**Module Code & Module Title**

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## Problem 1

Write a procedure, **tax,** to calculate (to the nearest pound) the tax a person owes, depending on his/her income. Calculate the tax using this table:

| **Income Tax rates** | |
|---|---|
| **Tax rate** | **Taxable income** |
| **Basic rate 15%** | £0 to £10,0000 |
| **Higher rate 30%** | £10,0000 to £350,000 |
| **Additional rate 40%** | Over £350,000 |

The procedure should show i) The salary ii) The tax rate iii) The amount of Tax iv) The amount left after tax and v) Be able to deal with any input, valid or not.

**Your tests of your procedure should include the following values, which should be included in your final presentation.**

tax (37000), tax (174530), tax (279000), tax (43550), tax (15330), tax (-130000),

**Solution, Formulae developed to calculate tax**

| Salary | |
|---|---|
| Deduction | |
| Provident Fund | |
| CIT | |
| Life Insurance | |
| Taxable Income | =B1-(B3+B4+B5)+SUM(C6) |

| Tax bracket | | Tax slab | Tax Rate | Tax Amount | Amount left after tax |
|---|---|---|---|---|---|
| 0 | 100,000 | =B9-A9 | 15% | =IF(C9>B6,B6*D9,D9*C9) | =IF(C9>B6,0,B6-C9) |
| 100,000 | 350,000 | =B10-A10 | 30% | =IF(C10>F9,F9*D10,C10*D10) | =IF(C10>F9,0,F9-C10) |
| 350,000 | over | =B11-A11 | 40% | =IF(D11>F10,F10*D11,D11*C11) | |
| | | | Total Tax | =E9+E10+E11 | |
| | | | Monthly Tax | =E12/12 | |

*Figure 1: Procedure to calculate tax.*

Above table shows the formulae used for the calculation of yearly and monthly tax owned by a person according to his/her salary. The salary, provident fund, Life insurance Deduction, CIT represents everything owned by a person. The tax bracket shows the range of the incomes. The tax slab shows the value after deduction of maximum to minimum value from tax bracket. The tax rate shows the rate of tax according to their income range. The tax amount shows the formula for the calculation of tax amount. The formula for tax amount is created by multiplying taxable income * tax rate if tax slab is greater than taxable income otherwise tax slab * tax rate. The formulae for amount left after tax is calculated if tax slab more than taxable income than 0 otherwise taxable income – tax slab. The total tax or yearly tax is calculated by adding all the tax amount obtained from calculations. The monthly tax is calculated by dividing total tax by 12. All the numeric values (B6, C9, F10, C11, etc.) represents the column and row position. Letter denotes column position whereas numbers denotes row position. The above formulae were created in excel sheet and all the tax amount for salary provided are shown below:

1. **At first calculating with Tax (0)**

| | A | B | C | D | E | F |
|---|---|---|---|---|---|---|
| 1 | Salary | 0 | | | | |
| 2 | Deduction | | | | | |
| 3 | Providient Fund | | | | | |
| 4 | CIT | | | | | |
| 5 | Life Insurance | | | | | |
| 6 | Taxable Income | 0 | | | | |
| 7 | | | | | | |
| 8 | Tax bracket | | Tax slab | Tax Rate | Tax Amount | Amount left after tax |
| 9 | 0 | 100,000 | 100,000 | 15% | 0 | 0 |
| 10 | 100,000 | 350,000 | 250,000 | 30% | 0 | 0 |
| 11 | 350,000 | over | 350,000 | 40% | 0 | |
| 12 | | | | Total Tax | 0 | |
| 13 | | | | Monthly Tax | 0 | |

*Figure 2: Calculation with 0 salary*

The above table shows the total tax and monthly tax as 0 because there is not any salary provided.

## 2. Tax (37000)

| | A | B | C | D | E | F |
|---|---|---|---|---|---|---|
| 1 | Salary | 37000 | | | | |
| 2 | Deduction | | | | | |
| 3 | Providient Fund | | | | | |
| 4 | CIT | | | | | |
| 5 | Life Insurance | | | | | |
| 6 | Taxable Income | 37000 | | | | |
| 7 | | | | | | |
| 8 | Tax bracket | | Tax slab | Tax Rate | Tax Amount | Amount left after tax |
| 9 | 0 | 100,000 | 100,000 | 15% | 5550 | 0 |
| 10 | 100,000 | 350,000 | 250,000 | 30% | 0 | 0 |
| 11 | 350,000 | over | 350,000 | 40% | 0 | |
| 12 | | | | Total Tax | 5550 | |
| 13 | | | | Monthly Tax | 462.5 | |

*Figure 3: Calculation for 37000 salary*

The above table shows the salary of 37000 should pay 5550 yearly tax and 462.5 as monthly tax.

