UNIVERSITY OF MUMBAI

Syllabus for Sem V & VI
Program: B.Sc.
Course: STATISTICS

(Credit Based Semester and Grading System with effect from the academic year 2013–2014)
T.Y.B.Sc.

STATISTICS

Credit Based Semester and Grading System
To be implemented from the Academic year 2013-2014

SEMESTER V
Theory

<table>
<thead>
<tr>
<th>Course</th>
<th>UNIT</th>
<th>TOPICS</th>
<th>Credits</th>
<th>L / Week</th>
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**Unit I: PROBABILITY I**

(i) Basic definitions: Random Experiment, Outcome, Event, Sample Space, Complementary, Mutually Exclusive, Exhaustive and Equally Likely Events.

(ii) Mathematical, Statistical, Axiomatic and Subjective probability.

(iii) Sub populations and partitions.
- Derivation of a) $A_{r,n}$: Number of distinguishable distributions of putting $r$ indistinguishable balls in $n$ cells;
- b) Number of distinguishable distributions of putting $r$ indistinguishable balls in $n$ cells such that no cell is empty.

(iv) Ordered samples and runs.

(v) Probabilities based on a) Maxwell Boltzmann, Bose Einstein and Fermi Dirac Statistics.

(vi) Addition Theorem for (a) two (b) three events.

(Ref. 1,2,5,7,8)

15 Lectures

**Unit II: PROBABILITY II**

(i) Theorems on Probability of realization of:
- (a) At least one  
- (b) Exactly $m$  
- (c) At least $m$ of $N$ events $A_1, A_2, A_3...A_N$.

Matching and Guessing problems.

(ii) Conditional Probability: Multiplication Theorem for two, three events.

Independence of two/three events - complete and pair wise.

(iii) Bayes’ theorem.

(Ref. 1,2,5,8)

15 Lectures

**Unit III: JOINT MOMENT GENERATING FUNCTION, TRINOMIAL AND MULTINOMIAL DISTRIBUTION**

(i) Definition and properties of Moment Generating Function (MGF) of two random variables of discrete and continuous type. Necessary and Sufficient condition for independence of two random variables. Concept and definition of Multivariate MGF.

(ii) **Trinomial distribution:**
- Definition of joint probability distribution of $(X, Y)$. Joint moment generating function, moments $\mu_{rs}$ where $r=0, 1, 2$ and $s=0, 1, 2$.
- Marginal & Conditional distributions. Their Means & Variances.
- Correlation coefficient between $(X, Y)$. Distribution of the Sum $X+Y$.

(iii) Extension to Multinomial distribution with parameters $(n, p_1, p_2,...p_{k-1})$ where $p_1+p_2+...+p_{k-1}+p_k = 1$. Expression for joint MGF. Derivation of: joint probability distribution of $(X_i, X_j)$. Conditional probability distribution of $X_i$.

15 Lectures
given $X_j = x_j$  

<table>
<thead>
<tr>
<th><strong>Unit IV: ORDER STATISTICS</strong></th>
<th>15 Lectures</th>
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<tbody>
<tr>
<td>(i) Definition of Order Statistics based on a random sample.</td>
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<td>(ii) Derivation of:</td>
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<tr>
<td>(a) Cumulative distribution function of $r^{th}$ order statistic.</td>
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<td>(b) Probability density functions of the $r^{th}$ order statistic.</td>
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<td>(c) Joint Probability density function of the $r^{th}$ and the $s^{th}$ order statistic ($r &lt; s$)</td>
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<td>(d) Joint Probability density function of all $n$ ordered statistics.</td>
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<td>(iii) Probability density function of Median (in the case of odd sample sizes) and Range for Uniform and Exponential distributions.</td>
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**REFERENCES**

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**Unit I : POINT ESTIMATION AND PROPERTIES OF ESTIMATOR- I**
Notion of a parameter and parameter space. Problem of Estimation,
Definitions of Statistic, Estimator and Estimate.
Properties of a good estimator:
(a) Unbiasedness: Definition of an unbiased estimator, biased
estimator, positive and negative bias, illustrations and examples (these should
include unbiased and biased estimators for the same parameters). Proofs of the
following results regarding unbiased estimators.
   (i) Two distinct unbiased estimators of \( \phi(\theta) \) give rise to
       infinitely many unbiased estimators.
   (ii) If \( T \) is an unbiased estimator of \( \theta \), then \( \phi(T) \) is unbiased
       estimator of \( \phi(\theta) \) provided \( \phi(.) \) is a linear function.
(b) Consistency: Definition, Proof of the following theorem: An
   estimator is consistent if its bias and variance both tend to zero
   as the sample size tends to infinity.
(c) Sufficiency: Concept and definition of Sufficiency, Neymann Factorization
   Theorem (without proof). Exponential family of probability distributions and
   Sufficient statistic.
(d) Relative efficiency of an estimator. Illustrative examples.

