Approved Course Pattern and Syllabi w.e.f. 2014-2015 academic year
M.Sc. (Meteorology)

First Semester

Course No.	Title of the Paper	Internal assessment marks	Semester end examination marks	Total Marks	Credits
Theory:					
M–101	Physics and Dynamics of Climate√	15	85	100	4
M–102	Physical Meteorology√	15	85	100	4
M–103	Dynamical Meteorology√	15	85	100	4
M–104	Physical Oceanography√	15	85	100	4
M–105	Meteorology and Oceanography Instruments	15	85	100	4
Practicals:					
M–106	Meteorology and Oceanography computations √	15	85	100	4
M–107	Observational Techniques√	15	85	100	4
M–108	Viva-voce	-	50	50	2
	Total	105	645	750	30

Second Semester

Theory:					
M–201	Synoptic Meteorology √	15	85	100	4
M–202	Dynamical Oceanography√	15	85	100	4
M–203	Satellite Meteorology and Satellite Oceanography√	15	85	100	4
M–204	Advanced Dynamical Meteorology and Numerical Weather Prediction	15	85	100	4
M-205	Elements of General Meteorology (OD)	15	85	100	
Practicals:					
M–206	Synoptic Analysis√	15	85	100	4
M–207	Computer Programming√	15	85	100	4
M–208	Viva-voce	-	50	50	2
	Total	105	645	750	30

Third Semester

Theory:					
M–301	Climate and Ocean Modelling√	15	85	100	4
M–302	Monsoon Dynamics√	15	85	100	4
M–303	Ocean Atmospheric Interaction√	15	85	100	4
M–304	Applied Meteorology	15	85	100	4
M-305	Global Warming and Climate Change (OD)	15	85	100	4
Practicals:					
M–306	Numerical Weather Prediction	15	85	100	4
M–307	Applied Meteorology	15	85	100	4
M–308	Viva-voce	-	50	50	2
	Total	105	645	750	30

Fourth Semester

M–401	Internship	50	100	150	6
	Dissertation	100	300	400	16
	Seminar	50	100	150	6
M–402	Viva-voce	-	50	50	2
	Total	200	550	750	30
	Grand Total (1+2+3+4 semesters)	515	2485	3000	120

√ Common Subjects for M.Sc (Physical Oceanography) also

M.Sc. Meteorology
First Semester
M-101/PO-101: Physics and Dynamics of Climate

Unit-I:
Introduction : Weather and climate concepts - World climate system - climate of the hemispheres. Global distribution of temperature, precipitation , pressure and winds - Circulation pattern during winter and summer seasons. Jet streams. Monsoons – Asia, Australia, E. Africa and North America; Systems of climatic classification - Koppen - Thornthwaite.

Unit-II:
General circulation of the atmosphere - convective and meridional circulation - Rossby's tricellular model - Palmen's modified model - Circulation indices - Experiments of General Circulation – Dishpan experiment; Dynamics of atmospheric circulation - Maintenance of the General circulation – Kinetic energy, angular momentum, absolute vorticity balance. NAO and Pacific oscillations.

Unit-III:
Global warming – Causes and consequences of global warming; Greenhouse effect, Effect of global warming on Indian monsoon systems, Volcanic eruptions and aerosols, Ozone hole; Nuclear winter, IPCC, Montreal Protocol, Kyoto Protocol and Copenhagen Protocol

Unit-IV
Fundamentals of Climate change - local and planetary evidences - carbon dating - theories of climate changes; Paleoclimate - Climate change and variations in Earth's orbit; Climate trends - ENSO - teleconnections of the world climate system - Impact of climate change on weather and climate; Climate change and agriculture.

Unit V:
Wind, Temperature and rainfall distributions in different seasons over India, Present rainfall and temperature tendencies over India.

Text Books:

1. Physical climatology, William D. Sellers.
2. Climatology - Bernhard, Haurwitz and James M. Austin.
3. Dynamical and physical Meteorology, George J.Haltiner and Frank L. Martin.
4. Physics of monsoon, Keshava Murthy and Sankar Rao
5. Essentials of Meteorology – C. Donald Ahrens
6. Global Physical Climatology by Dennis L. Hartmann
7. Global Warming- The complete briefing by Sir John Houghton

M-102/PO-102: Physical Meteorology

Unit-I:

The atmosphere- Composition of the atmosphere- major components- carbon dioxide, water vapour, aerosols, ozone and ozone depletion.

Vertical thermal structure of the atmosphere - Scale height, Troposphere, Stratosphere, Mesosphere, Ionosphere, Thermosphere and Exosphere.

Gas laws, Virtual temperature, the hydro static equation, Geopotential, Hypsometric equation

Unit-II:

The first law of thermo dynamics- joules law, specific heat enthalpy.

Adiabatic processes – concept of an air parcel, the dry adiabatic lapse rate, potential temperature, thermodynamic diagrams.

Water vapour in air – moisture parameters, latent heat, saturated adiabatic and pseudo adiabatic processes saturated adiabatic lapse rate.

Static stability- unsaturated air, saturated air, conditional and convective instability

The second law of thermodynamics – entropy, the Clasius and Clapeyron equation

Unit-III:

Radiation:

The spectrum of radiation – Black body radiation- Plank function, Wien's displacement law, Stefan Boltzmann law, radiative properties of non black bodies, Kirchhoff's law, green house effect.

Scattering absorption and emission by air molecules and particles; Atmospheric windows, radiative transfer in atmosphere, radiation balance at the top of the atmosphere, surface radiation budget, and net radiation.

Unit – IV

Clouds and precipitation:

Cloud classification, cloud condensation nuclei, curvature and solute effects, growth of cloud droplets by condensation, collision – coalescence.

Ice nuclei- Growth of ice particles in clouds Bergeron Findeisen process.

Formation of precipitation, drop size distribution.

Unit – V

Artificial modification of clouds and precipitation - modification of cold clouds, modification of warm clouds, thunderstorm electrification – charge generation, lightning and thunder, global electric circuit, cloud and precipitation chemistry- transport of particles and gases, nucleation scavenging, precipitation scavenging.

