India Meteorological Department

Meteorological Training Institute

Revised Syllabus
For
Advanced Meteorological /Met-II Training Course

(12 months duration)

In the General Meteorology/Forecasting discipline

Semester-I (6 months duration)

Content

& 1 working week = 5 working days
 # 1 working day = 6 periods of 75 minutes

Subject	Duration	Place
Meteorological Observation System (Surface & UA)	18 working days[#]	MTI
Dynamic Meteorology	10 working days	MTI
Physical Meteorology and Thermodynamics	12 working days	MTI
Synoptic Meteorology including Weather Analysis and Forecasting	12 working days	MTI
Climatology & Meteorological Statistics including Climate Change & Climate services	14 working days	MTI
Oceanography and Marine Meteorology	5 working days	MTI
Applied Meteorology (AgriMet, HydroMet, Seismology & Astronomy etc.)	13 working days	MTI
Environmental Meteorology		
Aviation Meteorology	5 working days	MTI
Satellite and Radar Meteorology & Met Telecommunication system	11 working days	MTI
Management & administration	5 working days	YASHDA
DBM & GIS	5working days	MTI
Joining + Relief + midterm exam+ final exam + viva voce	3 working weeks[&]	MTI
Total	25 working weeks = 6 months. Afterwards they will go for 2 weeks OJT at IITM, NWA, Weather Central, INOSHAC, Agri-Met division, Instrument lab, Radiation lab, AMO Mumbai/AFS, Lohegaon, Pune.	

Meteorological Observation System (Surface & UA)

(Total duration = 18 working days = 18 x 6=108 periods of 75 minutes duration)

Theory of Meteorological variables (58 Periods)

- General principles of observations: representativeness of observations, Metadata, general requirement of a meteorological observatory, sitting and exposure, measurement standards and definitions, uncertainty of measurements, source and estimation of errors, expressing the uncertainty, calibration and maintenance, Operational measurement accuracy requirements and instrument performance. Response characteristics of the instruments, lag and radiation errors, resolution, precision and accuracy, limitations of sensors and instruments **(4P)**
- Structure of the atmosphere, meteorological elements to be observed **(4 P)**
- Atmospheric Pressure: Units and scales, methods of observations, barometer - Fortin and Kew pattern - description reading, correction of barometer readings to standard conditions, reducing the value to mean sea level, exposure, electronic and aneroid barometers, QFE, QFF and QNH, barographs; comparison of barometers. **(4 P)**
- Atmospheric Temperature: Units and scales, description of dry bulb, wet bulb maximum, minimum and soil thermometers, methods of working, reading and resetting. Stevenson screen, exposure; care of the instruments; thermograph; comparison of instruments with standard instruments. Other methods of temperature measurements **(4 P)**
- Humidity – Units and scales, measurement methods, hygrometer, definitions and specifications of water vapour in the atmosphere, calculation of relative humidity from dry and wet bulb readings; vapor pressure; dew point temperature, psychrometers, psychrometric tables, hygrograph, Formulae for the computation of measures of humidity, modern humidity sensors **(4 P)**
- Wind - definition of wind, units and scales, Beaufort scale, methods of measurements, wind vane and anemometer (all types), pressure tube Dines anemograph, exposure conditions, high wind speed recorders, ultrasonic devices, 3-D wind sensors **(4 P)**
- Precipitation: definition, units and scales, Rain gauge - Description and working, self-recording raingauge exposure, automatic rain-gauges, measurement of snowfall and snow cover, precipitation gauge errors and suggested correction procedures, fast response rain

gauges, disdrometers **(4 P)**

- Clouds – Units and scales, Classification, types, description, amount, height of base determination, direction of movement, Ceilometers, Satellite cloud pictures. **(4 P)**
- Present and past weather – description, definition of various weather phenomena, symbolic representation **(2 P)**
- Visibility – definition, units and scales, measurement methods, visibility landmarks, night visibility, RVR observations, transmissometer **(4 P)**
- Codes – Surface, Ship, Upper-air, TEMP, Aviation Codes including charting. **(20 P)**

OBSERVING SYSTEMS AND THEIR MEASUREMENT
(Surface and Upper air - 50 Periods)

- Measurement at surface observatories and Automatic Weather Stations, Agromet observatories **(4 P)**
- Marine Observations: Ship Observations, ocean drifting buoys, moored buoys, ARGO, Airborn instrumentation **(4 P)**
- Measurements at Aeronautical Meteorological Observatories **(4 P)**
- Measurement at Radiation and BAPMoN stations **(4 P)**
- General idea of Satellite based observations, **(4 P)**
- **Observations through remote sensing based on satellites: atmospheric temperature and sea surface temperature measurements, measurement of water vapour and humidity, precipitation through satellite and radar, clouds including type, base and height through satellite based sensors.**
- Radar Measurements, multiparameter radars (especially polarimetric) and profiler radars and their capabilities in meteorology (besides wind measurement), use of the sun and radio stars in the case of radars and profilers, **(4 P)**
- Measurement of upper air pressure, temperature, wind and humidity: Methods of upper wind observations, Radiosonde, Optical theodolite, Radiotheodolite, Radars, Pilot balloon, methods of calculations; with tail method; with constant rate of ascent, theodolite, balloon and accessories; computation of upper winds; PB ascent at night; determination of azimuth of a datum point by pole star method, selection of site for PB observatory; computation of meteor reports; principles of measurement of upper air temperature, pressure and humidity

by meteorograph, radiosonde; principles of measuring winds by radar and radio theodolites, GPS radiosonde, GPS receiver, Radars, LIDARS, wind profilers. GPS Radio-Occultation techniques **(15P)**

- Radiation- Definitions, units and scales, measurement methods, Surface Solar and IR radiation, solar, terrestrial and net radiation, Radiometer sondes, Direct and Indirect, Sunshine P **(5 P)**
- Trace gases, ozone and Aerosol: Description of spatial and temporal distribution of trace gases, ozone and aerosols., Measurement Techniques: Column Ozone, Vertical distribution of Ozone, Surface Ozone,IMD's network for Ozone observation, Dobson spectrophotometer Measuring instruments for trace gases, pollutants and aerosols, ozone sondes, Aerosol measurement technique, IMD's network for aerosol observation. **(4 P)**
- Lightning detector, atmospheric electricity measurements, potential gradient and conductivity measurements, lightning flash meters, networks for radio location of lightning, Environmental parameters- instrumentation and techniques. **(4 P)**
- Quality Assurance and Management of observing systems, Quality management, sampling meteorological variables, testing, calibration and quality check and inter comparison, Integrated Observing System, Targeted Observations, Field Campaigns, Instrument standardization and comparisons **(4 P)**
- **Maximum sustained surface wind, gustiness, squall, gale,wind averaging (1-2-,3-, 5-,10 min), wind conversion factor, impact of wind associated with tornado, thunderstorm, depression and cyclones (Beaufort scale, Saffir Simpson wind scale, Dvork scale etc.), classification of wind.**
- **Measurement at Agromet Observatories.**

DYNAMIC METEOROLOGY
(Total duration = 10 working days = 60 periods of 75 minutes duration)

Theory (52periods)

Equation of Motion (5 P)

- Scopes of Dynamic Meteorology. Concept of continuum. Basic conservation laws governing the atmospheric motion.
- Frame of reference: Time rate of change of a vector in an inertial and in a rotating frame of reference & their relation.
- Vector equation of motion in an inertial & non-inertial frame of reference.
- Forces, their categorization and property.
- Local change of a field, advection of a field variable, local (Eulerian) derivative & total (Lagrangian) derivative of a field variable.
- Introduction to local tangential co-ordinate. Equation of motion in local tangential co-ordinate.
- Introduction to spherical polar co-ordinate. Equation of motion in spherical polar co-ordinate. Curvature terms.

Scale Analysis (4 P)

- Concept of order of magnitude. Dimensional analysis of different field variable
- Definition of scale of a weather system. Scale analysis of momentum equation for mid-latitude/tropical synoptic scale / mesoscale system.

Geostrophic Approximation (4 p)

- Definition and properties of geostrophic wind. Vectorial expression for geostrophic wind. Schematic diagram to show how geostrophic balance is achieved.
- Rossby number. Use of Rossby number as a tool to test the validity of geostrophic approximation. Regions of atmosphere where geostrophy is not a valid assumption.
  Relation between wind direction/speed and isobar/contour distribution under geostrophic relation. Computation of geostrophic wind at equator, 30N, 60N and 90N for given pressure gradient (say 2hPa/100km). Geostrophic scale.

- Ageostrophic wind, its definition and property. Vectorial expression for ageostrophic wind. Its relation with acceleration.

Hydrostatic Approximation (3 P)

- Simplification of vertical momentum equation for mid latitude synoptic scale system following scale analysis leading to hydrostatic approximation. Discussion on the validity of this approximation.
- Using above approximation, definition of atmospheric pressure at any point.
- Definition of geopotential and geopotential height of a point and corresponding units.
- Hypsometric equation and its use in computing thickness of a layer of atmosphere.

Natural Coordinate and balanced flow (4 P)

- Introduction to natural co-ordinate. Horizontal equation of motion in natural co-ordinate. Gradient balance and gradient wind. Physically possible different gradient flow. Examples. Sub & super – geostrophic flow. Special cases of gradient balance: -geostrophic balance, inertial balance, and cyclostrophic balance. Examples.
  Is gradient flow a balanced (no acceleration) flow?