**Unit II : PROPERTIES OF ESTIMATOR- II**
Minimum variance unbiased estimator (MVUE), Uniqueness property of MVUE.
Fisher information function, Statement and proof of Cramer-Rao inequality,
Cramer–Rao Lower Bound (CRLB), Definition of minimum variance bound
unbiased estimator (MVBUE) of \( \phi(\theta) \). Definition of Efficient estimator using
CRLB.

**Unit III : METHODS OF ESTIMATION**
a) Method of Maximum Likelihood Estimation (M.L.E.), Definition of likelihood
   as a function of unknown parameter, for a random sample from i) discrete
distribution ii) continuous distribution. Distinction between likelihood function
and joint p.d.f. / p.m.f.
   Derivation of Maximum Likelihood Estimator (M.L.E.) for parameters of
standard distributions (case of one and two unknown parameters). Properties of
M.L.E(without proof)
b) Method of Moments, Derivation of moment estimators for standard distributions (case of one and two unknown parameters). Illustrations of situations where M.L.E. and Moment Estimators are distinct and their comparison using Mean Square Error.

c) Method of Minimum Chi-square and Modified Minimum Chi-square.

(Ref. 1,3,8)

Unit IV: BAYESIAN ESTIMATION AND CONFIDENCE INTERVAL

Bayesian Estimation: Prior distribution, Posterior distribution, Loss function, Risk function, Bayes’ solution under Squared Error Loss Function (SELF) and Absolute Error Loss function.

Interval Estimation: Concept of Confidence Interval and Confidence Limits. Definition of pivotal quantity and its use in obtaining confidence limits. Derivation of 100(1-α) % equal tailed confidence interval for the parameters μ, μ₁ - μ₂ (Population variance(s) known / unknown), σ², σ₁²/σ₂² (Normal distribution). Confidence Intervals based on asymptotic property of M.L.E. Confidence interval for the parameters of Binomial, Poisson and Exponential distribution. Equidistant confidence interval for θ based on the random sample from Uniform distribution (0,θ) by using distribution of M.L.E.

(Ref. 1, 3, 8).

REFERENCES:


15 Lectures
<table>
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**Unit I: EPIDEMIC MODELS**

(i) The features of Epidemic spread. Definitions of various terms involved. Simple mathematical models for epidemics: Deterministic model without removals, Carrier model.

(ii) Chain binomial models. Reed - Frost and Greenwood models. Distribution of individual chains and total number of cases. Maximum likelihood estimator of ‘p’ and its asymptotic variance for households of sizes up to 4.

(Ref. 1)

15 Lectures

**Unit II: BIOASSAYS**


(Ref. 2, 3)

15 Lectures

**Unit III: CLINICAL TRIALS: AN INTRODUCTION**


Concept of odds ratio. Sample size estimation.

(Ref. 4, 5, 6, 7, 8)

15 Lectures

**Unit IV: BIOEQUIVALENCE**

Definitions of Generic Drug product. Bioavailability, Bioequivalence, Pharmacokinetic (PK) parameters $C_{\text{max}}$, $AUC_t$, $AUC_{0-\infty}$, $T_{\text{max}}$, $K_{el}$, $T_{\text{half}}$. Estimation of PK parameters using ‘time vs. concentration’ profiles. Designs in Bioequivalence: Parallel, Cross over (Concept only). Advantages of Crossover design over Parallel design.

Analysis of Parallel design using logarithmic transformation (Summary statistics, ANOVA and 90% confidence interval).

Confidence Interval approach to establish bioequivalence (80/125 rule).

(Ref. 9)

15 Lectures
REFERENCES:
<table>
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<th>Title</th>
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**Unit I: MORTALITY TABLES:**

(Ref.2,3)

15 Lectures

**Unit II: COMPOUND INTEREST AND ANNUITIES CERTAIN:**
Accumulated value and present value, nominal and effective rates of interest. Varying rates of interest. Equation of value. Equated time of payment. Present and accumulated values of annuity certain (immediate and due) with and without deferment period. Present value for perpetuity (immediate and due) with and without deferment Period. Present and accumulated values of (i) increasing annuity (ii) increasing annuity when successive installments form arithmetic progression (iii) annuity with Frequency different from that with which interest is convertible. Redemption of loan.