Text Books:

1. Dynamical and Physical Meteorology - G.J.Haltiner and F.L.Martin
2. Compendium of Meteorology (WMO Pub.) - Physical Meteorology, 1973, Vol.1, No.2
3. Physical Meteorology - H.G.Houghton
4. Atmospheric Thermodynamics - J.V.Iribarne and W.L.Godson.
5. J.M. Wallace, P.V. Hobbs, Atmospheric Science, 2nd ed., Academic Press
6. Meteorology for scientists and engineers –Roland B. Stull
7. Essentials of Meteorology – Donald Ahrens

M-103/PO-103: Dynamical Meteorology

Unit I:
Inertial and Non Inertial frames- Fundamental Forces-Pressure Gradient Forces, Gravitational Force, Friction or Viscous Force. Apparent forces- Centrifugal Force, Coriolis force, Effective Gravity. Momentum Equations- Cartesian Coordinate System, Spherical – Polar coordinate system. Scale analysis of momentum equations. Hydrostatic approximation. Balanced motion- Geostropic Wind, Gradient wind, Thermal Wind.

Unit – II:
Continuity equation – Horizontal divergence, Vertical motion. Isobaric coordinate system – Transformation of momentum & continuity equations. Circulation & Vorticity – Bjerknes circulation theorem. Application to Land & Sea breeze. Vorticity equation. Potential Vorticity – Application to Lee of the mountain trough, CAV Trajectories, Scale analysis of Vorticity equation.

Unit – III:
Dynamics of tropical atmosphere: Scale analysis of tropical motions, cumulus convection and convective heating, scale interaction in the tropics – Wave number domain, frequency domain, Adiabatic potential Vorticity.

Unit – IV:
Atmospheric boundary layer: Atmospheric turbulence, Boussinesq approximation, Reynolds equations, Turbulent kinetic energy; Momentum equations for PBL – well mixed boundary layer, the flux – gradient theory, mixing length theory, Ekman layer, Surface layer, Modified Ekman layer: Secondary circulations; Prandtl layer- Logarithmic Profile Properties of Prandtl Layer.

Text Books:

1. An Introduction to Dynamical Meteorology, J.R.Holton
2. Dynamical and Physical Meteorology, G.J.Haltiner and Martin
3. Dynamic Meteorology, Ed.Wiin Nielsen, WMO Publication
4. Dynamic Meteorology, B.Haurwith
5. Atmospheric and Oceanic Fluid Dynamics by Geoffrey K Vallis

M-104/PO-104: Physical Oceanography

Unit I:
Physical properties of seawater: Temperature, Salinity and Density; Temperature, Salinity and density distributions. Transparency of seawater, Sound in the sea, Light in the sea, Colour of seawater, Sea Ice.

Unit II:
Waves and tides: wave parameters, deep water waves, transformation of waves in shallow water, wave generation. Types of tides, tide producing forces, tidal theories.

Unit III:
Ocean circulation : wind induced currents ,Up welling, sinking; equatorial current system, west ward intensification of currents, warm and cold currents of major world ocean, seasonal currents in North Indian Ocean, Thermohaline circulation.

Unit IV:
Water masses: T-S diagram, Characteristics of water masses, Deep circulation water masses, Major water masses of the world oceans.

Unit V:
Marine geology: Continental shelf, Slope, Shelf sediments, mineral resources of the world ocean, submarine topography, mid oceanic ridge system. Manganese and other deposits and the factors controlling their distribution.
Marine biology: Classification of marine environment, Bio geo chemical cycles. Influence of Physical parameters (Temperature, salinity, waves, currents, tides etc.). Mangroves

Text books:

1. Introduction to Physical oceanography by M.P.M.Reddy.
2. Introduction to Physical oceanography by Robert.H.Stewart.
3. Introduction to dynamical oceanography by S.Pond and G.L.Pickard.
4. Oceans by Sverdrup,Johnson and Flemming.
5. Friedrich, H.: Marine Biology

M-105/PO-105: Meteorology and Oceanography instruments

Unit-I

Measurements of air temperature - Liquid in glass and electrical resistance thermometer.
Measurement of atmospheric pressure – kewpattern barometer, corrections of mercury barometer reading and aneroid barometer.
Measurement of humidity - psychrometer, dew point hygrometer, electrical resistive hygrometer.

Unit-II

Measurement of surface wind- wind wane, cup anemometer, sonic anemometer.
Measurement of precipitation-non recording rain gauges, tipping bucket gauge, optical rain gauge.
Measurement of radiation-Pyrheliometer, Pyranometer, net radiometer.
Measurement of upper air-pressure temperature and humidity, radio sonde, upper air wind - GPS system, pilot balloon observations.

Unit –III

Ground based remote sensing - Lidar, radar, Principles of radar, weather radar, precipitation estimation, radar equation for precipitation targets, Doppler radar-velocities measurements.
Basic concept of satellite sensors – advanced very high resolution radiometer-AVHRR, advanced microwave sounding unit-AMSU, scatterometer, synthetic aperture radar, altimeter, ocean color monitor, passive microwave radiometer.

Unit –IV

Marine observations- method of observation of atmospheric pressure, air temperature, humidity, wind, precipitation, salinity and sea surface temperature on board ships
Hydrographic instruments- echo sounder, CTD

Unit-V

Measurement of dynamic properties of the sea-current meter and wave measurements, tide gauges
Platforms for ocean measurements-research vessels, mooring, satellites – geostationary, polar orbiting, sea glider, Argo floats.

Text Books:

1. Guide to Meteorological and Oceanographic Instruments. WMO – No. 8
2. Meteorological instruments – Knowles Middleton and Athelstan F. Splihaus
3. An introduction to Meteorological instruments and measurement – Thomas D. Defelice
4. http:// www.es.flinders.edu.au
5. Satellite Oceanography – An Introduction to Oceanographers and Remote Sensing scientists. I.S.Robinson, Ellis Forward Limited.
6. Descriptive Physical Oceanography by M.P.M. Reddy

M-106/PO-106: Meteorology & Oceanography Computations practical

PART-A

1. Calculation of horizontal divergence from wind data
2. Calculation of absolute vorticity from wind data
3. Calculation of geostrophic wind
4. Calculation of gradient wind
5. Calculation of thermal wind
6. Calculation of vertical velocity
7. T - Φ gram analysis: analysis of aerological data
8. Potential temperature
9. Equivalent temperature
10. Equivalent potential temperature
11. Lifting condensation level
12. Equilibrium level
13. Stability indices
14. Elsasser's Radiation chart: Flux determination