Vertical Variation of Wind (4 P)

- Concept of vertical wind shear. Schematic explanation for horizontal temperature gradient leading to vertical shear of geostrophic wind.
- Different vertical co-ordintes, pressure (p), potential temperature (θ) etc. Pressure gradient force in p & θ co-ordinates. Horizontal equation of motion ~~with p as~~ in any vertical co-ordinate.
- Thermal wind: Definition, Thermal wind equation and properties of thermal wind.
- Application of the concept of thermal wind in explaining Sub tropical westerly jet, Tropical easterly jet, intensification of cold (warm) core low (high) with height, tilt of axis of low (high) towards cold (warm), cold and warm advection associated with veering/backing of geostrophic wind.
  How much N-S temperature gradient creates a easterly jet of strength 100kt at 16km from a westerly of strength 20kt at surface (msl)?

- Analysis of the shear hodograph and stability conditions.
- Concept of barotropic and baroclinic atmosphere.

Continuity Equation and Convergence (4 P)

- Equation of continuity with different vertical co-ordinates: Importance of 'p' as a vertical co-ordinate. Application of continuity equation: Dines compensation principle. Concept & importance of level of non-divergence (LND). Kinematical method of computing ω. Scale analysis of continuity equation. Concepts of incompressible fluid, homogeneous fluid and isotropic fluid.
- Moisture continuity equation.
- Divergence of an arbitrary vector field. Physical concept. 2-D (or 3-D) divergence as a fractional rate of change of area (or volume). Horizontal divergence in natural co-ordinate system & in other (Spherical polar or cylindrical) co-ordinate system.
- Momentum flux, moisture flux

Kinematics of Wind Field (3 P)

- Stream lines and trajectory, their definition and differential equation, stream function, Blatons equation.
  How to get a trajectory?

- Resolution of horizontal wind into pure translation, divergence, rotation, deformation. Invariance of divergence and vorticity under co-ordinate transformation. Equation and patterns of streamline for pure translation, divergence, rotation, deformation
- Velocity potential

Kinematics of Pressure Field (3 P)

- Mathematical definition of center of low, high & COL. Mathematical equation of trough & ridge. Expression for the velocity of an isobaric pattern. Mathematical equation for the slope of axis of low/high.

Circulation and Vorticity (9 P)

- Definition and mathematical expression of circulation. Circulation theorems, their detailed derivation, detail discussions on their application aspects. Detailed discussions about solenoidal vector.

- Concept of vorticity of an arbitrary vector field. Definition of atmospheric vorticity along with its mathematical expression. Physical meaning of Curl of any vector. Components of vorticity vector. Relation between circulation and vorticity.
- Vorticity for solid body rotation. Concept of planetary vorticity. Relative vorticity in natural co-ordinate. Explanation of curvature and shear vorticity with specific examples. Concept of potential vorticity.
- Vorticity equation in different co-ordinates. Physical interpretations for individual terms. Scale analysis of vorticity equation. Application of vorticity equation. Conservation laws for Barotropic (Rossby) potential vorcity & Baroclinic (Ertel) potential vorcity and their application.
- Vorticity advection

Pressure Tendency and Mechanism of Pressure Change (3 P)

- Pressure tendency equation: Its derivation and physical interpretation, in detail, of each term, representing different mechanisms of pressure change. Importance of net divergence in an atmospheric column. Different isobaric patterns and their movement

Basics of Planetary Boundary Layer (6 p)

- A brief introduction to PBL: Definition of PBL. Importance of PBL. Characteristics of PBL: the turbulent motion. Types of turbulent motion: Convective turbulence and Mechanical turbulence. Conditions favourable for Convective turbulence and Mechanical turbulence. A general idea about depth of PBL and its diurnal and seasonal variation at a place.
- Description of different sub layers in PBL.
- Boussinesq approximation and its physical interpretation. Governing equations in the PBL using Boussinesq approximation.
- Concepts of Reynolds average. It's difference from the mean part in perturbation theory. Precaution to be taken while Reynolds averaging.
- Concepts of eddy flux, eddy flux divergence in detail and their importance.

Practical (8 periods)

- Computation of divergence & vorticity using curvature method (1 P)
- Computation of geostrophic wind, gradient wind,vorticity (1 P)

- Computation of thermal wind and thermal advection (1 P)
- Computation of vertical velocity using kinematic method (1 P)
- Use GrADS to plot divergence, vorticity, vertical velocity, advection etc. and compute tilt of synoptic systems with height and plotting of cyclone tracks etc. from IMD's NWP model output. (4 P)

Physical Meteorology & Thermodynamics

(Total duration = 12 working days = 60 periods of 75 minutes duration)

Theory (33 Periods)

- **Atmospheric Thermodynamics (15 Periods)**

  - The Gas Laws, Concept of partial pressure of a constituent gas in a mixture of gasses, Dalton's law of partial pressure and equation of state for a mixture of gasses. (2 P)
  - Moisture in the atmosphere, Moisture parameters; Latent heat; Molecular weight of dry air, virtual temperature, work, energy and specific heats of gas; enthalpy; adiabatic process, equivalent temperature (2 P)
  - First law of thermodynamics and its application (2 P)
  - Second law of thermodynamics: enthalpy and other thermodynamic functions of state viz., entropy, Helmholtz free energy function and Gibbs free energy function , derivation of Clausius – Clapeyron equation using Gibbs free energy function; Thermodynamic diagrams; Normand's theorem; Saturated adiabatic and pseudo- adiabatic processes; Equivalent potential temperature, Dry and Moist static energy, Stability and instability by parcel and slice methods, conditional, convective and latent instabilities, convection and entrainment (4 P)
  - Hydrostatic equation: Geopotential, thickness and heights of constant pressure surfaces, Homogeneous, isothermal and constant lapse rate atmospheres; Standard atmospheres; Barometric altimetry. Precipitable water vapor: Rate of precipitation (3 P)
  - Total Precipitable water (TPW) (2)

- **Theory of Atmospheric radiation: (18 Periods)**
  - Electromagnetic spectrum: quantitative description of radiation; Kirchoff's Law, Planck's Law, Stefan-Boltzman's Law, Wien's displacement law, and Beer's Law; atmospheric radiative transfer: Concept on radiative equilibrium and discussion on radiative flux divergence. Scattering, Rayleigh, Mie and non dimensional scattering, absorption, and emission of radiation; Schwarzchild's equation, Refractive index variations discontinuities, refractivity turbulence (6 P)
  - Solar radiation, direct and diffuse, and global radiation and their measurements; Solar constant and its measurements; Albedo of Earth, Details of aerosol scattering

and their impact on direct and diffuse radiation, Atmospheric Aerosols turbidity and its impact of solar radiation. (4 P)

- Terrestrial radiation: Absorption of terrestrial radiation by atmosphere; Greenhouse effect, Radiative cooling of the atmosphere; Heat balance of the earth and atmosphere, Anthropogenic green house gases, green house effect, its role and examples from atmosphere of Venus, "Runaway green house effect" Sources of green house gases, linked with anthropogenic activities. (5 P)
- Refraction, scattering and diffraction of solar, IR and radio waves: Impact of dust and turbidity (3 P)

- **Theory of Atmospheric visibility**: visibility meters; Measurement of visibility during day and night. Impact of hydrometeors and Lithometeors on visibility, impact of air pollution and photochemical processes in the Atmospheric boundary layer on visibility **(3 P)**
- **Basics of Cloud Physics**: Spatial and temporal scales of clouds i. e. multiscale structure of clouds (cumulus, cumulus congestus, Cb, stratus etc.). Nucleation formation of cloud droplets, droplet growth by condensation, precipitation mechanisms in cloud, concepts of partial pressure and role of different hydrometeor in convective and stratiform rain formation (7 P)

Practical (27 Periods)

- Analysis of Radiosonde data using tephigrams: Computation of virtual temperature & other thermodynamic parameters. (7 P)
- Advanced analysis of radiosonde data for weather predictions: Study of stability conditions for given sounding data,identifying layers of instability. Computation of the precipitible water vapour amount. Computation of various stability Indices for prediction of thunderstorms. Energy computations like CAPE. (13 P).
- Computation of optical depth for use in radiation balance Studies. (7 P).

Climatology and Meteorological Statistics

(Total duration = 14 working days =14×6= 84 periods of 75 minutes duration)

Climatology (48 Periods)

- **Physical climatology:** Earth Sun relationship, Ecliptic and equatorial plane, Rotation and revolution of the earth Equinoxes, Solstices, Perihelion and Aphelion, Causes of seasons, Seasonal and latitudinal variation of insolation, Definition of climate , radiative forcing (2 P)
- **Climatic classification**: Geographical, genetic classification etc. Koppen, Thornthwaite, Penman (2 P)

Indian Climatology (16 P)

- Four seasons - (Pressure and wind distribution for mid- season months) (2 P):
- Winter - Western disturbances, fog, thunderstorms, hail, cold waves, sub-tropical jet stream; Northeast monsoon - Interaction of low and high latitude disturbances, easterly waves (3 P)
- Pre-monsoon: Cyclonic storms, tracks, Frequency, the cyclone genesis, intensity, landfall and associated weather – gale wind, heavy rainfall and storm surge, western disturbances, fog, dust storms, thunderstorms, Norwesters, heat waves, pre-monsoon thunderstorms, dust-raising winds, equatorial trough (3P)
- **Southwest monsoon season** – Onset and advance of southwest monsoon. Semipermanent systems of monsoon, Factors affecting distribution of monsoon rainfall, Active-break cycle, Monsoon breaks,. Synoptic systems in monsoon (monsoon lows and depression, MTCs, and monsoon trough). Interannual and intra seasonal variability of monsoon, links to El Nino/Southern Oscillation, mid-latitude interaction, Indian Ocean Dipole and Madden Julian Oscillation Index.(5 P)
- **Post monsoon season** - Withdrawal of southwest monsoon, Northeast monsoon (mean rainfall distribution, synoptic systems, inter-annual variability), Cyclonic storms in the Indian seas, trends in cyclonic disturbances, Western disturbances, Easterly waves. (3 P)

Synoptic Climatology (4 P)

- Extra-tropical – Air mass climatology - January and July; Geographical distribution of Fronts, Frontal zones - Extra-tropical cyclones – frequency, regions of blocking and cyclogenesis.

