



UNIVERSITY OF THE PUNJAB

Roll No.

Fifth Semester 2017
Examination: B.S. 4 Years Programme

PAPER: Mathematical Economics-I
Course Code: ECON-303

TIME ALLOWED: 30 mins.
MAX. MARKS: 10

Attempt this Paper on this Question Sheet only.

OBJECTIVE TYPE

PART-I (MCQs)

10

ENCIRCLE THE RIGHT ANSWER

1. Real number system consist of _____
a) Integer b) fraction c) rational and irrational numbers d) all
2. A function in which each term contain a coefficient as well as integer power of independent variables is called
a) Linear or quadratic b) polynomial c) both a and b d) none
3. Matrix algebra can only be applied to the system of _____ equations
a) Nonlinear b) linear c) quadratic d) none
4. A minor coupled with prescribed sign is called
a) Transpose b) co-factor c) both d) none
5. The analysis in which we study the all types of rates of changes
a) Partial analysis b) comparative static analysis c) both d) none
6. The point where a function changes its rates of change is called
a) Saddle point b) point of inflection c) maxima d) minima
7. In optimization under single inequality constraint, the method of _____ is applied while under several inequality constraints _____ is applied to get the optimal solution
a) Linear programming, Langrange multiplier b) Langrange multiplier, linear programming c) none
8. The marginal function are found from total function using
a) Derivatives b) integrals c) optimization d) none
9. If $p = a + c/b + d$ the $b + d$ should be _____ for unique positive solution
a) Greater than zero b) less than zero c) $b + d = 0$ d) none
10. The domain of exponential function consist of _____-but range is _____
a) Real number, positive real number b) integral numbers, rational numbers c) both



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TIME ALLOWED: 2 hrs. & 30 mins.
MAX. MARKS: 50

Attempt this Paper on Separate Answer Sheet provided.

SUBJECTIVE TYPE

PART II

20

GIVE SHORT ANSWERS OF THE FOLLOWING.

All questions carry equal marks:

1. Differentiate between exponential and logarithmic functions
2. Find the equilibrium P and Q for the following
 $Q_d = 3 - P^2$, $Q_s = 6P - 4$
3. What are the conditions for maxima and minima for a multivariable function $z = f(x, y)$
4. Find the equation of straight line passing through two point (3, 4) and (-5, 2)

PART III

30

All questions carry equal marks:

1. Write a comprehensive note on types of functions with examples and diagrams
2. Find the equilibrium solution for the two competing product model, if:

$$Q_{d1} = 24 - 3P_1 + P_2 \quad Q_{d2} = 16 + P_1 - 2P_2$$

$$Q_{s1} = -4 + 4P_1 \quad Q_{s2} = -4 + 3P_2$$

3. Given $Y = C + I + G$

$$\text{And } C = a + bY \quad I = I_0 \quad G = G_0$$

Find the values of Y and C by Matrix method

4. Solve the following equations by Matrix Inversion Method

$$8X_1 - X_2 = 16$$

$$2X_2 + 5X_3 = 5$$

$$2X_1 + 3X_3 = 7$$

5. The total cost function of the commodity x is $TC = 60 - 12X + 2X^2$. Find the level of output at which total cost is minimum. Find the average cost function and the level of output at which this function is minimum.



UNIVERSITY OF THE PUNJAB

Sixth Semester - 2017
Examination: B.S. 4 Years Programme

Roll No.

PAPER: Mathematical Economics II
Course Code: ECON-308

TIME ALLOWED: 2 hrs. & 30 mins.
MAX. MARKS: 50

Attempt this Paper on Separate Answer Sheet provided.

Subjective Part

Note: Attempt all questions.

Q2. Write short answers.

(5 X4= 20)

- I. What is meant by complex numbers?
- II. Write four Properties of definite integrals.
- III. State the Routh Theorem.
- IV. Find total variable cost (TVC) when $MC=12Q^2-3Q+10$
- V. Solve:

$$dy/dt+3y=2 \text{ where } y(0)=4$$

Q3. Give the frame work of Solow Growth model with its qualitative solution.

10

Q4. Find definite solution of

10

$$2y''(t)-12y'(t)+20y=40; Y(0)=4, Y'(0)=5$$

Q5. Solve the difference equation

10

$$Y^{t+2}-Y^{t+1}+1/4Y^t=2 \text{ where } y_0=4 \text{ and } y_1=7$$



UNIVERSITY OF THE PUNJAB

Roll No.