PART-B

1. Determination of Density using temperature and salinity.
2. Determination of Specific volume anomaly using S, T and D.
3. Stability and Richardson number.
4. Analysis of temperature data
    (a) Vertical profiles
    (b) Horizontal profiles
    (c) Identification of Upwelling and sinking
5. Determination of Heat budget parameters.
    (a) Latent heat
    (b) Sensible heat
    (c) Evaporation

M-107/PO-107: Observational Techniques

1. Measurement of atmospheric pressure by Fortin barometer, Kew pattern barometer.
2. Computation of height difference between two stations.
3. Measurement of relative humidity and calculation of actual vapour pressure.
4. Measurement of wind velocity using anemometer and air meter.
5. To calibrate a given thermistor for measurement of temperature.
6. Determination of wind direction and wind velocity at standard levels using Pilot balloon.
7. Measurement of Bulk SST and Skin SST.
8. Measurement of shortwave and Longwave radiation
9. Measurement of total column ozone, aerosol optical depth and precipitable water column
10. Automatic weather station- Measurements.
11. Current weather comparison
12. Cloud cover measurement

M-108/PO-108: Viva - Voce

Second Semester
M-201/PO-201: Synoptic Meteorology

Unit-I:
Synoptic data and collection: Surface and upper air weather data transmission - Code for inland, coastal and ship stations. Upper air data – PILOT and TEMP codes. Station models, Weather charts and analysis.
Air masses and fronts : Air mass production - Classification - Sources of air masses in winter and summer and their modification. Fronts and frontal surfaces - Principal frontal zones - frontogenesis and frontolysis. Extra - tropical cyclones - formation - Life cycle - Structure and movement. Zonal Index, Anticyclones and blocking.

Unit-II:
Kinematics of the pressure field : Characteristic curves - General expressions for their velocity and acceleration – Movement of troughs, ridges and pressure centres, Intensification and Weakening, deepening and Filling of surface pressure systems.

Unit-III:
Kinematics of the wind field: Relation between streamlines and trajectories. Trajectories in moving cyclones and anticyclones. Differential properties of the wind field. Application of geostrophic, gradient, thermal winds, divergence and vertical velocity computations, Confluence, Difluence, Dines compensation

Unit-IV:
Indian monsoons: Land and sea breezes – Definition of monsoon – Monsoon theories, Synoptic features associated with onset, withdrawal, active and break situations of southwest monsoon. Rainfall distribution and rain bearing systems during summer monsoon season - monsoon depression, Mid - tropospheric cyclones and Onset vortex. Prediction of weather elements: Seasonal prediction of monsoon rainfall and date of onset. Maximum and minimum temperatures – Fog.

Unit-V:
Northeast monsoon - onset and seasonal rainfall distribution – rainbearing systems.
Western disturbances, Heat & cold waves and Extreme weather events for India.

Text Books:

1. Weather analysis and forecasting – Vol.1 & 2 by B. Patterson
2. Tropical meteorology by H. Riehl
3. Climate and circulation of the tropics by S. Hasternath
4. Monsoon meteorology by C.S. Ramage
5. Jet stream meteorology by E.R. Reiter
6. Synoptic-Dynamic Meteorology in Midlatitudes: Volume II: Observations and Theory of Weather Systems by Howard B. Bluestein
7. Synoptic Meteorology-A Dictionary of Earth Sciences | 1999 | Ailsa Allaby and Michael Allaby

M-202/PO-202: Dynamical Oceanography

Unit I:
Statistics and Kinematics: Fields of gravity, Pressure and mass, barotropic and baroclinic fields, sigma t-surfaces, static stability, double diffusion, representation of field of motion in the sea, equation of continuity.

Unit II:
Equations of motion, non-linear terms in the equation of motion, equation of mean flow, Reynold's stress, Eddy viscosity, scaling equation of motion, dynamic stability.

Unit III:
Geostrophic currents: Barotropic and baroclinic fields, relative and slope currents, level of no motion, computation of relative currents in a two layer motion and in stratified ocean, Bjerkne's circulation theorem.

Unit IV:
Currents without friction, inertial motion, Geo potential, Geo potential surface and Isobaric surface, Margules's equation for two layer ocean, geostrophic current, relative current and slope current, level of no motion and absolute currents.

Unit V:
Currents with friction: Currents with friction, Ekman's solution to the equation of motion with friction present, Ekman transport and Upwelling, bottom friction and shallow water effect, Equatorial underwater current, Stommel's theory of western boundary currents.

Reference books:

1. Introduction to dynamical oceanography by S.Pond and G.L.Pickard
2. Fomin, L.M. 1964. Dynamic method in oceanography. Elsevier publication co.
3. http://www.sciencedirect.com/science

M-203/PO-203: SATELLITE METEOROLOGY AND SATELLITE OCEANOGRAPHY

UNIT-I

Remote sensing system, Satellite systems compared with ground based observing system.
Satellite orbits: Newton's laws, Kepler's laws, Kepler's equation, orientation in space, orbital elements, Geostationary orbits, Sun synchronous orbits, other orbits, revisit intervals.
Radiative Transfer: Electromagnetic radiation, black body radiation laws, non black bodies radiative transfer equation, Schwarzschild equation, gaseous absorption and scattering.
Satellite imagery: Creating images, spatial resolution, visible imagery, infrared imagery, water vapor imagery, microwave imagery.
Image enhancement techniques, weather systems observed in satellite imagery, Monsoons, Tropical Cyclones.

UNIT-II

Temperature and Humidity Retrieval: Sounding theory, retrieval methods, Limb sounding retrievals, the split window techniques.
Winds: clouds and vapor tracking, cloud motion winds, Ocean surface winds, Tropical Cyclone winds- Dvorak technique.

UNIT-III

Clouds: clouds from images
Precipitation: Visible and Infrared technique, Passive microwave technique, GOES precipitation index.
Estimation of earth radiation budget, outgoing Long wave Radiation, Soil moisture, vegetation index.

UNIT-IV

Ocean properties measurable from satellites
Ocean Color Remote Sensing: optical theory for Ocean color remote sensing, recovering useful information from ocean color, estimating water parameters from spectral band ratios, identifying Potential Fishing Zones.
IR measurement of Sea Surface Temperature – retrieving SST: IR Radiometer, AVHRR, ATSR, AIRS, Oceanographic application of IR SST data.
Passive microwave Radiometers: Physical principle of passive microwave radiometry, retrieval of Salinity, SST and surface wind from microwave measurements.