(Ref.2)

15 Lectures

**Unit III: LIFE ANNUITIES:**
Present value in terms of commutation functions of Life annuities and Temporary life annuities (immediate and due) with and without deferment period. Present values of Variable, increasing life annuities and increasing Temporary life annuities (immediate and due).

(Ref:1,2)

15 Lectures

**Unit IV: ASSURANCE BENEFITS:**
Present value of Assurance benefits in terms of commutation functions of:

(i) pure endowment assurance  
(ii) temporary assurance  
(iii) endowment assurance  
(iv) whole life assurance  
(v) special endowment assurance  
(vi) deferred temporary assurance

Net premiums: Net level annual premiums (including limited period of payment) for various assurance plans.

Office premiums.

(Ref:1,2)

15 Lectures

**REFERENCES:**

# DISTRIBUTION OF TOPICS FOR PRACTICALS

## SEMESTER-V

### COURSE CODE USSTP05

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## T.Y.B.Sc. STATISTICS Syllabus

Credit Based and Grading System

To be implemented from the Academic year 2013-2014

### SEMESTER VI

#### Theory

<table>
<thead>
<tr>
<th>Course</th>
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<td>Stochastic Processes</td>
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**Unit I: BIVARIATE NORMAL DISTRIBUTION**

i) Definition of joint probability distribution \((X, Y)\). Joint Moment Generating function, moments \(\mu_{rs}\) where \(r=0, 1, 2\) and \(s=0, 1, 2\). Marginal & Conditional distributions. Their Means & Variances.

Correlation coefficient between the random variables.

Necessary and sufficient condition for the independence of \(X\) and \(Y\).

Distribution of \(aX + bY\), where ‘a’ and ‘b’ are constants.

ii) Distribution of sample correlation coefficient when \(\rho = 0\).

Testing the significance of a correlation coefficient.

Fisher’s \(z\) – transformation.

Tests for i) \(H_0: \rho = \rho_0\) ii) \(H_0: \rho_1 = \rho_2\)

Confidence interval for \(\rho\).

(Ref. 2,3,5,9) 15 Lectures

**Unit II: GENERATING FUNCTIONS**

Definitions of generating function and probability generating function. Expression for mean and variance in terms of generating functions. Definition of a convolution of two or more sequences. Generating function of a convolution. Generating functions of the standard discrete distributions. Relation between:

i) Bernoulli and Binomial distributions ii) Geometric and Negative Binomial distributions in terms of convolutions.

(Ref.1,5) 15 Lectures

**Unit III: STOCHASTIC PROCESSES**

Definition of stochastic process. Postulates and difference differential equations for:

(i) Pure birth process

(ii) Poisson process with initially ‘a’ members, for \(a=0\) and \(a >0\)

(iii) Yule Furry process

(iv) Pure death process

(v) Death process with \(\mu_n = \mu\)

(vi) Death process with \(\mu_n = n\mu\)

(vii) Birth and death process

(viii) Linear growth model.

Derivation of \(P_n(t)\), mean and variance where ever applicable.

(Ref.1,7,9) 15 Lectures

**Unit IV: QUEUING THEORY**

Basic elements of the Queuing model.

Roles of the Poisson and Exponential distributions.

Derivation of Steady state probabilities for birth and death process. Steady state probabilities and various average characteristics for the following models:

(i) \((M/M/1) : (GD/\infty/\infty)\)

(ii) \((M/M/1) : (GD/\infty/e)\)

(iii) \((M/M/c) : (GD/\infty/\infty)\)

(iv) \((M/M/c) : (GD/\infty/\infty)\)

(v) \((M/M/c) : (GD/\infty/\infty)\)

(Ref.6) 15 Lectures
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**Unit I: MOST POWERFUL TESTS**


Definition of most powerful test of size $\alpha$ for a simple hypothesis against a simple alternative hypothesis. Neyman-Pearson fundamental lemma.

(Ref. 1,2) 15 Lectures

**Unit II: UNIFORMLY MOST POWERFUL & LIKELIHOOD RATIO TESTS**

Definition, Existence and Construction of uniformly most powerful (UMP) test. Likelihood ratio principle. Definition of test statistic and its asymptotic distribution (statement only). Construction of LRT for the mean of normal distribution for i) known $\sigma^2$ ii) unknown $\sigma^2$ (two sided alternatives). LRT for variance of normal distribution for i) known $\mu$ ii) unknown $\mu$ (two sided alternatives hypotheses).