- Zonal index & Index cycle

Mean State of the global Atmosphere (8 P)

- Mean temperature structure (global distribution and vertical structure)
- Mean Geopotential Height structure
- Mean Atmospheric Circulation (global distribution, vertical structure, variability of the circulation)
- Precipitation, evaporation, runoff and cloudiness

Mean State of the Oceans (6 P)

- Mean and vertical temperature, density and salinity structure
- Mean Ocean circulation
- SST anomalies and Asian summer monsoon (interannual variability of date of monsoon onset and quantum of Indian summer monsoon rainfall) - Tropical Biennial Oscillation – Role of ocean in the Active – Break cycle of monsoon - Relation between tropical deep Convection and SST, El Nino
- Ocean state and cyclones

Climate Change and sea level rise: Ocean in relation to long term changes in Monsoon, tropical cyclones and Climate, Land use changes and climate.(2 P)

Climate services: Climate products and their application in agriculture, water, health and Disaster risk reduction etc.(2P)

Mean state of the cryosphere & Biosphere (2 P): Role of the cryosphere in the climate, General features of the cryosphere, effect of biota on climate (deforestation)

Basics of Climate data analysis (4 P)

- Role of ocean on climate(2p)

Statistics (36 Periods)

Theory (24 Periods)

- Introduction - The purpose of statistics, Population and sample**,** Censuses and surveys**,** Descriptive statistics and inductive statistics**,** Fields of applications. Statistical variables - qualitative and quantitative, discrete and continuous variables. (2 P)

- Description of data patterns – center, spread, shape, and gaps & outliers, Histograms and bar charts, difference between bar charts and Histograms, various plots (Dot plots, Stem plots, Box plots, Cumulative plots, Scatterplots), Tabular displays (one -way and two-way tables). (2 P)
- Measures of central tendency – Mean, median, mode quartile, decile, and percentile, Standard Score (z-Score). (2 P)
- Variability - Range, Interquartile Range (IQR), mean deviation, quartile deviation, Sums of squares, Variance, Standard Deviation.(2 P)
- Basic probability concepts – events and event space, random variables, definition of probability, joint and conditional probabilities, odds, expectation, Bayesian theorem (3 P)
- Distributions - Distribution basics, Probability & cumulative probability distributions, Discrete & Continuous distributions – Binomial, Poisson, Gamma, Normal, Standard normal, Student's t, Chi-square, F-distribution (4P)
- Estimation and Hypothesis Testing (2 P)
- Time series analysis – basic concepts, Principles of stochastic processes, Auto-correlation theory, Application of Auto-correlation and auto regressive processes, Spectral analysis, Co-spectral methods, Example: Analysis of Intra-seasonal oscillations, Compositing techniques and spatial correlation patterns. (5 P)
- Analysis of variance ANOVA/ MANOVA (2 P)

Practical (12 P)

- Calculating the statistics using the formulations.
- Introduction to Matlab and R-software
- Basic statistical analysis using MS Excel and R-software.

ENVIRONMENTAL & APPLIED METEOROLOGY

(Total duration = 13 working days = 78 periods of 75 minutes duration)

A. Environmental Meteorology (30P)

- Air pollution: Basic ideas about Air pollution; Air quality, Sources of air pollution and important pollutants – gaseous and particulate matter, meteorology and air quality modeling, Environment Impact Assessment. Pasquil's stability criteria, mixing length, Ventilation co efficient, and pattern of dispersal of smoke from stationary source under different wind and temperature conditions. Ambient Air Quality Standards.
  Aerosol Sources: Natural Sources, Anthropogenic Sources, Gas to particle conversion, Aerosol removal processes, Chemical composition of Aerosols, physical and chemical properties.CCN nuclei,Aerosol transport, distribution and residence time,Aerosol Size Distribution, Aerosol Radiation Characteristics, Rayleigh Scattering, MIE Scattering, Aerosol Radiative Forcing, Aerosol Optical Depth, Single Scattering Albedo,Modeling : the Climatic Effects of Anthropogenic Aerosols,Indirect Effect of Anthropogenic Aerosols (Twomey Effect) (14 P)
- Micrometeorology - Definition and generation of microclimates, elements of microclimatology, Urban meteorology(3 P)
- Basic ideas on Bioclimatology and Applied Climatology (4 P)
- Climate change-Global warming, climate trends and prediction, ozone depletion, ozone and health impacts, Green house gas, Ocean acidification (9 P)

B. Applied Meteorology (48 P)

Basics of Agricultural Meteorology (12 Periods)

- **Concept of Agricultural meteorology :** Introduction to Agrometeorology, Scope and importance of agrometeorology, Familiarization with important activities of Agrimet Division, energy and water budget of crops, and crop yield relationship with weather elements, crop weather calendar
- **Agromet observatory/Agromet observations:** Agromet instruments their installation, Maintenance, Inspection of observatories, Time of observations, use and archival
- **Agroclimatic Zones :** General concept, criteria for climatic classification, climatic classification in India Objectives, Agroclimatic, classifications and their applications) (Rainfall analysis, drought studies including drought monitoring, Evaporation, Evapotranspiration, Dry land farming, Pest & Disease etc.
- **Agromet advisory services (AAS)** : Importance of Agromet advisory services to farmers, Development from AAS to IAAS, Components of AAS bulletins, Preparation of special weather charts and bulletins for AAS, use of research data for operational work, Dissemination, Feedback collection.

Basics of Seismology (12 Periods)

1. Seismology; Internal structure of the Earth; Plate tectonics; Physics of earthquake process; Types of faults and fault mechanisms; Seismicity and Seismotectonic features – (2 P)
2. Elastic wave theory; Seismic wave propagation & characteristics; Travel time tables; Velocity models; Seismic tomography – (2 P)
3. Earthquake source parameters; Magnitude, Intensity, Energy, etc.; Earthquake statistics; Digital data analysis and location of earthquakes; Seismological operations and information dissemination – (2 P).
4. Seismometry – Sensors; Recording systems; Communication systems; Local, regional and global networks; Micro-earthquake monitoring – (2 P)
5. Seismic Zoning; Seismic Hazard, Vulnerability & Risk; Seismic Microzonation; Disaster mitigation, management and preparedness – (2 P)
6. Earthquake precursors & prediction; Early warning of tsunamis – (2 P)

Basics of Hydrology: (12 P)

1. **Hydrological cycle**, Estimation of Design Storm: Characteristics of rainfall in India, major river basins in India, Rainfall Analysis, Estimation of Standard Project Storm, Probable maximum Precipitation, Return Period Analysis, Spatial and Temporal Distribution of Rainfall.
4. **Hydrometeorological Disasters** : Definition of flood, Types of floods (seasonal ,flash, urban) Causes of flood, Various methods of Quantitative Precipitation Forecast (Synoptic Analog , Use of NWP outputs), Droughts, Rainfall Monitoring, Dynamical statistical models, satellite and Radar techniques for Quantitative Precipitation forecast and various methods for Quantitative Precipitation Estimate (QPE).
5. **Rainfall Runoff Relations**: Rainfall Runoff Models Unit Hydrograph

Basics of Astronomy (12 Periods)

1) BASIC DEFINITIONS IN ASTRONOMY & TYPES OF TELESCOPES AND THEIR MOUNTS: Magnification, field of view, resolving power in context of telescopes and comparison with the abilities of humaneye. Spatial resolution and Rayleigh criterion. Stellar magnitudes, detectability limits of telescopes.Astronomical distances, parallax method. Plate scale,f-number and image sizes obtained with telescopes. Types of telescopes: Refracting type, color aberrations,spherical aberrations, reflecting type. Newtonian, Cassegrain, Coude arrangement etc. Mounts: German equatorial, fork, horse-shoe, alt-azimuth. New telescopes for the future.

2) BLACK BODY RADIATION AND ASTROPHYSICAL CONSEQUENCE

Stellar spectrum formation, Kirchoff's laws of radiation, Absorption and emission spectrum with both exhibiting line and band type spectra, Black body radiation laws and relatedspecial cases. Stellarspectral sequence and effective temperature.Stellar spectral classification and relation to HR diagram. Spectral line from a star and concepts of equivalent width, various types of line broadening effects.

3) ATMOSPHERIC EFFECTS

Absorption, scintillation, atmospheric extinction, scattering, turbulence, 'seeing effect', air-mass and extinction coefficient, 'seeing noise', 'seeing disk', scale length of Fried's parameter r0. Active and adaptive optics. Night sky brightness and nightsky pollution.

4) NIGHT SKY EXPERIMENT:To estimate the temperature of an artificial star by photometry. To study the atmospheric extinction for different colors. To study the effective temperature of stars by B-V photometry.