UNIT-V

Radar Altimeters over the Ocean: Principles of satellite altimetry, measuring distance with a radar altimeter, Ocean currents from altimetry, estimating wave height and wind speed.
Sea surface roughness and Scatterometry : Measuring the radar energy reflected from Sea, microwave interaction with Sea surface. Empirical relationships between wind and radar back scattering.

Synthetic Aperture Radar (SAR) imaging of the Ocean: principle of SAR, Range resolution, Aperture synthesis, SAR imaging of Ocean waves. Hydrodynamic modulation, Tilt modulation, Velocity modulation, Ocean information from SAR images.

Text books:

1. Measuring the oceans from space- Ian S.Robinson
2. The principles and methods of satellite oceanography- Ian S. Robinson
3. Discovering the ocean from space- Ian S. Robinson
4. The unique applications of satellite oceanography – Ians Robinson
5. Satellite meteorology an Introduction – stanley Q. Kidder, Thomas H. Vander Harr
6. Satellite Meteorology R.R.Kelkar
7. Applications with Meteorological satellites – W. Paul Menzel
8. Fundamentals of Remote sensing – George joseph
9. Oceanographic applications of Remote Sensing – Motoyoshi Ikeda, Frederic W.Dobson

M-204 : Advanced Dynamical Meteorology & Numerical Weather Prediction

Unit I:
Atmospheric energetics - Energy equation. Kinetic energy. Internal energy, Potential energy, Morgules theory of conversion of Potential & Internal energies to Kinetic energy. Available Potential energy, CAPE, CINE. Expression for APE. General circulation of atmosphere – Maintenance of the mean circulation of kinetic energy balance of the atmosphere, Angular momentum consideration. Absolute Vorticity consideration.

Unit II:
Linear perturbation theory – Perturbation Method .Properties of Waves Sound waves, Gravity wavers –External and Internal gravity waves, Rossby waves, Inertial waves, Geostropic adjustment process, Equatorial wave theory.

Unit III:
Numerical models – Filtered models: Filtering of sound and gravity wave models: Barotropic model; Equivalent barotropic model; Barotropic instability Numerical methods – Computation of Jacobian and Laplacian; solution of Helmholtz and Poisson equations using relaxation method; Finite difference method- Forward and centered finite difference methods, semi – implicit method- computational instability.

Unit – IV:
Barotropic Models – Two level model; Quasi- Geostropic multi level models; Omega equation; Linear balanced model; Nonlinear balanced model, Baroclinic instability. Primitive equation models – sigma coordinate system; Two level primitive equation model; multilevel primitive equation models. Introduction to meso scale models: Nonhydrostatic assumption, basic structure of MM5 and WRF models and their applications.

Unit – V:
Objective analysis- Cressman method, method of optimum interpolation. Initialization; Static initialisation; Dynamic intialisation – Normal mode initialisation, Newton relaxation or Nudging. Nonlinear instability, Aliasing. Arakawa Jacobian. Staggered grid systems

Text Books:

1. An Introduction to Dynamical Meteorology, J.R.Holton
2. Introduction to Theoretical Meteorology by S.L. Hess
3. Tropical Meteorology by T.N.Krishnamurti, WMO publications
4. Numerical Weather Prediction G.J. Haltiner, John Wiley
5. Numerical Prediction and Dynamical Meteorology by G.J.Holtiner , R.T.Williams, John Wiley
6. Numerical weather analysis and forecasting by P.D.Thompson.

M-205 : Elements of General Meteorology (OD)

Unit-I:

State of the atmosphere : weather and Climate, Main constituents of dry air; Vertical thermal structure of the atmosphere; Environmental lapse rate; Standard atmosphere; Hydrostatic equilibrium; Hydrostatic equation; Geopotential; Equipotential surfaces.

Unit II:

Moisture variables- Absolute humidity, specific humidity, relative humidity, mixing ratio; Virtual temperature. Vertical stability of the atmosphere: Dry adiabatic lapse rate; Standard adiabatic lapse rate.

Unit III:

Radiation: Solar radiation, terrestrial radiation; mean heat balance of the earth - atmosphere system; atmospheric green house effect.
Fundamental and Apparent forces; Equations of motion; Geostropic wind, gradient wind, thermal wind.

Unit-IIII:

Circulation and systems: Land and sea breezes, thunder storms, tornadoes, dust storms; trade winds; ITCZ; Monsoons- Definition of monsoon, summer and winter monsoons over India, rain-bearing systems of monsoons; Tropical cyclones – Their structure and movement; Extra-tropical cyclones– their structure and movement;

Unit-IV:

Air masses and fronts; Jet streams – Definition, Jet streams affecting India. Impact of Global warming on Climate with special reference to India.

Text Books:

1. Dynamical and Physical Meteorology - G.J.Haltiner and F.L.Martin
2. Compendium of Meteorology (WMO Pub.) - Physical Meteorology, 1973, Vol.1, No.2
3. Physical Meteorology - H.G.Houghton
4. Atmospheric Thermodynamics - J.V.Iribarne and W.L.Godson
5. An introduction to Dynamic Meteorology – JR Holton
6. Monsoons – PK Das
7. Our weather – PA Menon

M-206/PO-206: Synoptic Analysis practical

1. Decoding weather messages of surface and upper air
2. Plotting of surface and upper air data and preparation of weather chart
3. Analysis of surface and upper data
4. Case study of Bay cyclone.
5. Case study of Monsoon disturbance.
6. Case study of western disturbance.
7. Case study of break monsoon situation

M-207/PO - 207: Computer oriented numerical and statistical programming

1. Correlation Coefficient and Linear Regression
2. Curve Fitting by the method of least squares
3. Multiple Regression
4. Analysis of Variance (ANOVA)
5. Auto correlation and Partial auto correlation
6. Gauss Siedel Iterative Method
7. Newton Raphson Method
8. Simpson's $1/3^{rd}$ Method
9. Runge Kutta 2^{nd} order method
10. Euler method for solving differential equation

M-208/PO-208: Viva -Voce

Third Semester
M-301/PO-301: Climate and Ocean Modeling

Unit-I

Physical Modelling and Numerical Modeling; Uses of modeling, different methods and approaches in modeling, Diagnostic models, Prognostic models. Lagrangian and Eularian approaches in modeling, primitive equation models. Model dimension and coordinates, Model domain, temporal and spatial resolution of the models. Model initialisation; Model forcing.

Unit -II

General circulation and climate modeling: Introduction to climate modeling. Energy balance models- their structure; zero dimensional energy balance models; one dimensional energy balance models.