Sixth Semester - 2017

Examination: B.S. 4 Years Programme

PAPER: Mathematical Economics II
Course Code: ECON-308

TIME ALLOWED: 30 mins.
MAX. MARKS: 10

Attempt this Paper on this Question Sheet only.

Objective Part

Q.1: Encircle the correct answer.

1. If the slope of phase line is negative, then time path will be:
 - a) Perpetual
 - b) Convergent
 - c) Divergent
 - d) All of these

2. The general solution of $dy/dt + ay = 0$ is:
 - a) y/a
 - b) $Y(t) = Ae^{-at}$
 - c) $Y(t) = A(-a)^t$
 - d) $Y(t) = b/a$

3. Complementary function 'Yc' shows the solution of:
 - a) Reduced equation
 - b) Complete equation
 - c) Difference equation
 - d) None

4. Particular integral 'Yp' shows the:
 - a) Complementary function
 - b) Inter-temporal equilibrium
 - c) Zero
 - d) None

(P.T.O.)

5. The Cartesian form of $Re^{i\theta}$ is:

- a) $(h+vi)$
- b) $R \cos\theta$
- c) $R \sin \theta$
- d) $R(\cos\theta+i \sin\theta)$

6. $dy/dt+ty=y^2=is$

- a) Linear differential equation
- b) Difference equation
- c) Bernoulli equation
- d) None

7. According to Domar growth model output is function of:

- a) Labor
- b) Capital
- c) Labor and Capital
- d) Money supply

8. $Y_{t+1} - Y_t = 3$ is:

- a) Quadratic equation
- b) Differential equation
- c) Difference equation
- d) All

9. If the slope of phase line is positive, then time path will be:

- a) Convergent
- b) Divergent
- c) Perpetual
- d) All of these

10. $dy/dt + 2t = y^3$

- a) Quadratic equation
- b) Cubic equation
- c) Bernoulli equation
- d) None



UNIVERSITY OF THE PUNJAB
Sixth Semester - 2018
Examination: B.S. 4 Years Programme

Roll No.

PAPER: Mathematical Economics II

TIME ALLOWED: 15 Mints.

Course Code: ECON-308 Part – I (Compulsory)

MAX. MARKS: 10

Attempt this Paper on this Question Sheet only.

Please encircle the correct option. Each MCQ carries 1 Mark. This Paper will be collected back after expiry of time limit mentioned above.

Q1. Tick the Correct answer

1. Square root of negative number is called:
 - a) complex number
 - b) imaginary number
 - c) both
 - d) none
2. Solution of $\int k e^x dx$
 - a) k
 - b) e^x
 - c) $k e^x$
 - d) None of the given
3. Derivative of $\sin \theta$ is:
 - a) $\cos \theta$
 - b) $-\cos \theta$
 - c) $-\sin \theta$
 - d) $\tan \theta$
4. $\int x^2 dx$ is:
 - a) Proper integral
 - b) Improper integral
 - c) Indefinite integral
 - d) None of these
5. According to Euler relation the polar form of complex number $(h+vi)$ is:
 - a) $R (\cos \theta + i \sin \theta)$
 - b) $R e^{i\theta}$
 - c) $R \cos \theta$
 - d) $R \sin \theta$
6. Derivative of $\cos \theta$:
a) $\cos \theta$ b) $-\cos \theta$ c) $-\sin \theta$ d) $\sin \theta$
7. Particular integral shows:
a) reduced form equation b) inter temporal equilibrium c) nothing
8. According to Domar growth model, output is function of:
a) labor b) capital c) K/L d) K and L
9. $dy/dt + 3ty = e^4 y^6$ is a:
a) linear diff equation b) Bernoulli equation c) both d) none
10. $dy/dt + ty = 3t^2 y$ is a:
a) linear differential equation b) Bernoulli's equation
c) difference equation d) an identity



UNIVERSITY OF THE PUNJAB

Sixth Semester - 2018

Examination: B.S. 4 Years Programme

Roll No.

PAPER: Mathematical Economics II
Course Code: ECON-308 Part – II

TIME ALLOWED: 2 Hrs. & 45 Mins.
MAX. MARKS: 50

Attempt this Paper on Separate Answer Sheet provided.