5) CONCEPTS OF TIME, RA, DEC etc. and POSITIONAL ASTRONOMY:

Definitions of local time, UT, ST etc. co-ordinate system, Celestial Sphere, Zenith, Nadir, Celestial Horizon, Celestial Pole, Celestial Equator, Meridian, Ecliptic, First point of Aries and Libra (Definition only). Basic idea on three system of Celestial Coordinates: (i) Horizontal System ii) Equatorial System (iii) Ecliptic system

6) ASTRONOMICAL PARAMETERS and PHENOMENA:

Precession and Nutation (Basic idea), Conjunction, Opposition, Elongation, Eclipses, Occultation and Transit of Planets over the Solar disc (Basic idea).

7) CALENDRIC ASTRONOMY and Basics of SOLAR SYSTEM

Different types of Calendar: (i) Solar, (ii) Lunar, (iii) Luni Solar Indian National Calendar and Gregorian calendar. A brief description of Planets and Moon, Phases of the Moon, Basic structure of the Sun, Sunspot number, Asteroids, Meteors and Comets (Basic idea).

Oceanography and Marine Meteorology

(Total duration = 5 working days = 30 periods of 75 minutes duration)

- **Acquisition and communication of** ocean data (2p)
- Physical properties of sea water,(5 P)
- Atmospheric Boundary Layer over Ocean:-(4 P)
- Oceanic boundary layer : (5P)
- Energy balance at the ocean surface (5P)
- Ocean waves and Swell, their generation and propagation, Tsunamis and Tides in the ocean (2 p)
- Marine Pollution and its impact on Coastal and Marine ecosystem (2P)
- Deep ocean circulation (1 P)
- Marine Meteorology :Marine Meteorological organization. Voluntary observing fleet. Meteorological broadcasts for shipping. Weather warnings issued to posts. Marine climatology.(2 P)

SYNOPTIC METEOROLOGY INCLUDING WEATHER ANALYSIS AND FORECASTING

(Total duration = 12 working days =12×6= 72 periods of 75 minutes duration)

THEORY (48 Periods)

- Scales of weather systems (Meso, Synoptic and Planetary scales) - Map projections - representation and analysis of fields of meteorological elements on synoptic charts - Vertical time/cross sections and their analysis. Representation and analysis of fields of meteorological elements and derived products on synoptic charts - Vertical time/cross sections and their analysis. **(3P)**
- Wind and pressure analysis - Isobars on level surface and contours on constant pressure surface - Isotherms, thickness field - Geostrophic, gradient and thermal winds – Jet streams - Slope of pressure systems - Streamline and isotach analysis. Preparation, analysis, interpretation, application and limitations constant PV charts **(3 P)**
- Ordinary thunderstorm - Severe thunderstorm (Squall-line, Multi-cell, Super-cell) – Role of CAPE, CINE and Vertical Wind Shear - Synoptic conditions favorable for thunderstorm - Norwesters, Dust-storm (Andhl), Hail storm, Tornado, Squall, Meso-high, Gust front , Down-burst and Micro-burst, **(5 P)**
- Tropical cyclone - Life cycle - Surface wind – Vertical structure in wind, temperature and angular momentum – Eye, Wall Cloud and Spiral cloud bands - Cyclone Genesis - Intensification of Cyclones – T-number - Movement of cyclones – Land fall - monitoring and prediction of heavy rain, gale wind, storm surge, Interaction with nearby cyclones - Storm surge, coastal inundation along with storm surge, warning bulletins including generation, presentation and dissemination, heavy rainfall monitoring, forecasting and warning services, dynamical statistical method of forecasting and location specific forecast **(5 P)**
- Asian summer monsoon - Monsoon onset over Kerala - Active and Break monsoon phases – Monsoon trough – Cross equatorial Low Level Jetstream – Tibetan Anticyclone - Tropical Easterly Jetstream - Monsoon depression – Mid Tropospheric Cyclone - Offshore troughs/vortices – Influence of northern hemisphere mid-latitude westerly troughs – discussion on Kelvin waves, MJO, SST, Indian Ocean dipole, ElNino, ENSO -Monsoon and NW pacific typhoons – Monsoon and orography - Intra-seasonal variability of

Monsoon (15 and 40 day modes) - Withdrawal of monsoon – Monsoon and the Indian ocean - Summer monsoons of Americas, Africa and Australia **(8 P)**

- North east monsoon in India. **(3P)**
- Western Disturbance and Its structure and associated weather (3 P)
- Easterly wave and its structure and associated weather. **(3 P)**
- Diurnal and local effects - Sea and land breezes - Slope and valley winds - Fog - Mountain wave - Clear Air Turbulence - Nowcasting - Meso-network - Use of radar and satellite in meso-scale analysis and forecasting. **(3 P)**
- Short range weather forecasting & tools and technique for synoptic analysis: Persistence, climatology and steering methods - Movement and development of synoptic scale systems - Analogue techniques - Prediction of individual weather elements - Prediction of visibility, surface and upper level winds, sea and swell - Interpretation and use of numerical model outputs in weather forecasting , Forecast bulletin & products. **(5 P)**
- Nowcasting**:** Tools, Methodology/roadmap, check list, bulletins and products (text and graphics) generation, presentation and dissemination (3P)
- Tools and Techniques for Synoptic Analysis.(4P)
    a. Digitised Forecaster's workstation (Synergy system in IMD),
    b. public weather service (PWS) system,
    c. Special Module available in synergy system for specific purpose, viz., Module for preparation of significant weather chart, Tropical Cyclone Module)
    d. Interpretation of NWP models analysis and predictions.
    e. Basic conceptual model
    f. Synoptic climatology
    g. Roadmap and check list for daily watch on severe weather events (e.g. Monsoon Watch, Daily Tropical Weather Watch for Cyclogenesis, Thunderstorm activities etc).
    h. Preparation of report on severe weather.

Practical (24 Periods)

- General Surface chart analysis
- Streamline and isotach analysis
- Analysis of constant pressure charts
- Analysis of Jet streams
- Analysis of thickness charts and thermal wind

- Vertical time/cross section analysis

Analysis of NWP derived products, their interpretation and their limitations.

Analysis of tropical weather systems-surface and upper air (one case each)

a)*Tropical Cyclone – formulation of bulletins and warnings*

b)Monsoon Depression

c)Active and Break Monsoon

d)Western Disturbance

e)North-east Monsoon/Easterly wave

AVIATION METEOROLOGY

Total duration = 5 working days = 30 Periods of 75 minutes

TOPIC	Sub topic	Objective: On completion the trainees should be able to:	No. of periods
1. An overview of Aviation Organisations and their functioning.	1. Definitions 2. WMO, ICAO, CAeM 3. Functioning of IMD's Aeronautical Meteorological Organisation 4. The rights and responsibilities of aviation met offices, the terms and conditions of MoU/ LoA with AAI and other users 5. Meteorological publications of ICAO, DGCA, AAI, and IMD 6. Registers and formats used in Aviation met services 7. Regulatory materials (Annex-3/ CAR/ Codes/ Manual)	a. List the mandate of the organisations b. Describe the functioning of MWO, AMO and AMS c. Describe the role and responsibilities of Aviation Met Forecaster d. Documents and procedures to be maintained e. Describe the rights and responsibilities of aviation met offices, the terms and conditions of MoU/ LoA with AAI and other users f. Describe the various publications, registers and formats their use in aviation met service provision	5
2. Effect of Weather on aviation	1. Effect of various atmospheric parameters on different phases of flight operation 2. Altimeter setting procedures, concept of QNH, QFE and ICAO Standard Atmosphere 3. Airport minima, low visibility procedures, categories of runways 4. Weather hazards to aviation 5. Climatology of weather hazards	a. Explain the effect of weather elements on aircraft operation b. Explain Altimeter setting procedures, concept of QNH, QFE and ICAO Standard Atmosphere c. Explain the concept of airport minima, low visibility procedures, categories of runways d. List the weather hazards and explain its effect on aircraft operation e. Describe broad features of climatology of hazardous weather for each FIR	5
3. observation and reporting of weather for Aviation services	1. METAR/ SPECI code and template 2. SPECI Criteria 3. Reporting of meteorological elements in METAR/ SPECI 4. Concepts of TREND forecast 5. Prepare a METAR/ SPECI message with TREND forecast using the given observations 6. MET Report/ SPECIAL Report Template 7. Examples	a. Explain the latest METAR/ SPECI code form and Template b. Explain the SPECI criteria c. Prepare a METAR/ SPECI message using the given observations d. Explain the latest MET Report/ SPECIAL Report template e. Prepare a MET REPORT/ SPECIAL message using the given observations f. Issue TREND forecast g. Verify TREND forecast	5
4. Tools for forecasting	1. Tools and products available for aviation weather forecasting and their use	a. To describe the source of information/ product and their use in aviation weather forecasting	2
5. Terminal Aerodrome	1. Description of the TAF code form and Template 2. Forecast of various elements in	a. Explain TAF code and general concepts	4

Forecast (TAF)	TAF 3. TAF verification procedures	b. Prepare TAF using given information/ products/ Charts c. Verify TAF	
6. Area/ Local forecast	1. Description of Area/ Local forecast template 2. Verification procedures	a. Prepare Area/ Local Forecast using given information/ products/ Charts b. Verify Area/ Local forecast	2
7. Take-off forecast	Description of take-off forecast	a. Issue take-off forecast b. Verify take-off forecast	1
8. Route Forecast	1. ROFOR Code 2. Decoding of the coded ROFOR in plain language 3. Instructions on preparation of MET- T3 4. Preparation of a route forecast in MET- T3 form 5. Preparation of a route forecast in ROFOR code form 6. Verification procedures	a. Describe ROFOR code b. Issue route forecast in ROFOR code c. Decode a ROFOR and prepare the route forecast in MET-T3 format. d. Verify ROFOR	6