Radiative convective models: The structure of Global Radiative convective models: Radiation computation – Short wave radiation , long wave radiation, heat balance at the ground , Convective adjustment; Sensitivity experiments with radiative convective models.

Unit- III

Two dimensional models- Zonally averaged climate models – spatial and temporal structure; statistical and dynamical climate models; representation of convection, cloud cover, precipitation, radiation and surface characteristics in 2-D SDMs.

Three dimensional atmospheric general circulation models – the structure of general circulation climate models. Numerical information – Grid point general circulation models; Phillips experiment. Spectral general circulation models- Spectral method; Triangular and rhomboidal truncation; spectral Transform method. Regional climate models: Formulation; boundary conditions, specific applications.

Unit - IV

Introduction to Ocean modeling; Basic equations, wind driven barotropic models, simple thermohaline models, baroclinic models, mixed layer models. Shallow water models. Status of operational models in Indian Ocean:

Global ocean models: Modular Ocean model (MOM), Parallel ocean model (POM), Regional oceanic Modelling Systems (ROMS).

Coastal Models: storm surge models, SLOSH- Sea level & Over land surge assimilation model. Coupled Ocean and Atmospheric model.

Unit- V

Physics in general circulation climate models – Radiative transfer, Boundary layer; surface parameterization; Convection; large scale rainfall.

Physics in ocean modeling – Shallow water equation, sub-grid scale parameterization , 4 dimensional data assimilation; Model validation; Indian Ocean boundary conditions, model forcing conditions over Indian Ocean.

Text Books:

1. Introduction to three dimensional general circulation models. W.M. Washington and Parkinson.
2. A Climate Modelling Primer. A.H Sellers and K. McGuffie.
3. Numerical prediction and Dynamic meteorology. G.J. Haltiner and R.T. Williams. John Wiley.
4. Atmosphere, ocean and Climate dynamics by John Marshall.
5. Numerical models for Ocean circulation – Pond S. and Bryan.
6. Dynamics and modeling of ocean waves – Komen G.J and Cavaleri L.

M-302: Monsoon Dynamics

Unit -I:
Global perspective of monsoon, CTCZ, ITCZ over Indian ocean - structure and movement, 5-7 day, 30-50 day oscillations (MJO), 10-20 day oscillations. Regional circulation systems: Jet streams and their characteristics, Easterly waves-structure and movement.

Unit II
Monsoon variability: Inter annual variability and decadal variability, Teleconnections of Indian summer monsoon with southern oscillation, El-Nino, La Nina, Indian Ocean dipole mode, NAO, Arctic Oscillation and Antarctica Oscillation, Reversal of monsoon system, winter monsoon.

Unit -III:
Monsoon rain bearing systems: Monsoon trough/CTCZ, Depressions, onset vortex, Mechanism of formation, structure and dynamics; Monsoon Elements; monsoon mesoscale process, seasonal prediction and predictability of monsoon, coupled monsoon system, the role of ocean in the life cycle of Indian monsoon system. ICRP programs with special reference to Indian Monsoon dynamics. Monsoon Index, Monsoon Mission.

Unit-IV:
Tropical cyclones: structure and mechanics – Life cycle, surface and upper air structures, budgets of momentum and energy, formation and movement – variability of hurricane intensity, Impact of global warming on the frequency of tropical cyclones

Unit-V
Thunder storms – CAPE and CINE, Favourable conditions for severe thunderstorms, influence of vertical wind shear, stability indices, Life cycle and structure of thunderstorm, Dust storm(Andhi), Kalabaisaki, Hail storm.
Tornadoes: Tornadoes in Indian subcontinent, structure of Tornado

Text books:

1. Weather analysis and forecasting- Vol.1 and 2 by B.Petterson
2. Tropical meteorology by H. Reihl
3. Climate and Weather in tropics - H. Reihl
4. Climate and circulation of the tropics by S. Hasternath
5. Tropical Meteorology by G.C. Asnani.
6. Monsoon Meteorology P.K Das.
7. The physics of the monsoon R. N. Keshava Murthy and M. Sankar Rao
8. The Asian Monsoon- Bin Wang

M 303/PO 303: Ocean Atmosphere Interaction

Unit I:
The significance of Air-Sea Interaction: Atmospheric and Oceanic Interaction at various scales; Concept of Boundary Layer, Barrier Layer, Thermal inversion; Atmospheric Heat Budget; Variations of wind, temperature and moisture over the sea surface. Air sea temperature differences, Wind stress and resultant drag coefficient with variation to wind speed, Upper ocean boundary layer, Oceanic heat budget.

Unit II:
Physical interaction between the ocean and atmosphere: Radiation, Heat exchange through latent and sensible heat, Oceanic forcing by air-sea exchange of moisture and heat, Momentum transfer and drag, Oceanic impact on the marine atmospheric circulation.

Unit III:
Wind Waves and the Mechanisms of Air-Sea Transfer : The Origin of Wind Waves, Instability Theory, Properties of Instability Waves, The Breaking of Waves, Momentum Transfer in a Breaking Wave, Water-side Resistance, Air-side Resistance, Pathways of Air-Sea Momentum Transfer.

Unit IV:
Mixed Layers in Contact**:** Mixed Layers, Thermoclines, and Hot Towers, Mixed Layer Turbulence , Laws of Entrainment, Entrainment in a Mixed Layer Heated from Below, Mixed Layer Cooled from Above.

Unit V:
Large Scale Air-Sea Interaction: Ocean – Atmosphere interaction in tropics
Characteristics of ENSO, ENSO and Air – Sea coupling; ENSO and the Indian Monsoon Warm Pool in Indian and Pacific Oceans.

Text Books:

1. Atmosphere – Ocean Dynamics, Adrian E. Gill, 1992.
2. Climate and Circulation of the Tropics, S. Hasternath, 1988.
3. The Oceans and climate by G.R.Bigg, 1996.
4. Ocean – Atmosphere interaction and climate modeling, Beris A. Kagan, 1995
5. Air-Sea Interaction Law and Mechanisms by G.T. Csanady
   Breaking and Dissipation of ocean surface wave By Alexander Babanin

M 304: Applied Meteorology

UNIT-I: Agricultural Meteorology

Hydrological cycle and its components. Surface energy balance. Diurnal and annual variations of soil at different depths. Crop protection from adverse meteorological phenomena-droughts, heavy rains, storms, cold waves and frost, heat waves, shelter from winds. Crop Weather calendars. Agro meteorological forecasting, crop-yield forecasting. Remote sensing applications to agriculture, Climate change relating to agriculture.