Q2. Write short answers of the following questions

(5 x 4 =20)

- Find $\int X \ln X \, dX$
- What is difference between Euler and Maclaurin series?
- Find the roots of the equation $2X^2 - X + 1 = 0$
- Find Y_c and Y_p of $dy/dt - 2y = 0$ where $y(0) = 9$
- What is meant by exact differential equations?

Q3. Solve the following difference equation and verify your answer.

$$Y_{t+2} - 2Y_{t+1} + 2Y_t = 1 \quad \text{where } Y_{(0)} = 3, Y_{(1)} = 4 \quad (10)$$

Q4. Is the following equation exact? If not, try a possible integrating factor to solve the equation.

$$2y t^3 dy + 3y^2 t^2 dt = 0 \quad (10)$$

Q5. Derive Kuhn Tucker condition for verifying the optional values found in non-linear programming. (10)



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Roll No.

Fifth Semester 2018

Examination: B.S. 4 Years Programme

PAPER: Mathematical Economics-I
Course Code: ECON-303

TIME ALLOWED: 30 mins.
MAX. MARKS: 10

Attempt this Paper on this Question Sheet only.

NOTE: Attempt all questions

OBJECTIVE

- Q. #: Select the correct answer. (1 X 10 = 10)
- I. Real number system consist of:
a. (a) Integer (b) Fraction (c) Rational and Irrational number (d) all
- II. Slope of the function $y = 3x^2$ at $x = 2$
a. (a) 3 (b) 2 (c) 12 (d) 3x
- III. The price elasticity of demand in $PQ=200$ is
a. (a) 200 (b) 0 (c) Unity (d) Infinity
- IV. The matrix which has zero determinant is called as
a. (a) Singular Matrix (b) Non-Singular matrix (c) Identity Matrix (d) None of these
- V. Slope of Straight line passing through the points (15, 27) and (20, 10)
a. (a) Positive (b) Negative (c) Zero (d) None of these
- VI. A minor coupled with prescribed sign is called:
a. (a) Transpose (b) Co-factor (c) Both a and b (d) none
- VII. Minor with a specific algebraic sign is called as
a. (a) Matrix (b) Identity (c) Co-factor (d) Transpose
- VIII. The slope of quadratic function at its maximum point is
a. (a) Positive (b) Zero (c) Negative (d) None of These
- IX. Under perfect competition, total revenue function is
a. (a) Cubic Function (b) Linear Function (c) Quadratic Function (d) none
- X. If $Qd_1 = 400 - 3P_1 - 4P_2$ and $Qd_2 = 200 - 7P_1 - 4P_2$ then these two goods will be
a. (a) inferior goods (b) complements (c) substitutes (d) griffon goods



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MAX. MARKS: 50

Attempt this Paper on Separate Answer Sheet provided.

SUBJECTIVE TYPE

NOTE: Attempt all questions

Q.2 Write the short answers

(4 X 5 = 20)

- (i) Differentiate between exponential and logarithmic function
- (ii) What do you mean by non-singular matrix?
- (iii) State duality theorems?
- (iv) If $TC = Q^3 - 3Q^2 + 100Q + 60$
- (v) If $Q = 70 - 5P$

Then find the slope of TR (Total Revenue)

Q.3 If $Q_d = 20 - 3p$ $Q_s = -5 + 29$

$$Q_d = Q_s$$

- a) Find equilibrium price (p) and equilibrium quantity (Q). (5)
- b) Find Elasticity of demand and elasticity of supply at P and Q (5)

Q.4 If $A = \begin{bmatrix} 2 & 3 & 0 \\ 5 & 4 & 1 \\ 1 & 6 & 3 \end{bmatrix}$ Find A^{-1} ? (10)

Q.5 Find $\frac{dy}{dx}$ of

- (i) $Y = (9x^2 - 7)^4$ (5)
- (ii) $Y = \ln\left(\frac{6x}{4-x^2}\right)$ (5)



UNIVERSITY OF THE PUNJAB

Fifth Semester – 2019

Examination: B.S. 4 Years Program

PAPER: Mathematical Economics-I
Course Code: ECON-303 Part-I (Compulsory)

MAX. TIME: 15 Min.
MAX. MARKS: 10

Roll No. in Fig.