Satellite and Radar Meteorology & Met Communication and Information system
(Total duration = 11 working days = 66 periods of 75 minutes duration)

Satellite Meteorology (34 Periods)

Theory (20 periods)

- Remote Sensing: Principles of remote sensing, Application in meteorology, Introduction to satellite meteorology, Orbital mechanics. (1 P)
- Meteorological Satellites: Polar, geostationary and low-inclination orbits, Current and future meteorological satellites of the world. Payloads on meteorological satellites, NOAA, INSAT, Kalpana, Metop, MeghaTropiques, Scatterometers (1P)
- Satellite derived products, SST, CTT, NDVI, AOD, OLR, CMV etc. Use of various satellite-derived products,QPE and TPW (3 P)
- Basic Principles of Sounding: Processing of data from infrared and microwave sounders. Retrieval of products from sounders, Temperature and humidity profiles and total ozone. (3 P)
- Interpretation of Satellite Images: Characteristics of various channels, Identification of typical clouds and weather systems from cloud imageries, Satellite bulletin and its interpretation. Tropical cyclones, their identification and grading using Dvorak's technique. Interpretation of microwave channel images. (5P)
- Systems and Techniques: Automatic Weather Station (AWS), DTH-based Digital Cyclone Warning Dissemination System (DCWDS), Digital Meteorological Data Dissemination (DMDD), GPS technique for Integrated Precipitable Water Vapour (IPWV) measurement. (2 P)
- INSAT Meteorological Data Processing System (IMDPS): Hardware details, Earth station. (1 P)
- Assimilation of satellite data in NWP models (2 P)
- Use of satellite in very short range forecast to now casting. (2 P)

Practical (14 Periods)

- Study of typical satellite images from both geostationary and polar orbiting satellites, Identification of different types of clouds and weather systems from satellite images, Interpretation of microwave channel images.(3 P)
- Issue of satellite bulletins. (2 P)
- Assessment of T-number of tropical cyclone from satellite images using Dvorak's technique. (6 P)
- Use of satellite-derived products for weather analysis and forecasting. (3 P)

Applied Radar Meteorology (14 Periods)

- Basics of radar Meteorology: Radar equation (with derivation): RADAR depiction of various phenomenon; RADAR reports; Interpretation of RADAR echoes; Anomalous propagation,

radar estimation of precipitation, identification of convective and startiform precipitation, melting band.

- Introduction to Weather radars. Different frequency bands used in the weather radars and their applications. Principles of pulsed radar, Polarimetric radars.
- Definitions of Beam width, Pulse width, PRF, Antenna gain, back scattering cross section, Reflectivity factor (η) and radar reflectivity factor (Z). Anomolous propagation of EM waves.
- Principle of Doppler Weather radar. Block diagram of Doppler Weather radar and explanation of its major components. Introduction to DWR Base products Z, V and W.
- Derived DWR products,viz., CAPPI, SRI etc. – their interpretation and use in Nowcasting
- Warning products (Severe Weather Index, HHW) Analysis of severe weather events (thunderstorms, hailstorms, line squall, heavy rainfall prediction, aviation safety and tropical cyclones) recorded by DWR and development of the nowcasting technique for their prediction.

Basics of Meteorological Communication and Information systems (10 P)

- Importance of Met. Telecommunication ,Overview of National & International Meteorological Telecom. Setup ,GTS , RTH New Delhi (AMSS , CIPS , SYNERGY , PWS , CLISYS),VSAT, SADIS etc.
- Introduction to WIS (GISC, DCPC, NC, Meta data).
- Introduction to LAN, MAN, WAN, Ethernet & Fiber Optic cable, communication protocol, TCP / IP, VPN, etc.
- Introduction to communication devices like MODEM (wireless/ wireline),SWITCH, HUB, ROUTER, etc.

DATABASE MANAGEMENT SYSTEM

Total Duration = 18 Periods of 75 minutes

S. No.	Name of Topic	Course content
1.	**Introduction(1P)**	An overview of database management system – History, Purpose of database system, database system vs file system, Database system concept and architecture, data model schema and instances, database language and interfaces, advantages and disadvantages of database system.
2.	**Basic concepts of DBMS(1P)**	Introduction and applications of DBMS, Purpose of data base, Data Independence, Database System architecture- levels, Mappings, data definitions language, DML, Overall Database Structure, Database users and DBA
3.	**Relational Model(1P)**	Structure of relational databases, Domains, Relations, Relational algebra–fundamental operators & syntax, relational algebra queries
4.	**Entity-Relationship model(2P)**	Basic concepts, Design process, constraints, Keys, Design issues, E-R diagrams, weak entity sets, extended E-R features - generalization, specialization, aggregation, reduction to E-R database schema
5.	**Relational Database design(2P)**	Functional Dependency – definition, trivial and non-trivial FD, closure of FD set, closure of attributes, irreducible set of FD, Normalization, Decomposition using FD- dependency preservation, Multi-valued dependency, Join dependency.
6.	**Query Processing & Query Optimization(2P)**	Overview, measures of query cost, selection operation, sorting, join, evaluation of expressions, transformation of relational expressions, estimating statistics of expression results, evaluation plans, materialized views
7.	**Transaction Processing Concept(2P)**	Transaction concepts, properties of transactions, serializability of transactions, testing for serializability, System recovery, Two-Phase Commit protocol, Recovery and Atomicity, Log-based recovery, concurrent executions of transactions and related problems, Locking mechanism, solution to concurrency related problems, deadlock, two-phase locking protocol.
8.	**Distributed Database(1P)**	Distributed data storage, concurrency control, directory system.
9.	**Security(1P)**	Introduction, Discretionary access control, Mandatory Access Control, Data Encryption
10.	**SQL Concepts(3P)**	Basics of SQL, DDL, DML, DCL, structure – creation, alteration, defining constraints – Primary key, foreign key, unique, not null, check, IN operator, aggregate functions, Built-in functions– numeric, date, string functions, set operations, sub-queries, correlated sub-queries, join, Exist, Any, All , view and its types., transaction control commands
11.	**PL/SQL Concepts(2P)**	Cursors, Stored Procedures, Stored Function, Database Triggers

Management Development program

Course Duration: 5 Days

Objectives :

1. To realize self potential & further improve upon it.

2. Importance of attitude & behavior for effectiveness.

3.To sensitize participants about importance of Management skill to enhance overall effectiveness & efficiency in personal life , professional life & social life , overall development.

Coverage :

Module I: Effective Leadership & Team building

Module II : Effective Communication & Presentation Skill and skill for forecast dissimination., media interaction

Module III : Time & Stress management-work-life balance

Module IV : Project Management & Quality Management

Module V : Organizational Behavior

Module VI : Purchase Management & Procurement Rules

Module VII : Good Governance, RTI

Module VIIa: Knowledge management

Module VIIb: GOI Functioning service & financial management, Citizen Charter

Module one: Leadership & Teambuilding with OBL

Learning Outcomes:

Skills-building program will enable you to: -

1. Introspect on your current approach to leadership - Understand the "chemistry" of high-performing teams
2. Learn and practice Basic Leadership Skills to motivate and energize the people around you

3. Realize your own true potential-and, thereby, that of your organization/Dept. too.

Content:

- Attitude & Behavior
- Leadership skill & competencies
- Leadership Theories
- Leadership style & impact
- Demand of Leadership in service sector Be a Leader without limits
- Emotional intelligence in team & team building
- Transform your TEAM into Highly motivated, cohesive team, ready to take on the toughest of work challenges

- Sharpening skills to work well as members of team and also as leaders
- Developing high performance teams
- Aligning individuals to team objective
- Creating a positive work environment
- Interpersonal Relations
- Leading Change

Module two: Effective communication & Presentation skill

Learning Outcomes:

1. Sensitize the participants on the importance of effective communication at work.

2. Develop systematic & positive approach for verbal & nonverbal communication.

3. Polish their presentation, interpersonal & social networking skills

Content:

- Basics of effective communication
- Three style of Communication
- Work place communication: Skill & art of listening ,speaking, reading & writing
- Nonverbal communication, Body language , Gestures ,Postures
- Business presentations & writings
- Preparing Effective power point presentation
- Meeting management & team communication
- Electronic communication
- Media Communication & Public Relation

Module Three: Work –Life Balance (Time & Stress Management)

Learning outcomes

1. Understand and identify personal causes of stress

2.Apply some of the principles of time management to increase productivity on the job and at home, and enhance

the quality of work with less stress

Content:

- Self-knowledge and goal-setting
- Time Management Matrix
- Prioritizing: Put First Things First
- Planning & scheduling to make the most of your time
- Controlling Major Time Wasters
- Time management techniques
- Effects of stress

- Reactions to stress
- Identifying your stressors
- Gaining control and managing stress positively

Module Four: Project Management & Quality Management

Learning outcomes : This Module will facilitate you to get hold of basics of project management ,tools and techniques to assess and appraise a project right from the setting up of project objectives ,track and report them till the project closure.

