relations for multi-conductor lines, surface voltage gradients on conductors, distribution of voltage gradient on sub conductors of bundle.;
4. 4. **Corona:** Corona and corona loss, corona loss formula, attenuation of travelling waves due to corona, audible noise-generation and characteristics, corona pulses--their generation and properties, properties of pulse, radio interference.

5. 5. **Lightening:** Lightening phenomenon, lightning stroke mechanism, principle of lightning protection, tower foot resistance, insulator flash over and withstand voltage, lightning arresters and their characteristics.

6. 6. **H.V. testing and Lab equipments :** Standard wave-shapes for testing, wave-shaping circuits: principles and theory; impulse generator, generation of ac high voltage for testing, generation of direct voltage, measurement of high voltage, general layout of H.V. Laboratory.

Text Books: 1. E.H.V. AC Transmission: R.D. Begamudre, Wiley Eastern Ltd.
2. H.V. Engg.: V. Kamaraju and M.S. Naidu, T.M.H., N.Delhi.

Note: 8 questions are to be set – at least one from each unit. Students have to attempt any five questions.

EE-444-E ELECTRICAL POWER QUALITY

L T P
3 1 -

Exam.	: 100
Sessionals	: 50
Total	: 150
Duration of exam.	: 3 hrs.

1. INTRODUCTION TO ELECTRICAL POWER QUALITY: Definition of Power Quality, Power Quality Issues, Power Quality v/s Equipment Immunity, Electric Power Quality Standards.
2. POWER FREQUENCY DISTURBANCES: Common Power Frequency Disturbances, Voltage Sag, Isolation Transformers, Voltage Regulators, Static Uninterruptible Power Source Systems.
3. ELECTRICAL TRANSIENTS: Types and Causes of Transients, Atmospheric Causes, Switching Loads On or Off, Interruption of Fault Circuits, Capacitor Bank Switching, Motor Start Transient, Power Factor Correction, Capacitor Switching Transient.
4. HARMONICS: Definition of Harmonics, Causes of Voltage and Current Harmonics. Individual and Total Harmonic Distortion, Effect of Harmonics on Power System Devices, Guidelines for Harmonic Voltage and Current Limitation, Harmonic Current Mitigation.
5. MEASURING & SOLVING POWER QUALITY PROBLEMS: Power Quality Measurement Devices, Harmonic Analyzers, Transient-Disturbance Analyzers, Oscilloscopes, Data Loggers and Chart Recorders, True RMS Meters, Power Quality Measurements.

REFERENCE BOOKS:

(1) G.T. Heydt, *Electric Power Quality.* 2nd ed. West Lafayette, IN: Stars in a Circle, 1994.
(2) A Ghosh, G. Ledwich, *Power Quality Enhancement Using Custom Power Devices.* Kluwer Academic, 2002
(3) R.C. Dugan, M.F. McGranaghan and H.W. Beaty, *Electric Power Systems Quality.* New York: McGraw-Hill.1996.
(4) C. Sankaran, *Power Quality.* CRC, 2002.
(5) J. Arrillaga, D.A Bradely and P.S. Bodger, *Power System Harmonics.* New York: Wiley, 1985.

EE-446-E ARTIFICIAL INTELLIGENCE

L	T	P
3	1	-

Exam.	: 100
Sessionals	: 50
Total	: 150
Duration of exam.	: 3 hrs.

UNIT-1: FOUNDATIONAL ISSUES IN ARTIFICIAL INTELLIGENCE: Foundation and history of AI, AI problems and techniques, AI programming languages, introduction to LISP and PROLOG, problem spaces and searches, blind search strategies, Breadth first- Depth first - heuristic search techniques, Hill climbing, best first - A* algorithm, AO* algorithm- game tree, Min max algorithms, game playing- alpha beta pruning.

Unit-2: KNOWLEDGE REPRESENTATION: Issues, predicate logic, logic programming, semantic nets, frames and inheritance, constraint propagation, representing knowledge using rules, rules based deduction systems.

Unit-3: APPROXIMATE REASONING: Reasoning under uncertainty, review of probability, Baye's probabilistic inferences and Dempster Shafer theory, Heuristic methods, symbolic reasoning under uncertainty, Statistical reasoning, Fuzzy reasoning, Temporal reasoning, Non-monotonic reasoning.

Unit-4: PLANNING & LEARNING: Planning in situational calculus, Representation for planning, Partial order planning algorithm, Learning from examples, Discovery as learning, Learning by analogy, Explanation based learning, Introductory remarks on learning by Neural Networks and Genetic Algorithms.

Unit-5: APPLICATIONS: Rule based systems architecture, Expert systems, Knowledge acquisition concepts, AI application to robotics, and current trends in intelligent systems.