UNIT-2: Hydrometeorology

Definition and its scope. Storm modelling, Rainfall return periods, PMP models. Rainfall-Runoff models, Flood forecasting, Drought categories and assessment techniques. Fundamentals of the evaporation process, methods to determine evaporation: energy balance, aerodynamic; Penman-Monteith methods.

UNIT-3: Aviation Meteorology

Role of meteorology in aviation, SIGMET, weather hazards associated with takeoff cruising and landing, inflight – icing, turbulence, visibility, fog, clouds, rain, gusts, wind shear and thunderstorms. Understanding the Jet stream. Nowcasting and very short range forecasting.

UNIT-4: Air Pollution Meteorology

Sources and Classification of air pollutants, Meteorology and air pollution. Micrometeorological studies in Air pollution - Monin – Obrukhov length scale – diabatic conditions in the surface layer, surface layer models. Ekman-spiral characteristics, Urban Heat islands, Asian brown cloud, Forest fires. Detection of Aerosols. Modelling of Air Pollutants- Box Model, Gaussian Model, diffusion and dynamic models.

UNIT-5: Climate Change

The Climate system – Sun, Atmosphere, Ocean, Ice and energy balance of the earth. History of climate change – glacial cycle (100, 000), interglacials, insterstadial events, year to decadal. Greenhouse gases and global warming – GHGs trend, Global temperature trend, Global distribution of emissions, IPCC. The Kyoto Protocol, Climate change –Extreme weather events, The Measurement of Climate Change, Global warming and the hydrological cycle.

Text Books :

1. Hydrometeorology - C.J.Wiesner
2. Agro meteorology : G.Z.Venkskevitch, Israel Program for Scientific Transition, IPST press, Jerusalem, 300 pp., 1961
3. Guide to Agricultural Meteorological Practices: WMO No.134, 1981.
4. Lecture Notes for training Class IV Agricultural Meteorological personnel, WMO No.593, 1982.
5. Land use and agro system management under severe climatic conditions, WMO No.633, 1986.
6. Agroclimatic/Agrometeorological Techniques, S.Jeevananda Reddy, Jeevan Charitable Trust, ICRISAT Colony, Secunderabad, 1993

M-305: Global Warming and Climate Change

Unit – I

The Climate system – Sun, Atmosphere, Ocean, Ice and energy balance of the earth.
History of climate change – glacial cycle (100, 000), interglacials, insterstadial events, year to decadal.

Unit – II
Greenhouse gases and global warming – GHGs trend, Global temperature trend, Global distribution of emissions, IPCC
Sources of CO_2 in the Land, Ocean and atmosphere

Unit – III
The history of climate and the human species, human-caused climate change, impacts of climate change on human well-being and the natural world, climate change-anthropogenic.

Unit – IIII
The Kyoto Protocol, Climate change –Extreme weather events, The Measurement of Climate Change, Global warming and the hydrological cycle, Climate change impact on ecosystems, Agriculture

Unit – IV
Possible remedies of global warming – Reducing Carbon Emissions, Energy use and Emission trading, Future Emissions and Energy Resources, Current and Future sources of Methane, Biological sources of Nitrous oxide, Role of Scientist and Human being.

Text Books

1. Global Warming: A Very Short Introduction by Mark Maslin
2. Global Warming The Complete Briefing by John T Houghton
3. Intergovernmental Panel on Climate Change, (Cambridge University 2007)
4. Ruddiman, William F.2001. Earth's Climate: Past and Future
5. Henderson-Sellers, A., and P.J. Robinson, 1999. Contemporary Climatology (second edition). Prentice-Hall.
6. Houghton, J.T., 2001, (ed). Climate Change 2001, The Scientific Basis. 881pp.
7. Kuhn, T.S., 1962 and updates. The Structure of Scientific Revolutions (excerpts; no purchase necessary)
8. Contemporary Climatology, by Peter J. Robinson and Ann Henderson-Sellers.
9. Climate Change: A Multidisciplinary Approach, by William James Burroughs
10. Current trends in Global Environment by A.L. Bhatia (2005)

M 306 : Numerical Weather Prediction Practicals

Part - A

1. Computation of vorticity using geopotential height: Solution of Laplacian
2. Computation of advection : Solution of Jacobian
3. Relaxation for solution of barotropic vorticity equation
4. Preparation of computer code for (3) to obtain tendency field
5. Computation of surface fluxes
6. Numerical computation of LCL
7. Numerical computation of moist adiabatic
8. Computation of heating rates –Kuo scheme
9. Barotropic Instability
10. Baroclinic Instability
11. Cyclone track forecasting using Mesoscale models

M 307: Applied Meteorology Practical

Part-A

1. Handling of INSAT and NOAA data
2. Channel separation and corrections
3. Converting pixel values to brightness temperature (Bt)
4. Interpretation and applications of satellite images in conjunction with surface and upper air synoptic charts
5. Application of satellite cloud pictures for different synoptic systems
6. Estimation of intensity of tropical cyclone using Dvorak's technique
7. Retrieval of Sea Surface Temperature
8. Estimation of rainfall using infrared and microwave data
9. Diurnal variation of rainfall over Oceans

Part-B

1. Determination of average depth of precipitation
2. Evaporation and evapotranspiration models
3. Determination of the depth of precipitable water
4. Analysis of drought through water budget method
5. Stream flow analysis
6. River yields- water balance techniques
7. Soil heat flux
8. Soil temperature profile
9. Calculation of the bulk density of the soil and the total amount of soil water
10. Derivation of agro-climatic variables from weekly rainfall (R) and weekly potential evapotranspiration (PE).