Content:

- Project Management – Knowledge & principles
- Project Management Practices – activity based
- Project Appraisal /Evaluation Methodology & Practices
- Case Studies on project appraisal / /Discussion on various projects
- Quality Management

Module Five : Organizational Behavior

Learning outcome

To sensitize participant about individual behavior & organizational culture

Content

- *Individual Behavior*
- *Group Dynamics*
- *Effects Of Informal group*
- *Factors affecting Performance*
- *Organizational theories*
- *Team Motivation*
- *Handling Conflicts*
- *Gender Issues*
- *Value & culture*
- *Decision Making*
- *Strategy management****Module Six : Purchase Management***
  Learning Outcome:

OVERVIEW Purchasing Objectives of Purchasing Principles of Purchasing Functions of Purchasing Department. Methods of Purchasing Steps in Purchase Procedure.

- *Purchase Management*
- *Objectives of Purchasing*
- *Principles of purchasing*
- *Functions of Purchase Departments*
- *Procedures /steps /rules*
- *Method of purchasing*
- *Tendering & contracting*

Module Seven Good Governance

Learning outcomes :

To understand various factors contributing to good governance

Content :

- *Importance of good governance*
- *Administration & Management*
- *Transparency & accountability*
- *Responsiveness*
- *GOI structure & its functioning*
- *Service & conduct Rules*
- *Financial Rules*
- *Citizen Charter*
- *Knowledge Management*

Methodology

This is a highly experiential and interactive program. It will involve: - Individual and group exercises - Case discussions and role plays - Diagnostic surveys, self-evaluation, and on-the-spot feedback - Learning-by-doing techniques

Appendix-II

India Meteorological Department

Meteorological Training Institute

Revised Syllabus
For
Advanced Meteorological /Met-II Training Course

(12 months duration)
In the General Meteorology/Forecasting discipline

Semester-II (6 months duration)

May 2014

Content

Subject	Duration	Place
Geophysical fluid dynamics.	10 working days*	MTI
Advanced Physical Meteorology.	10 working days	MTI
Advanced weather analysis & forecasting.	9 working days	MTI
Advanced Aviation Meteorology	5 working days	MTI
Climate Science.	10 working days	MTI
Physical Oceanography & Ocean-Atmosphere interaction.	7 working days	Faculties from INCOIS, NIOT and IITM are to be invited at MTI.
Numerical weather Prediction.	20 working days	MTI,IITM or NWP division of HQ & NCMRWF
Advanced Statistics	4 working days	MTI, IITM
Computer Programming & application.	5 working days	MTI ,IITM, C-DAC
Hydro Meteorology	5 working days	MTI
On the Job training	2 working weeks	MTI or other Institutes of MoES.
Mid-term & final exam+Viva-voce+Project presentation+Relief+ CH	4 working weeks	MTI
Total	**85 working days+6 working weeks = 17working weeks+6 working weeks=23 working weeks**	

& 1 working week = 5 working days
 # 1 working day = 6 periods of 75 minutes

Geophysical fluid dynamics

(Total durations =10 working days =60 periods of 75 minutes duration)

Quasi-geostrophic theory (6 P) :

Quasi-geostrophic approximations, Beta-plane approximation. Governing equations in isobaric co-ordinates using quasi-geostrophic approximation. Quasi-geostrophic vorticity equation: Thermodynamic energy equation, Geopotential tendendency (χ) equation: Conservation of quasi-geostrophic potential vorticity. Diagnostic ω (omega) equation (With and without diabatic heating term)

Advanced Planetary Boundary Layer (15 p)

- Derivations of governing equations for mean motion in PBL.
- K-Theory/ Flux-gradient theory/ Similarity theory. Its limitation. Mixing length theory.
- Derivation of logarithmic vertical profile of horizontal wind in viscous sub layer using similarity theory. Concept of roughness length and Von-Karman constant.
- Ekmann layer: Derivation of vertical profile of mean horizontal wind in atmospheric/ oceanic Ekmann layer. Derivation of depth of Ekmann layer. Concept of Ekmann layer pumping. Secondary circulation. Spin down. Derivation of the Relation between mass transport in oceanic Ekmann layer and surface wind stress. A dynamical explanation for El-Nino and La-Nino. Convective boundary layer (CBL) or well mixed boundary layer. The turbulent kinetic energy equation.. Physical interpretation, in detail, of the Buoyancy production or loss (BPL) term and mechanical production (MP) term in association with convective and mechanical turbulence, concept of Flux Richardson number. Monin-Obukov theory and Kolmogorov theory.

Perturbation Theory and shallow water equation &atmospheric waves (12 P)

- Perturbation theory-Why perturbation method has been proposed? Hypothesis in Perturbation method. To show that perturbation method can remove non- linearity from governing equation.
- Atmospheric waves - Basic concepts: Wave number, Frequency, Phase speed and group velocity. Sound wave, Rossby wave, Gravity wave (external, internal and inertia), simple

inertia wave, Kelvin wave, Mixed Rossby Gravity wave- dispersion relation and physical interpretation. Eliassen-Palm flux and its conservation law.

- Dynamics of stratified fluids: Concepts of stratification, Static stability, The importance of stratification: The Froud number, Boussinesq approximation, **(5P)**
- **Hydrodynamic instability (10 P hours):** General definition of Hydrodynamic instability. Classification of Hydrodynamic instabilities. Static instability: Derivation of the criterion for Brunt-Vaisalla instability. Dynamic instabilities: Inertial instability, barotropic instability and baroclinic instability. Derivation of the criteria for above instabilities. Energetics and mechanism of above instabilities.
- **Fundamentals of atmospheric energetics (7 P):** Energetics aspects of General circulation- Definition of Atmospheric energetics. Different form of atmospheric energies, viz., internal energy, potential energy and kinetic energy. Derivation of global internal energy, global potential energy and global kinetic energy equation. Detailed physical interpretations of generation of potential energy, internal energy and its conversion into kinetic energy. Detailed physical interpretation for generation mechanism of global kinetic energy, its conversion into potential and internal energy and the dissipation of kinetic energy. Belt of sub tropical anticyclone, the source region for global kinetic energy. Global energy equation. Dynamical explanation for the sun to be source of atmospheric energy. Equivalence of internal and potential energy in a stably stratified hydrostatic atmosphere. Physical explanation for the proportionality of I.E and P.E in hydrostatic and stably stratified atmosphere. Introduction to total potential energy (TPE), derivation of its expression. Concept of available potential energy (APE) and the derivation of the expression for it. Qualitative comparison of APE in a region based on day-to-day charts. Concept of zonal APE, KE, PE and eddy APE, KE, PE.
- **Angular momentum budget of atmosphere (5 P)-** Global angular momentum balance equation. Interpretation of mountain torque, frictional torque and meridional transport of zonal angular momentum. Different mechanisms for meridional transport of zonal angular momentum. Concept of Hadley and Walker circulation

Advanced Physical Meteorology

(Total Duration = 10 working days=60 Periods of 75 minutes)

Theory (Duration = 50 Periods)

- Atmospheric Electricity: Basic concepts regarding fair weather field (Mathematical derivations) and its maintenance and thunderstorm electricity (excluding detailed mathematical derivations, instrumental measurements etc) (10 P)
- Upper Atmosphere and Ozone: Different techniques of exploration of upper atmosphere; thermal structure of tropopause stratosphere, mesosphere and thermosphere and their physical explanation, QBO and stratospheric warming; Tropospheric Ozone : Chemical Properties of Ozone, Units of Measurements, Formation of Tropospheric Ozone, Health Effects . Stratospheric Ozone: Formation of Ozone in Stratosphere, Stratospheric Ozone Depletion, Antarctic Ozone Hole, Impacts of UV Radiation, Stratospheric Ozone Depletion over the Arctic, Control Strategies and International Treaties, ozone temporal and spatial variations of Ozone; measurements of ozone; Umkher effect. Ozone hole, CFC and related concepts.(10 P)
- Cloud Physics and Weather Modification : Atmospheric aerosols and condensation nuclei, initial stage of condensation, curvature and solute effects, growth of cloud droplets by diffusion and by collision and coalescence; collection efficiency; ice nuclei, mechanism of growth of precipitation from clouds in tropics and extra-tropics, rain making experiments, Thunderstorm and hail. Simple cloud models. Cloud Physics measurements: Surface, airborne and satellite (like MODIS), Field campaign like CAIPEX (20 P)
- Advanced concept of Air pollution; Transport model in ABL for dispersion of aerosol/air pollutants. Acid rain, smog and impact of air pollution on human health and structures. Boundary layer structure in urban areas. Indoor pollution. Air quality monitoring & forecasting(10 P)

Practicals (10 P)

- Ventilation co-efficient.
- Study of surface wind data at a station.
- Computation for preparing windroses
- Graphical preparation of typical wind roses
- Running Transport model

Physical Oceanography & Ocean – Atmosphere Interaction

(Duration = 7 working days= 42 Periods of 75 minutes)