Text Book:

1. Artificial Intelligence: A Modern Approach,. Russell & Norvig. Prentice Hall, 1995.

Reference Books:

1. Elain Rich and Kevin Knight, "Artificial Intelligence", TMH, 1991.
2. Staurt Russel and Peter Norvig, "Artificial Intelligence - A modern approach", PHI, 1998.
3. Patrick Henry Winston, "Artificial intelligence", 3rd Ed., Addition Wesley, 1992.
4. Dan W. Patterson, "Artificial Intelligence", PHI, 1990

Note: Eight questions will be set in all by the examiner taking at least one question from each unit. Students will be required to attempt five questions in all.

IC-405-E **COMPUTER BASED INSTRUMENTATION AND CONTROL**

L T P		
3 1 -	Theory	: 100 Marks
	Class Work	: 50 Marks
	Total	: 150 Marks
	Duration of Exam	: 3Hrs

UNIT 1. INTRODUCTION:
Necessity and functions of computers. Level of automation and economy of computer control. Centralized computer control Vs distributed computer control.

UNIT 2. COMPUTER ARCHITECTURE:
Micro and mini computer, functional models of I.O. system .

UNIT 3. INTERFACING:
Sampling; Multiplexing; A/D and D/A converters, interfacing with different types of transducers - Analog / Digital, Electrical and non electrical selection of sensors; Micro computer interfacing standard buses Serial buses; Serial data communication protocols.

UNIT 4. STRUCTURAL STUDY OF AUTOMATIC PROCESS CONTROL:
Fundamental of automatic process control, building block of automatic system, direct and distributed digital control system. Programmable controllers.

UNIT 5. PERSONAL COMPUTER IN REAL LIFE ENVIRONMENT:
Introduction, personal computer: system and facility, PC bus and signals, interrupts, interfacing PC with outer world, PC in RTE, Real time application of IBM PC PC based distributed control system

UNIT 6. PROGRAMMING AND APPLICATION:
Modeling and simulation for plant automation, PLC Architecture and programming of PLC, industrial control application: cement plant, thermal power plant , water treatment plant, steel plant,

TEXT BOOK :
1. Computer based industrial control: Krishan Kant,; PHI

NOTE : Eight questions are to be set - at least one from each unit. Students have to attempt five questions.

EE-450-E POWER MANAGEMENT

L	T	P
3	1	-

Exam.	: 100
Sessionals	: 50
Total	: 150
Duration of exam.	: 3 hrs.

1. **INTRODUCTION:**
   Power Scenario, Power Development, Planning, Power resources, Environment- Power matters Plan, Pre-feasibility and feasibility studies, State relations for Power etc.
2. **RESOURCES:**
   Resources, Geophysical study, Seismic Considerations, Environmental Restraints, Resettlement and Rehabilitation.
3. **PROCUREMENT:**
   Contracting and Procurement, Consulting Services, Types of Contracts, Project Management, Organization and Economy Management, Organizational Planning and Time Scheduling, Project Cost Control.
4. **ENGINEERING:**
   Engineering & General Layout of Equipments, Generator, Transformer and Switch Gear and Control Equipment, Construction Methods, Operation and Maintenance Principle, Maintenance organization and planning, Availability, life cycle cost & future development. Visits to sites.
5. **POWER SECTOR:**
   Power sector structure in different states, Regulatory Regime in those states, Power utilities in Haryana, Grid management, Power financing, Visit to sites.
6. **POWER STATION:**
   Management of Fuel, water Resource Electricity deviend scenario storage and handling, Pricing, Contract etc., Human resource management. Visit to sites.
7. **RISK & HAZARD:**
   Introduction to risk, rules and regulation Aspects of Risk & Hazard Health & risk assessment visit to site.
8. **ELECTRICITY INDUSTRY STRUCTURE & SAFETY REGULATIONS BILL & ETC.:**
   State and Central Power boards / Power corporations.

Reference Books:

1. 1. Electricity Bill, Safety & Conservation Act
2. 2. Arora & Dom Kundwar, *A Course in Power Plant Engineering*, Pub.: Dhanpat Rai Pub, 2000.
3. 3. Jain & Bala Subranmanyam, "Power Plant Engineering", Dhanpat Rai Pub.,
4. 4. Butter Worth, A.B. Gill, "Power Plant Performance Management", Pub: 1984.
5. 5. P.C. Sharma, "Power Plant Engineering", Dhanpat Rai Pub.,
6. 6. David A. Decenzo, Stephen P. Robbins, *Human Resource Management*. New Delhi: PHI Pvt. Ltd., 2004.
7. 7. P.K. Nag, *Power Plant Engg.* N.Delhi: TMH, 2003.