Roll No. in Words.

Signature of Supdt.

Attempt this Paper on this Question Sheet only.

**Please encircle the correct option. Division of marks is given in front of each question.
This Paper will be collected back after expiry of time limit mentioned above.**

Q.1. Encircle the right answer, cutting and overwriting is not allowed. (1x10=10)

1. When we give one value to independent variable and attain one value for dependent variable then it is called:
 - a) Relation
 - b) Function
 - c) Multi-valued function
 - d) Decreasing function
2. The general representation of implicit function is:
 - a) $I=f(y)$
 - b) $Y=f(I)$
 - c) $F(x, y) = 0$
 - d) $Y=f(x)$
3. Slope of function $Y=f(x)=11$ is
 - a) Positive
 - b) Negative
 - c) Infinite
 - d) Zero
4. If $Q_d = 10 - 2P_1 + P_2$, here the positive sign of P_2 shows that goods are:
 - a) Complements
 - b) Substitutes
 - c) Luxuries
 - d) Inferior
5. The variable whose value is determined within the model is called:
 - a) Endogenous variables
 - b) Exogenous variables
 - c) Independent variables
 - d) Dependent variables
6. According to the transpose property if $(AB)^t = \dots$
 - a) $A^t B^t$
 - b) $B^t A^t$
 - c) $A^{-1} B^t$
 - d) $A^t B^{-1}$
7. If the matrix has zeros above or below the principle diagonal, then it is called:
 - a) Diagonal matrix
 - b) Identity matrix
 - c) Tri-angular matrix
 - d) Null matrix
8. If $QP = a$, this type of function has elasticity equal to:
 - a) $E > 1$
 - b) $E < 1$
 - c) $E = 1$
 - d) $E = 0$
9. If $f(x) = (dy/dx) > 0$, then the function is:
 - a) Increasing function
 - b) Decreasing function
 - c) Implicit function
 - d) Explicit function
10. If $d(TC)/dQ = 0$, $d^2(TC)/dQ^2 > 0$, then the cost will be:
 - a) Maximum
 - b) Minimum
 - c) Increasing
 - d) Decreasing



UNIVERSITY OF THE PUNJAB

Fifth Semester – 2019

Examination: B.S. 4 Years Program

Roll No.

PAPER: Mathematical Economics-I
Course Code: ECON-303 Part – II

MAX. TIME: 2 Hrs. 45 Min.
MAX. MARKS: 50

ATTEMPT THIS (SUBJECTIVE) ON THE SEPARATE ANSWER SHEET PROVIDED

Q.2 Write the short answers (4 X 5 = 20)

- (i) Differentiate Singular and Non-singular matrix
- (ii) Differentiate Endogenous variable and Exogenous variable
- (iii) Differentiate Function and Relation.
- (iv) Write down the properties of Matrix Inversion.
- (v) If $Q = 70 - 5P$. Then find the slope of TR (Total Revenue)

Q.3 If $Q_d = 20 - 3p$ $Q_s = -5 + 29$ and $Q_d = Q_s$

- a) Find equilibrium price (p) and equilibrium quantity (Q). (5)
- b) Find Elasticity of demand and elasticity of supply at P and Q (5)

Q.4 a) If slope = 3 and intercept is at (0, 5). Find the equation of straight line.

b) If $Q_d = 20 - 5P$ and $Q_s = 4 + 3P$ (Govt. Imposes 20 % tax on supplier) then find the values of P and Q with and without tax. (4, 6)

Q.5 Use Cramer's Rule to solve the following equations systems:

$$\begin{aligned} 8X_1 - X_2 &= 16 \\ 2X_2 + 5X_3 &= 5 \\ 2X_1 + 3X_3 &= 7 \end{aligned} \quad (10)$$



UNIVERSITY OF THE PUNJAB

B.S. 4 Years Program / Sixth Semester – 2019

Paper: Mathematical Economics II

Course Code: ECON-308 Part – I (Compulsory)

Time: 15 Min. Marks: 10

Roll No. in Fig.

Roll No. in Words.

Signature of Supdt.:

ATTEMPT THIS PAPER ON THIS QUESTION SHEET ONLY.

Division of marks is given in front of each question.

This Paper will be collected back after expiry of time limit mentioned above.

Q.1. Encircle the correct choice.