- **Physical properties of sea water:** temperature, salinity and density and their space – time variations - Formation and classification of water masses. - T-S diagram -. Water masses of the ocean with special reference to Indian Ocean - Acoustical and optical characteristics of seawater**. (8 P)**
- **The significance of Ocean-Atmospheric Interactions. Concept of a system (Ocean/Atmosphere). Ocean-Atmosphere boundary layers:** Concept of Boundary Layer formation; Atmospheric Boundary Layer, Oceanic Boundary Layer, structure and Evolution,Water(SST) Temperature, Air Temperature, Moisture and wind profile Evolution. Air sea temperature differences. Fresh water flux - Salinity variation in the vertical - Barrier layer.Turbulence, characteristics of Boundary Layer Spectrum. Integral scales of Eddies, K-theory /Taylor micro scale, Kolmogorov scale and Larger Scale, and Monin- Obukhov Similarity theory. **(9 P)**
- **Atmospheric and Oceanic Boundary Layer Physics:** Balance of forces and transport in the Ekman layer - Upwelling / downwelling – Wind driven gyres and western boundary currents -Physical interaction between the ocean and atmosphere; Heat exchange through Short wave, long wave and net radiation, latent and sensible heat fluxes; Momentum transfer and drag coefficient.Atmospheric Heat Budget, Oceanic Heat Budget. Heat Budget of the Arabian Sea and Bay of Bengal. Methods for determination of vertical transports in the Maritime Friction Layer: Direct Method (Cross-correlation Method); Aerodynamic Methods- Aerodynamic Profile Method, Bulk Aerodynamic Method; Budget Method, Bowen's ratio. Measurement of surface stress, drag generation mechanisms. Wind stress and resultant drag coefficient with variation to wind speed. **(10 P)**
- **Atmospheric and Oceanic scales of motion and interaction at various scales:** Atmospheric Circulation, Oceanic Circulation. Oceanic impact on the marine atmospheric circulation. Ocean waves and Swell, their generation and propagation, Tsunamis and Tides in the ocean – Oceanic Kelvin and Rossby waves. **(7 P).**
- **Coupling Mechanisms - 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, Indian Ocean dipole; ICRPMONEX, BOBMEX,ARMEX. **Air-Sea Interaction studies using Satellite data (8P)**

Numerical Weather Prediction (Theory)

(Total duration = 20 working days = 120 period of 75 minutes)

Theory (65 periods)

- **Numerical Methods (12 P):** Different methods for solving model equations: Initial and boundary conditions, Finite difference method: space and time differencing technique, truncation errors, and Implicit & semi implicit scheme. Numerical stability criterion (CFL), Discrimination technique used for basic governing equations, Spectral method, Spectral representation, spectral co-efficient, spectral transform, Triangular and Rhomboidal truncation. Finite Element techniques, special discretization on icosahedral-hexagons, etc
- **Dynamical models (5 P):** Non-divergent barotropic model, Prediction of geopotential using this model. Equivalent Barotropic model, Derivation, Determination of Equivalent level. Two-layer baroclinic model, Prediction of mean and thermal vorticity using this model. Primitive equation model in σ- coordinate.
- **Parameterization of physical processes (12 P):** Dry and moist adiabatic adjustment, saturation point (LCL).Cumulus parameterization schemes. Surface forcing, shallow and deep convection, verification methods for convection schemes. Parameterization of PBL. Radiation. Principle of radiative transfer. Gravity wave drag and its parameterisation Biosphere and Land surface processes. Parameterisation of air-sea interaction processes.
- **Data Assimilation (16 P):** Different objective analysis schemes, Cressman techniques, OI scheme (Optimum interpolation). Global Data Assimilation System: ,Different formats of data and their interchangability. Decoding and quality control of GTS conventional/non-conventional observations, processing of non-GTS (satellite radiance) observations, Grid Statistical Interpolation (GSI) scheme, Ensemble data Assimilation technique, Hybrid data assimilation technique. Regional data assimilation system: variational data assimilation, 3D & 4 D variational data assimilation technique (WRF Var), sensitivity analysis in variational assimilation, estimation theory, Kalman filtering, Processing Doppler Radar Data for quality control and mesoscale data assimilation. Oceanic data assimilation: data assimilation at mesoscale, assimilation of altimetry data. Initialization: Static Dynamic, Normal mode, Dynamic normal mode & Physical, Nudging, Synthetic data generation/vortex initialization. Ensemble Data Assimilation techniques, Hybrid Data Assimilation, Storm-scale Data Assimilation
- **Operational Numerical Models (12 P):** Operational NWP modelling system: Global Forecast System, Regional and mesoscale forecast system (WRF, ARPS), Nowcast model, Couple Model (Climate Forecast system), Ensemble prediction system, multi-model ensemble technique, Cyclone model Hurricane WRF, vortex relocation and initialization, Antarctica model Polar WRF, Air quality model WRF (Chem), Storm Surge modelling, Ocean State modelling, Crop Weather Model.
- **NWP Products (8 P):** Different products: Direct and Derived, Post processing of model output: Model output verification: Verification methods for short & medium range forecast. Forecast skills, Forecast errors, Systematic errors. Down scale of NWP model like location specific forecast, NWP products for aviation services, hydrological services, agro-meteorological services, NWP products for localised severe weather, monsoon rainfall prediction, prediction of Western disturbances. NWP based objective cyclone forecast system, NWP based location specific forecast, GIS application for NWP, NWP products in Web, NWP Data Management

Practical (55 Periods)

- Simple programmes on Cressman technique, Statistical Interpolation. Initialization of numerical models Applications of an operational variational assimilation scheme in numerical weather prediction (shallow water model). Radar & Satellite Data assimilation, Fog forecasting (onset, duration and dissipation). (15 P).
- Linux O.S, script writing, an introduction to High Performance Computing System, Pre-processing of observations, Configuration of WRF model with GFS, Experiment with nesting and nest down techniques, WRF data assimilation, data sensitivity experiments, sensitivity experiments for physical parameterization. (15 P).
- Model diagnosis: Graphics package for illustration of NWP products, Case study of monsoon depression, cyclonic storm, localised severe weather with the use of derived products like divergent, vorticity, flow pattern, precipitable water content, vertically integrated moisture flux, rainfall etc. Use of model verification tool MET. Model outputs verification tools/ post-processing : Exercises based on the Verification packages such as MET, MODE, R, etc. Visualization of model outputs based on graphic packages such as VAPOR, NCL and RIP. (15 P).
- Experiments with nowcast tool, one dimension column model, storm scale NWP model ARPS, Cyclone prediction, storm surge prediction. Case studies with Radar & Satellite Data assimilation, Fog forecasting (onset, duration and dissipation). (10 P).

Advanced Weather analysis & forecasting

(Duration = 10 working days= 60 Periods of 75 Minutes)

Theory (36 Periods)

- Mid latitude Synoptic Meteorology: Zonal index & Index cycle. Air masses and fronts – Fronto-genesis - Slope of frontal surface - Extra tropical cyclone and its structure and life cycle - Fronts and associated weather - Development of cyclones and anticyclones - Application of pressure tendency equation - Importance of vorticlty advection, temperature advection and diabatic heating Jet Stream and Tropopause; long waves; cut-off lows and highs, blocking.
- Very Short Range (up to 24 hours) forecasting using mesoscale models – their use in aviation and general forecasting.
- Short Range (1 to 3 days) forecasting using regional and global models.
- Numerical model downscaling techniques
- Model Output Statistics (MOS) and their use in Short Range (1 - 3 day) (1-5 days) forecasting of weather elements
- Techniques for forecast verification – skill scores for circulation characteristics and magnitude (intensity) of weather elements.
- Quantitative Precipitation Forecasting in the different seasons and in situations with (a) monsoon depressions (b) tropical cyclone – genesis, intensity, adverse weather with tracks (c) western disturbance (d) active monsoon with withdrawal, strong Low Level Jetstream etc
- Use of coupled Atmosphere – Ocean – Land models – use of SST and soil moisture anomalies to extend the length of the forecast period
- Numerical Model Forecast outputs routinely available on the World Wide Web – Indian model output products available on the web – near real time atmospheric and oceanic data (analysed and in maps or as grid point data) routinely available on the web
- Human intervention in model output forecasts before dissemination as forecasts and warnings to users
- Medium, Extended and Long range NWP forecast outputs – Ensemble, Super Ensemble and Multi Model Ensemble forecasts
- Probabilistic forecast, extreme weather forecast and (Ensemble Prediction system) EPS grams.
- Interpretation of EPS grams

PRACTICALS (24 Periods)

- Exercises using reanalyzed global data and GrADS and other available software
    - 850 and 200 hPa winds and jetstreams of Jan, Apr, Jul and Oct (JAJO)
    - Hadley circulation using mean meridional winds 0E-180E and 180E-0E (JAJO)
    - Walker circulation using mean zonal winds 05S-05N
    - 850 and 200 hPa Stream function of Jan-April-July-Oct (JAJ0)
    - 850 and 200 hPa Velocity Potential of JAJO
    - Vertical velocity at 500 hPa of JAJO
    - Vorticity/divergence at 850/700 hPa levels
- Construction of air parcel trajectory using 06 hourly reanalyzed / forecast wind data
- Exercises using grid point data sets and GrADS software
    - Sea Surface Temperature JAJO
    - GPI rainfall rate JAJO
    - Outgoing Longwave Radiation JAJO
    - Vertically Integrated Moisture (TMI) JAJO
    - QuickScat winds JAJO of tropics
- Extrapolation using Doppler Radar and Satellite Pixel data for Nowcasting weather (1 to 4 hour forecasting)
- Use of Meso-scale model outputs for short range prediction of weather elements (1 to 24 hour forecasting)
- Use of Regional and Global model outputs for 1 to 3 day forecasting of
    - Thunderstorm areas
    - Tropical cyclone tracks
    - Monsoon rain (area and intensity)
    - Rossby waves
    - Jet streams
    - Monsoon onset, Active – Break monsoon
    - Monsoon depressions
    - Western disturbance
- Use of Model Output Statistics in weather prediction for 1 to 3 days Use of Regional and Global model outputs (1-5 days forecasting).