M 308/PO 308 : Viva Voce

Fourth Semester

M 401/PO 401: Dissertation

M 402/PO 402 : Viva - Voce

Approved Course Pattern and Syllabi w.e.f. 2014-2015 academic year
M.Sc. (Physical Oceanography)

First Semester

Course No.	Title of the Paper	Internal assessment marks	Semester end examination marks	Total Marks	Credits
Theory:					
PO–101	Physics and Dynamics of Climate	15	85	100	4
PO–102	Physical Meteorology	15	85	100	4
PO–103	Dynamical Meteorology	15	85	100	4
PO–104	Physical Oceanography	15	85	100	4
PO–105	Meteorology and Oceanography Instruments	15	85	100	4
Practicals:	Meteorology and Oceanography				
PO–106	computations	15	85	100	4
PO–107	Observational Techniques	15	85	100	4
PO–108	Viva-voce	-	50	50	2
	Total	105	645	750	30

Second Semester

Theory:					
PO–201	Synoptic Meteorology	15	85	100	4
PO–202	Dynamical Oceanography	15	85	100	4
PO–203	Satellite Meteorology and Satellite Oceanography	15	85	100	4
PO–204	Indian Ocean Dynamics	15	85	100	4
PO-205	Elements of Physical Oceanography (OD)	15	85	100	4
Practicals:					
PO–206	Synoptic Analysis	15	85	100	4
PO–207	Computer Programming	15	85	100	4
PO–208	Viva-voce	-	50	50	2
	Total	105	645	750	30

Third Semester

Theory:					
PO–301	Climate and Ocean Modelling	15	85	100	4
PO–302	Coastal and Estuarine Dynamics	15	85	100	4
PO–303	Air Sea Interaction	15	85	100	4
PO–304	Applied Oceanography	15	85	100	4
PO-305	Coastal zone Management (OD)	15	85	100	4
Practicals:					
PO–306	Physical Oceanography	15	85	100	4
PO–307	Applied Oceanography	15	85	100	4
PO–308	Viva-voce	-	50	50	2
	Total	105	645	750	30

Fourth Semester

PO–401	Internship	50	100	150	6
	Dissertation	100	300	400	16
	Seminar	50	100	150	6
PO–402	Viva-voce	-	50	50	2
	Total	200	550	750	30
	Grand Total (1+2+3+4 semesters)	515	2485	3000	120

M.Sc. Physical Oceanography

First Semester

PO – 101: Physics and Dynamics of Climate

[Common Syllabus with M.Sc. (Meteorology) First Semester]

PO-102: Physical Meteorology

[Common Syllabus with M.Sc. (Meteorology) Second Semester]

PO – 103: Dynamical Meteorology

[Common Syllabus with M.Sc. (Meteorology) First Semester]

PO – 104: Physical Oceanography

[Common Syllabus with M.Sc. (Meteorology) First Semester]

PO – 105: Meteorology and Oceanography Instruments

[Same as M.Sc. (Meteorology) First Semester]

PO – 106: Meteorology and Oceanography computations

[Same as M.Sc. (Meteorology) First Semester]

PO – 107: Observation Techniques (Practicals)

[Same as M.Sc. (Meteorology) First Semester]

Second Semester

PO-201: Synoptic Meteorology
[Common Syllabus with M.Sc. (Meteorology) Second Semester]

PO-202: Dynamical Oceanography
[Common Syllabus with M.Sc. (Meteorology) Second Semester]

PO-203: Satellite Meteorology and Oceanography

[Common Syllabus with M.Sc. (Meteorology) Second Semester]

PO 204 : Indian Ocean Dynamics

Unit-I

Physical characteristics of the Indian Ocean – size, shape, ocean basin, mid oceanic ridge system, ocean floor and seas

Physical, dynamical and biological characteristics of the Arabian Sea and Bay of Bengal

Physio – Chemical and marine ecosystem of the Andaman Sea.

Unit- II

Surface forcing – winds, radiation; river discharge, Ekman spiral/transport, Geostrophic currents, meanders and rings, Warm pool, Langmuir cells/circulation.

Regions of upwelling and sinking along Indian Ocean.

Surface circulation– Gyre systems along north and south Indian Ocean

Unit-III

Indian Ocean currents - SW & NE monsoon drift (Indian monsoon current), Somali Current, Equatorial counter current, Indonesian through flow, south equatorial current, East Madagascar current, Mozambique current, Agulhas current, Leeuwin current, west Australian current, south Australian counter current, west wind drift.

Unit-IV

Indian Ocean cross-equatorial flow

Variability of Indian Ocean currents – monsoon circulation, Great Whirl, circulation pattern during the events of ENSO and IOD.

Unit-V

Thermohaline circulation - Thermal structure of Indian Ocean, variability of Mixed Layer, thermocline, salinity fluctuations, water mass characteristics of Indian Ocean, under currents and thermohaline circulation.

Text books

1. Ocean Circulation – Prepared by open university course team
2. The Indian Ocean : A Perspective – by Rabin Sen Gupta, Ehrlich Desa
3. Ocean circulation and climate – Observing and modeling the global ocean - Gerold Siedler, John Church, John Gould.
4. Ocean and Climate – Grant R. Bigg

PO-205: Elements of Physical Oceanography

Unit I:
Physical properties of seawater: Temperature, Salinity and Density; Temperature, Salinity and density distributions. Transparency of seawater, Sound in the sea, Light in the sea, Colour of seawater, Sea Ice.

Unit II:
Waves and tides: wave parameters, deep water waves, transformation of waves in shallow water, wave generation. Types of tides, tide producing forces.

Unit III:
Ocean circulation : wind induced currents ,Up welling, sinking; equatorial current system, west ward intensification of currents, warm and cold currents of major world ocean, seasonal currents in North Indian Ocean, Thermohaline circulation.

Unit IV:
Marine geology: Continental shelf, Slope, Shelf sediments, mineral resources of the world ocean, submarine topography, mid oceanic ridge system. Manganese and other deposits and the factors controlling their distribution.

Unit-V
Marine biology: Classification of marine environment, Bio geo chemical cycles. Influence of Physical parameters (Temperature, salinity, waves, currents, tides etc.). Mangroves

Text books:

1. Introduction to Physical oceanography by M.P.M.Reddy.
2. Introduction to Physical oceanography by Robert.H.Stewart.
3. Introduction to dynamical oceanography by S.Pond and G.L.Pickard.
4. Oceans by Sverdrup,Johnson and Flemming.

PO-206: Synoptic Analysis
[Common Syllabus with M.Sc. (Meteorology) Second Semester]

PO-207: Computer Programming (Practicals)

[Common Syllabus with M.Sc. (Meteorology) Second Semester]

Third Semester

PO-301: Climate and Ocean Modelling

[Common Syllabus with M.Sc. (Meteorology) Third Semester]

PO 302 : Coastal and Estuarine dynamics

Unit I:

Coastal processes – transformation of waves in shallow water – refraction, diffraction, reflection. Coastal and near shore circulation-long shore currents, rip currents and tidal currents. Sediment transport rate – onshore and offshore transport – coastal features – LEO observation

Unit II:

Sea level changes :Periodic sea level changes – short term variations – long term changes – Impact of global warming on sea level – impacts of sea level rise. Strom surge and tsunamis.