Ref. (1,2,3) 15 Lectures

**Unit III: SEQUENTIAL PROBABILITY RATIO TEST (SPRT)**

Sequential test procedure for testing a simple null hypothesis against a simple alternative hypothesis. Its comparison with fixed sample size (Neyman-Pearson) test procedure. Definition of Wald’s SPRT of strength ($\alpha$, $\beta$). Problems based on Bernoulli, Binomial, Poisson, Normal, Exponential distributions. Graphical /tabular procedure for carrying out the tests.

(Ref. 1,6,8,9) 15 Lectures

**Unit IV: NON-PARAMETRIC TESTS**

Need for non parametric tests. Distinction between a parametric and a non parametric test. Concept of a distribution free statistic. Single sample and two sample Nonparametric tests. (i) Sign test (ii) Wilcoxon’s signed rank test (iii) Median test (iv) Mann–Whitney test (v) Run test.

Assumptions, justification of the test procedure for small & large samples.

(Ref. 5) 15 Lectures
REFERENCES:

3. Lehmann, E. L: Testing of Statistical Hypothesis, Wiley &sons
4. Rao, C. R.: Linear Statistical Inference,
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<tbody>
<tr>
<td>USST603</td>
<td>OPERATIONS RESEARCH TECHNIQUES</td>
<td>2.5 Credits (60 lectures)</td>
</tr>
</tbody>
</table>

**Unit I: INVENTORY CONTROL**

Introduction to Inventory Problem

Deterministic Models:

- Single item static EOQ models for:
  - (i) Constant rate of demand with instantaneous replenishment, with and without shortages.
  - (ii) Constant rate of demand with uniform rate of replenishment, with and without shortages.
  - (iii) Constant rate of demand with instantaneous replenishment without shortages, with at most two price breaks.

Probabilistic models: Single period with

- (i) Instantaneous demand (discrete and continuous) without setup cost.
- (ii) Uniform demand (discrete and continuous) without setup cost.

(Ref. 1, 4, 5)

**Unit II: GAME THEORY**


Dominance property, Derivation of formulae for (2x2) game.

Graphical solution of (2xn) and (mx2) games.

(Ref. 1)

**Unit III: REPLACEMENT**

Replacement of items that deteriorate with time and value of money

- i) remains constant
- ii) changes with time.

Replacement of items that fail completely: Individual replacement and Group replacement policies.

(Ref. 5)

**Unit IV: DECISION THEORY**

Decision making under uncertainty: Laplace criterion, Maximax (Minimin) criterion, Maximin (Minimax) criterion, Hurwicz \( \alpha \) criterion, Minimax Regret criterion.

Decision making under risk: Expected Monetary Value criterion, Expected Opportunity Loss criterion, EPPI, EVPI. Bayesian Decision rule for Posterior analysis.

Decision tree analysis along with Posterior probabilities.

(Ref. 1)
REFERENCES:
<table>
<thead>
<tr>
<th>Course Code</th>
<th>Title</th>
<th>Credits</th>
</tr>
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<tr>
<td>USST604</td>
<td>FORECASTING &amp; RELIABILITY</td>
<td>2.5 Credits (60 lectures)</td>
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</table>

**Unit I : TIME SERIES**
Estimation of trend by: (i) Freehand curve method (ii) Method of Semi Averages (iii) Method of Moving Averages (iv) Method of Least Squares.
(v) Exponential Smoothing method
Estimation of seasonal component by: (i) Method of simple averages (ii) Ratio to moving average method (iii) Ratio to trend method.
(Ref.1,2) 15 Lectures

**Unit II : SIMULATION**
Sampling from probability distribution. Inverse method. Generation of random observations from i) Uniform distribution ii) Exponential distribution iii) Gamma distribution iv) Normal distribution. Simulation techniques applied to inventory and Queuing models.
(Ref.4,5) 15 Lectures

**Unit III: LINEAR REGRESSION**
Linear regression model with one or more explanatory variables. Assumptions of the model, Derivation of Ordinary Least Square (OLS) estimators of regression coefficients, (for one and two explanatory variables models). Properties of least square estimators (without proof). Coefficient of determination $R^2$ and adjusted $R^2$.
Procedure of testing:
(i) overall significance of the model
(ii) significance of individual coefficients
(iii) Significance of incremental contribution of explanatory variable for two explanatory variables model.
Confidence intervals for the regression coefficients.
Autocorrelation: Concept, Detection using Durbin Watson Test, Generalized Least Square (GLS) method.
Heteroscedasticity: Concept, Detection using Breusch-Pagan-Godfrey test.
Weighted Least Square (WLS) estimators
Multicollinearity: Concept, Detection using (i) R square & t ratios (ii) Variance Inflation Factor (VIF)
(Ref: 8,9) 15 Lectures

**Unit IV: RELIABILITY**
Concept of reliability, Hazard-rate. Bath tub curve.
Failure time distributions: (i) Exponential (ii) Gamma (iii) Weibull (iv) Gumbel. 15 Lectures
Definitions of increasing (decreasing) failure rate.
System Reliability. Reliability of (i) series; (ii) parallel system of independent components having exponential life distributions. Mean Time to Failure of a system (MTTF).