Advanced AVIATION METEOROLOGY

Total duration = 5 working days = 30 Periods of 75 minutes

TOPIC	Sub topic	Objective: On completion the trainees should be able to:	No. of periods
9. SIGMET	1. Template for SIGMET 2. Elements of SIGMET 3. Types of SIGMET 4. Issue of SIGMET 5. Verification of SIGMET 6. SIGMET Test procedures	a. Explain the SIGMET template b. Issue SIGMET from the given information c. Verify SIGMET d. Explain SIGMET Test procedures	6
10. Aerodrome warning, Warning for light aircrafts and Wind shear warning	1. Responsibility of AMO and AMS in issuing warnings 2. Warning elements and Warning format/ Template 3. Issue Aerodrome warnings 4. Verification of aerodrome warnings 5. Issue wind shear warning	a. Explain the responsibilities of AMO and AMS in relation to issuance of warnings b. List the warning elements c. Explain the format of the warnings d. Issue Aerodrome warnings e. Issue wind shear warning f. Verify the warnings	5
11. Tropical Cyclone Advisory Centre and Volcanic Ash Advisory Centre	1. Responsibility of TCAC and VAAC 2. Template of TCAC advisory with example 3. Template of VAAC Advisory with example	a. List the responsibilities of TCAC and VAAC b. Explain the templates of TCAC advisory and VAAC advisory and explain given advisories. c. Use the advisories in SIGMET preparation	4
12. World Area Forecast Centre (WAFC) Products	1. Objectives and responsibilities of WAFS 2. WAFC products: Specifications and their validity. 3. Weather symbols used in SIGWX charts 4. Reception of products and data formats	a. List the WAFC products available b. Describe a given SIGWX chart. c. Use WAFC products in briefing	2
13. Briefing and documentation	1. List of documents to be provided 2. List of items to be displayed in met offices 3. Briefing of low level flights 4. Online Briefing System (OLBS) of IMD	a. List the items to be provided in documentation b. List the items to be displayed in an aviation met office c. To retrieve the products from OLBS or other sources and prepare briefing folder for scheduled flights. d. To upload messages/ forecasts/ warnings on OLBS e. Prepare a briefing folder for flights covering various levels.	4

14. Aeronautical Telecommunication Network (ATN)	1. Basics about aeronautical telecommunication net work	a. Explain the aviation telecommunication network AMSS and SADIS b. Describe the filing time and transit time and priority of aviation met messages c. Explain ROBEX scheme d. Explain method to identify the errors in the messages and rectify and resubmit them e. Explain VOLMET and other meteorological broadcasts	4
	2. AMSS and SADIS		
	3. Filing time, transit time and priority of various aviation meteorological messages		
	4. Basic concept of OPMET and ROBEX scheme		
	5. Monitoring of data transmission and rectification of errors of the messages in error queue in AMSS.		
	6. Basics of VOLMET broadcast and other meteorological broadcasts		
15. Accident Investigation	1. Introduction	Explain the procedures to be followed by various offices	1
	2. Responsibilities of AMS/ AMO in accident investigation		
	3. Responsibilities of RMC		
	4. Preparation of Reports		
16. VIP/VVIP movement	1. Basic procedure to be followed during VIP/ VVIP Flights	Explain the procedures to be followed by various offices	1
17. Airport Meteorological Instruments	1. Basic functions, siting and use of airport meteorological system	1. List and Describe the components of airport met instruments system	1
	2. Reporting of manual RVR	2. To narrate the procedures of assessing RVR manually	1
	3. NOTAM Procedure	3. Explain NOTAM procedure	1
Total classes			**30**

Climate Science

(Total duration = 10 working days = 60 periods of 75 minutes)

- Global Climates in brief (4 P)

  Asia, Africa, North America, South America, Europe, Australia, Arctic and Antarctic.

- Angular momentum cycle (4 P)
- Water Cycle (4 P) ,
- Energetics and the Ocean-Atmosphere Heat Engine (4 P)
- Variability in the climate system (12 P)
  - Monsoon (southwest and northeast) Variability, diurnal, intraseasonal, Interannual, decadal, long term trends from observations, Teleconnection patterns, Walker circulation , tropical –extratropical interaction(5 P)
  - El Nino/ Southern Oscillation, Climatology, Dynamics and prediction, links with global climate, Madden Julian Oscillations, Coupling of Ocean and Atmosphere in ENSO – Indian Ocean Dipole– Relation between ENSO.IOD and Indian monsoon, Indian Ocean Dipole, statistics, dynamics and links with global climate.(5P)
  - North Atlantic Oscillation, Arctic Oscillation, North Pacific Oscillations, PDO, NH Teleconnection Patterns (2P)
- Climate modeling and prediction : Numerical simulation of climate, model simulations of mean climate, Extended range prediction : Scope and different methods : Fundamentals and methods of extended and long range forecasting, IMD's long range forecast models, Dynamical models for long range & extended range forecasts and the recent advances in dynamical model forecasting, Predictability, Skill of long & extended range forecasts (12 P)
- Science of Climate Change : Basics of Climate Change (science), Climate Feedbacks (water vapour, cloud, oceans, snow and ice), Role of aerosols, Observed climate change over India and globe, Future climate projections, IPCC report results (10 P)
- Paleo-climatalogy (4 P)
- Hands-on training on analyses of observed climate data (IMD gridded data,GPCP,CMAP,APHRODITE,ISCCP etc) reanalysis (NCEP, ERA, MEERA, JMA etc) products, satellite data and climate model outputs (eg. CMIP5 data) using packages like GrADS, ferret, CDO etc.(6 P)

HydroMeteorology

(Total duration = 5 working days = 30 periods of 75 minutes)

- Hydro-meteorological services provided by IMD, Hydrological cycle. (1 period)
- Characteristics of rainfall in India, Rainfall producing weather systems, Analysis of Real-time Weather Maps for Rainfall forecast across India. (3 periods)
- Rainfall Network design. (1 period)
- Estimation of average rainfall of an area/ basin. (2 periods)
- Rainfall monitoring and Operational Rainfall Statistics. (2 periods)
- Estimation of Design Storm: Rainstorm, Estimation of Standard Project Storm, Probable maximum Precipitation, DD & DAD curves. (4 periods)
- Extreme Rainfall Analysis, Return Period Analysis, Analysis of short duration Rainfall, IDF curve, Temporal Distribution of Rainfall. (4 periods)
- Hydro met Disasters: Flood, Drought, GLOF, cloudburst, landslides etc. (3 periods)
- Quantitative Precipitation Forecast: Various methods of Quantitative Precipitation Forecast Rain-producing Weather Systems, Analysis of Real-time weather charts for rainfall forecasting, dynamical statistical technique, use of NWP outputs.
- (Synoptic Analog, Use of NWP outputs), Satellite applications ** (Quantitative Precipitation Estimate, Delineation of flood inundation from remote sensing satellite), Radar Applications ** related to rainfall estimates (intensity and cumulative rainfall). (4 periods)
- Rainfall-Runoff Relationship: Concept of Hydrograph, Rainfall Runoff Models. (2 periods)
- Snow Hydrology: Variation in characteristics of Snow (size, shapes of snow crystals, density) with age, estimation of snow cover from satellite imageries, Snow Melt Model (degree day method). (2 periods)
- Development in Water Resources: Water Demands of Future, Water Scarcity, River Linking, Rain Water Harvesting, Impact of Climate Change on Water Resources, Trend in rainfall, any other current topic of importance. (2 periods)
- Quantitative Precipitation Estimate
- Hydro-dynamical modelling and inundation mapping due to floods and storm surge.

- Note: All the topics mentioned above includes practical also except items under 1, 3, 8, 10 and 12.
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Advanced Statistics

(Total duration = 4 working days = 24 Periods of 75 minutes)

Theory (20 Periods)

- Multivariate Regression Analysis including stepwise regression (2 P)
- Cluster and Factor Analysis (2 p)
- Principal Component Analysis/ Empirical Orthogonal Functions(2 P)
- Matrix concepts (2 P)
- Canonical Correlation Analysis (3 P)
- Discriminant Analysis, Log Linear Analysis (3 P)
- Advanced Time series Analysis & filters (3 P)
- Artificial Neural Network, weather Generators (2 P)
- Self Organizing Maps (1P)
- Principal component regression, spectrum analysis, Ensemble Empirical Mode Decomposition (EEMD) technique and intrinsic Mode functions (IMF).

Practical (4 Periods)

- Calculating the statistics using the formulations. Advanced statistical analysis using MS Excel, SPSS, MATlab and R-software

Computer Programming and applications

(Duration = 5 working days=30 Periods of 75 minutes duration)

Theory (16 P)

- HPC architecture-(1 P)
- Basics of MPI programming (2 P)
- Different data formats (ASCII, Binary, HDF, NetCDF, Conversions, GRIB) (1 P)
- Basic Concepts of Parallel processing paradigms and parallel program execution (2 P)
- Fortran-90 Programming and MATLAB. (10 P)
    - Additional features in Fortran 90 and features in C,C+ & C++ .(6 P)
    - MATLAB (4 P)

Practicals (12 P)

- Practical application of the Statistical Package (SPSS /SYSTAT/ R Software /Mathlab) (4 P)
- FORTRAN practicals (Applicaion in Numerical analysis & statistics)(4 P)
    - Practical application of the graphic packages like Grads ,Ferret, NCL graphics (4 P)

Basic concept of of Networking (2 P)