Unit III:

Beach features :Beach cycles, beach profiles-erosion and accretion, beach stability – artificial nourishment – coastal defence structures – planning and design of coastal structures – tidal inlets and Lakes, deltas.

Unit IV:

Estuaries: Classification, tides in estuaries, estuarine circulation and mixing, Hydrology and hydrograph, sedimentation in estuaries.

Unit V:

Salinity intrusion in estuaries, effect of stratification, Tides and tidal currents in estuaries coastal pollution: mixing and diffusion dispersal of pollutants in estuaries, tidal prism concept. .

Reference books:

1. Coastal and Estuarine Dynamics by A.T. Ippen
2. Estuaries: A Physical Introduction by K.R. Dyer
3. Coastal Engineering by Kiyoshi Horikawa

PO-303: Ocean Atmosphere Interaction

[Common Syllabus with M.Sc. (Meteorology) Third Semester]

PO 304 : Applied Oceanography

Unit I:
Concepts of absorption, scattering, attenuation, heat conduction, reflection and refraction of sound propagation in the sea. Sound velocity vertical structure of the sea. Physical characteristics of the sea related to sound transmissions. Acoustic Wave Equation – Normal mode theory and Ray theory.

Unit II:
Transmission of sound in shallow waters, Transmission of sound in deep waters. Echo sounder principle - Interpretation of Echo sounding records, Acoustic tomography.

Unit III:
Wave generation, Jeffrey's theory, Sverdrup and Munk theory, wave growth and propagation, Group velocity. Wave forecasting - SMB method, sea and swell forecasting through PNJ method, co cumulative spectrum, dispersion, angular spreading and the concept of wave forecasting filter.

Unit IV:
Coastal meteorology: winds, aerosols. Internal waves, oil spills, coastal lows.CRZ regulations, Potential Fishing zones. Coastal hazards and mitigation.

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Unit V:
Energy from the sea: harnessing of tidal energy, wave energy and thermal energy.

Reference books:

1. Fundamentals of Marine Acoustics - Jerald W.Caruthers, 1977
2. Introduction to the theory of sound transmission with Application to Ocean - C.B.Officer, 1958
3. Observing and forecasting of ocean waves – H.Q pub. No. 603, US Navy
4. Coastal Engineering by Kiyoshi Horikawa

PO-305 : Coastal Zone Management

Unit-I

Waves, tides and currents: Deep water waves, shallow water waves, wave propagation, sea and swell waves their generation.

Unit-II

Tides, Sea level variations, Storm surges and tsunamis; Warm currents, cold currents, Longshore currents, rip currents and tidal currents.

Unit-III

Ocean resources: Potential fishing zones (PFZ), Gas hydrates, Harnessing of the Ocean

Unit-IV

Energy Resource: Ocean Thermal Energy Conversion (OTEC) plants, wave energy and tidal energy; Coastal constructions: Jetties, groins, breakwaters, maintenance of entrance channels etc.

Unit-V

Coastal zone management: Classification of Coastal Regulatory Zone (CRZ), Genesis of CRZ, Laws relevant for coastal zone management, prohibited activities, relevant legislations, Coastal security, Tidal flats, deltas, Maintenance of Aquaculture farms.

Text books

1. An Introduction to Coastal Zone Management by Timothy Beatley, David Brower, Anna K. Schwab
2. The Coast: Hazardous Interactions within the Coastal Environment by Timothy M. Kusky
3. GIS for Coastal Zone Management - by Darius J Bartlett, Jennifer L Smith
4. Coastal Zone Management Imperative for Maritime Devloping Nations - by Bilal U Haq, Gunnar Kullenberg
5. Coastal zone management handbook by John R. Clark

PO-306: Physical Oceanography Practicals

Part – A

1. Wave Data Analysis – Rose Diagrams
2. Wave Refraction Diagrams
3. Computation of Longshore currents
4. Computation of relative currents.
5. Beach Profiles
6. Estimation of MLD from T/S profiles
7. Argo data analysis.

Part – B

1. Computation of short-wave Radiation at the Ocean surface
   a) Octa model, b) Synoptic approach
2. Computation of Long-wave Radiation at the Ocean surface
   a) Brunt's formula, b) Anderson's formula
3. Computation of Wind Stress at the ocean surface
   a) For different wind speeds (5, 10, 15 m/s),
   b) With variable coefficient of Cd
4. Computation of Latent Heat Flux at the Ocean surface
   a) For different wind speeds (5, 10, 15 m/s)
   b) With variable coefficient of Ce
5) Computation of sensible heat flux at the ocean surface
   a) For different wind speeds (5, 10, 15 m/s)
   b) With variable coefficient of Ch
6. Computation of Atmospheric Heat Budget.
7. Computation of Bowen's ratio.

PO-307: Applied Physical Oceanography (Practicals)

Part - A

1. Water Level Measurements in Estuary
2. Measurement of Tidal Currents
3. Wave Forecasting Methods
4. Analysis of sea level variations along the India coast using tide gauge and altimeter data
5. Computation of wave energy using significant wave height, density and gravity

Part –B

6. Sound speed computations from hydrographic data.
7. Computation of Acoustic Intensity.
8. Preparation of maps of sound channel axis.
9. Estimation of Insolation at the Ocean surface using INSAT data
10. Estimation of Upwelling/Downwelling phenomena from ERS-1 Scatterometer data.

PO-308: Viva –Voce

Fourth Semester

PO-401: Dissertation

PO-402: Viva –Voce

Model question paper

M. Sc Meteorology/ Physical Oceanography

Time :3 hours **Max. Marks : 85**

PART –A

Answer all questions (5 × 3 = 15)

All questions carry equal Marks

1) Unit I
2) Unit II
3) Unit III
4) Unit IV
5) Unit V

PART –B

Answer all questions (5 × 5 = 25)

All questions carry equal Marks

6) a) Unit I

OR

b) Unit I

7) a) Unit II

OR

b) Unit II

8) a) Unit III

OR

b) Unit III

9) a) Unit IV

OR

b) Unit IV

10) a) Unit V

OR

b) Unit V

PART –C

Answer any three questions (3 × 15 = 45)

All questions carry equal Marks

11) Unit I
12) Unit II
13) Unit III
14) Unit IV
15) Unit V