(1x10=10)

- (i) The reverse process of derivative is called:
(a) Definite integral (b) improper integral
(c) indefinite integral (d) None of these
- (ii) When two limits of integration are identical the value of the definite integral is:
(a) one (b) zero
(c) infinite (d) all of these
- (iii) If the equation is $\frac{dy}{dx} = 2$ then particular integral is:
(a) 2 (b) $2t$
(c) Zero (d) $2t^2$
- (iv) The differential equation of the form: $\frac{dy}{dt} + ty = 3ty^2$ is called:
(a) First order difference equation (b) Second order difference equation
(c) Simultaneous differential equation (d) Bernoulli equation
- (v) The value of $\cos\left(\frac{3\pi}{4}\right)$ is:
(a) $\frac{1}{\sqrt{2}}$ (b) $-\frac{1}{\sqrt{2}}$
(c) $\frac{1}{2}$ (d) $\frac{\sqrt{3}}{2}$
- (vi) The integration of one (1) with respect to x is:
(a) x (b) y
(c) zero (d) constant
- (vii) If the slope of supply and demand curve are same then the time path will be:
(a) Explosive (b) Damed
(c) uniform (d) all of these
- (viii) In Solow Growth model output is function of:
(a) Capital (b) Labor
(c) Land (d) Capital and Labor
- (ix) The relationship between the rate of growth of money wage and the rate of unemployment is:
(a) Positive (b) Negative
(c) Positive & Negative (d) None of these
- (x) Particular integral (y_p) of the equation $y''(t) = -10$ is
(a) $-10t^2$ (b) $-10t$
(c) $-5t$ (d) $-5t^2$



UNIVERSITY OF THE PUNJAB
B.S. 4 Years Program / Sixth Semester – 2019

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Paper: Mathematical Economics II
Course Code: ECON-308 Part – II

Time: 2 Hrs. 45 Min. Marks: 50

ATTEMPT THIS (SUBJECTIVE) ON THE SEPARATE ANSWER SHEET PROVIDED

- Q.2 Write short answers. (5x4=20)
- (i) Solve: $\int \ln x \, dx$
 - (ii) Given the demand function $P_d = 25 - Q^2$ and supply function $P_s = 2Q + 1$. Assuming pure competition find the consumer's surplus.
 - (iii) Define integrating factor.
 - (iv) For second order differential equation $y''(t) + a_1y'(t) + a_2y = 0$. Show that sum of roots is $-a_1$ and product of roots is a_2 .
 - (v) Define Convergence and the Roth theorem.
- Q.3 For a general exact differential equation $Mdy + Ndt = 0$, derive the formula for the general solution of an exact differential equation:
$$\int Mdy + \int Ndt - \int \left(\frac{\partial}{\partial t} \int Mdy \right) dt = 0$$
 10
- Q.4 Find the polar and exponential forms of the following complex numbers:
(a) $\frac{3}{2} + \frac{3\sqrt{3}}{2}i$ (ii) $4(\sqrt{3} + i)$ 5+5=10
- Q.5 Find the general solution of:
 $y_{t+2} + \frac{1}{4}y_t = 5$ 10



UNIVERSITY OF THE PUNJAB

B.S. 4 Years Program : Fifth Semester – Fall 2021

Paper: Advanced Mathematical Economics Course Code: ECON-307-A

Roll No.

Time: 3 Hrs. Marks: 60

Q.1. Answer the following short questions: (6x5=30)

- I. Explain the concept of Maximum Principle.
- II. Find Particular Solution of: $y^{(4)}(t) + 6y'''(t) + 14y''(t) + 16y'(t) + 8y = 2$
- III. Find characteristic roots of: $(r + 4)(r + 4)(r^2 + 2r + 2) = 0$
- IV. Write complementary function of characteristic equation $(r + 4)(r + 4)(r^2 + 2r + 2) = 0$.
- V. Explain the concept of Primal and Dual.
- VI. Explain Two Variable Phase Diagrams.

Answer the following questions. (3x10=30)

- Q. 2. Test convergence of the path of $y_{t+2} - 8y_{t+1} - 2y_t = 10$, using Schur Theorem.
- Q. 3. Using Routh Theorem, find dynamic stability of $y'''(t) + 4y''(t) + 5y'(t) - 2y = -2$
- Q. 4. Write Kuhn Tucker Conditions for numerical, $C = (x_1 - 4)^2 + (x_2 - 4)^2$, $2x_1 + 3x_2 \geq 6$, $-3x_1 - 2x_2 \geq -12$, $x_1, x_2 \geq 0$. Further solution not required.