(Ref 6,7)

REFERENCES:
### DISTRIBUTION OF TOPICS FOR PRACTICALS

#### SEMESTER-VI

**COURSE CODE USSTP07**

<table>
<thead>
<tr>
<th>Sr. No.</th>
<th>Practical Topics (from Course USST601)</th>
<th>Sr. No.</th>
<th>Practical Topics (from Course USST602)</th>
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<tbody>
<tr>
<td>6.1.1</td>
<td>Bivariate Normal Distribution</td>
<td>6.2.1</td>
<td>Testing of Hypothesis 1</td>
</tr>
<tr>
<td>6.1.2</td>
<td>Tests for correlation and Interval estimation</td>
<td>6.2.2</td>
<td>Testing of Hypothesis-2</td>
</tr>
<tr>
<td>6.1.3</td>
<td>Generating Function</td>
<td>6.2.3</td>
<td>SPRT</td>
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<tr>
<td>6.1.4</td>
<td>Stochastic Process</td>
<td>6.2.4</td>
<td>Non Parametric test-1</td>
</tr>
<tr>
<td>6.1.5</td>
<td>Queuing Theory -1</td>
<td>6.2.5</td>
<td>Non Parametric test-2</td>
</tr>
<tr>
<td>6.1.6</td>
<td>Queuing Theory -2</td>
<td>6.2.6</td>
<td>Use of R software.</td>
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**COURSE CODE USSTP08**

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<tbody>
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<td>Inventory-1</td>
<td>6.4.1</td>
<td>Time series-1</td>
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<td>6.3.2</td>
<td>Inventory-2</td>
<td>6.4.2</td>
<td>Time series-2</td>
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<tr>
<td>6.3.3</td>
<td>Game Theory</td>
<td>6.4.3</td>
<td>Simulation</td>
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<tr>
<td>6.3.4</td>
<td>Replacement</td>
<td>6.4.4</td>
<td>Reliability</td>
</tr>
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<td>6.3.5</td>
<td>Decision Theory-1</td>
<td>6.4.5</td>
<td>Multiple regression model -1</td>
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<td>Decision Theory-2</td>
<td>6.4.6</td>
<td>Multiple regression model- 2</td>
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</tbody>
</table>
Internal Assessment of Theory Core Courses Per Semester Per Course

1. One Class Test .................................. 20 Marks
2. One Assignment .................................. 10 Marks.
3. Active participation in class instructional deliveries ..........05 Marks.
4. Overall conduct as a responsible student, mannerism etc ....05 Marks.

Semester End Examination- THEORY

At the end of the semester, examination of two hours duration and 60 marks based on the four units shall be held for each course.

Pattern of Theory question paper at the end of the semester for each course:

There shall be Five compulsory Questions of Twelve marks each with internal option. Question 1 based on Unit I, Question 2 based on Unit II, Question 3 based on Unit III, Question 4 based on Unit IV and Question 5 based on all four Units combined.

Semester End Examination- PRACTICALS

At the end of the semester, examination of three hours duration and 100 marks (80+10*+10**) shall be held for each course as shown below.

<table>
<thead>
<tr>
<th>Practical course</th>
<th>Part A</th>
<th>Part B</th>
<th>Duration</th>
<th>Marks out of</th>
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<tbody>
<tr>
<td>USSTP05</td>
<td>Questions from USST501</td>
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<td>3 hours</td>
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<tr>
<td>USSTP06</td>
<td>Questions from USST503</td>
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<td>80</td>
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<tr>
<td>USSTP07</td>
<td>Questions from USST601</td>
<td>Questions from USST602</td>
<td>3 hours</td>
<td>80</td>
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<tr>
<td>USSTP08</td>
<td>Questions from USST603</td>
<td>Questions from USST604</td>
<td>3 hours</td>
<td>80</td>
</tr>
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</table>

**2. Viva ...........................................10 Marks.

Pattern of Practical question paper at the end of the semester for each course:
Every paper will consist of two parts A and B. Every part will consist of two questions of 40 marks each. Students to attempt one question from each part.