UNIVERSITY OF THE PUNJAB

B.S. 4 Years Program / Fifth Semester – Spring 2022

Paper: Advanced Mathematical Economics Course Code: ECON-307-A

Roll No.

Time: 3 Hrs. Marks: 60

THE ANSWERS MUST BE ATTEMPTED ON THE ANSWER SHEET PROVIDED

Q.1. Answer the following short questions. (6x5=30)

- I. Find Particular Solution of: $y^{(4)}(t) + 6y'''(t) + 14y''(t) + 16y'(t) + 8y = 2$
- II. Find characteristic roots of: $(r + 2)(r + 2)(r^2 + 2r + 2) = 0$
- III. Write complementary function of characteristic equation $(r + 2)(r + 2)(r^2 + 2r + 2) = 0$.
- IV. Explain Routh Theorem.
- V. Explain the concept of Primal and Dual.
- VI. Explain use of Linear Programming in Economics.

Answer the following questions. (3x10=30)

- Q. 2. Test convergence of the path of $y_{t+2} + 2y_{t+1} + 2y_t = 12$, using Schur Theorem.
- Q. 3. Explain Dynamic Input-output Models with example(s).
- Q. 4. Solve the model: $X_{t+1} + \frac{1}{2}y_{t+1} - \frac{1}{7}y_t = 2$, using Routh Theorem.



UNIVERSITY OF THE PUNJAB

B.S. 4 Years Program / Fifth Semester – Spring 2022

Paper: Advanced Mathematical Economics Course Code: ECON-307-A

Roll No.

Time: 3 Hrs. Marks: 60

THE ANSWERS MUST BE ATTEMPTED ON THE ANSWER SHEET PROVIDED

Q.1. Answer the following short questions. (6x5=30)

- I. Find Particular Solution of: $y^{(4)}(t) + 6y'''(t) + 14y''(t) + 16y'(t) + 8y = 2$
- II. Find characteristic roots of: $(r + 2)(r + 2)(r^2 + 2r + 2) = 0$
- III. Write complementary function of characteristic equation $(r + 2)(r + 2)(r^2 + 2r + 2) = 0$.
- IV. Explain Routh Theorem.
- V. Explain the concept of Primal and Dual.
- VI. Explain use of Linear Programming in Economics.

Answer the following questions. (3x10=30)

- Q. 2. Test convergence of the path of $y_{t+2} + 2y_{t+1} + 2y_t = 12$, using Schur Theorem.
- Q. 3. Explain Dynamic Input-output Models with example(s).
- Q. 4. Solve the model: $X_{t+1} + \frac{1}{2}y_{t+1} - \frac{1}{7}y_t = 2$, using Routh Theorem.



UNIVERSITY OF THE PUNJAB

B.S. 4 Years Program / Sixth Semester – Spring 2022

Paper: Mathematical Economics II

Course Code: ECON-308

Roll No.

Time: 3 Hrs. Marks: 60

THE ANSWERS MUST BE ATTEMPTED ON THE ANSWER SHEET PROVIDED

Q.1. Answer the following short questions. (6x5=30)

- I. Define higher order difference equations.
- II. Solve Bernoulli equation: $\frac{dy}{dt} + \frac{1}{2}y = \frac{1}{2}(t+1)y^3$
- III. Find the general solution: $\frac{dy}{dt} + 3ty = 0$
- IV. Find the roots of the characteristic equation: $2x^2 + x + 10 = 0$
- V. Explain difference between imaginary and complex numbers
- VI. If $MC = 250 + 30Q - 9Q^2$ and $FC = 66$ find total cost function.

Answer the following questions. (3x10=30)

- Q. 2. Solve by using 4-step procedure: $t^2 dy + 3y dt = 0$
- Q. 3. Solve the cobweb model: $Q_{d,t} = 20 - 6P_t$ and $Q_{s,t} = -5 + 6P_{t-1}$
- Q. 4. Solve the model: $X_{t+1} + \frac{1}{2}y_{t+1} - \frac{1}{7}y_t = 2$, using Schur Theorem.