### 3. Tax (174530)

| | A | B | C | D | E | F | G |
|---|---|---|---|---|---|---|---|
| 1 | Salary | 174530 | | | | | |
| 2 | Deduction | | | | | | |
| 3 | Providient Fund | | | | | | |
| 4 | CIT | | | | | | |
| 5 | Life Insurance | | | | | | |
| 6 | Taxable Income | 174530 | | | | | |
| 7 | | | | | | | |
| 8 | Tax bracket | | Tax slab | Tax Rate | Tax Amount | Amount left after tax | |
| 9 | 0 | 100,000 | 100,000 | 15% | 15000 | 74530 | |
| 10 | 100,000 | 350,000 | 250,000 | 30% | 22359 | 0 | |
| 11 | 350,000 | over | 350,000 | 40% | 0 | | |
| 12 | | | | Total Tax | 37359 | | |
| 13 | | | | Monthly Tax | 3113.25 | | |
| 14 | | | | | | | |

*Figure 4: Calculation for 174530 salary*

The above table shows the salary of 174530 should pay 37359 yearly tax and 3113.25 as monthly tax.

### 4. Tax (279000)

| | A | B | C | D | E | F |
|---|---|---|---|---|---|---|
| 1 | Salary | 279000 | | | | |
| 2 | Deduction | | | | | |
| 3 | Providient Fund | | | | | |
| 4 | CIT | | | | | |
| 5 | Life Insurance | | | | | |
| 6 | Taxable Income | 279000 | | | | |
| 7 | | | | | | |
| 8 | Tax bracket | | Tax slab | Tax Rate | Tax Amount | Amount left after tax |
| 9 | 0 | 100,000 | 100,000 | 15% | 15000 | 179000 |
| 10 | 100,000 | 350,000 | 250,000 | 30% | 53700 | 0 |
| 11 | 350,000 | over | 350,000 | 40% | 0 | |
| 12 | | | | Total Tax | 68700 | |
| 13 | | | | Monthly Tax | 5725 | |

*Figure 5: Calculation for 279000 salary*

The above table shows the salary of 279000 should pay 68700 yearly tax and 5725 as monthly tax.

## 5. Tax (43550)

| | A | B | C | D | E | F | G |
|---|---|---|---|---|---|---|---|
| 1 | Salary | 43550 | | | | | |
| 2 | Deduction | | | | | | |
| 3 | Providient Fund | | | | | | |
| 4 | CIT | | | | | | |
| 5 | Life Insurance | | | | | | |
| 6 | Taxable Income | 43550 | | | | | |
| 7 | | | | | | | |
| 8 | Tax bracket | | Tax slab | Tax Rate | Tax Amount | Amount left after tax | |
| 9 | 0 | 100,000 | 100,000 | 15% | 6532.5 | 0 | |
| 10 | 100,000 | 350,000 | 250,000 | 30% | 0 | 0 | |
| 11 | 350,000 | over | 350,000 | 40% | 0 | | |
| 12 | | | | Total Tax | 6532.5 | | |
| 13 | | | | Monthly Tax | 544.375 | | |
| 14 | | | | | | | |

*Figure 6: Calculation for 43550 salary*

The above table shows the salary of 43550 should pay 6532.5 yearly tax and 544.375 as monthly tax.

## 6. Tax (15330)

| | A | B | C | D | E | F | G |
|---|---|---|---|---|---|---|---|
| 1 | Salary | 15330 | | | | | |
| 2 | Deduction | | | | | | |
| 3 | Providient Fund | | | | | | |
| 4 | CIT | | | | | | |
| 5 | Life Insurance | | | | | | |
| 6 | Taxable Income | 15330 | | | | | |
| 7 | | | | | | | |
| 8 | Tax bracket | | Tax slab | Tax Rate | Tax Amount | Amount left after tax | |
| 9 | 0 | 100,000 | 100,000 | 15% | 2299.5 | 0 | |
| 10 | 100,000 | 350,000 | 250,000 | 30% | 0 | 0 | |
| 11 | 350,000 | over | 350,000 | 40% | 0 | | |
| 12 | | | | Total Tax | 2299.5 | | |
| 13 | | | | Monthly Tax | 191.625 | | |

*Figure 7: Calculation for 15330*

The above table shows the salary of 15330 should pay 2299.5 yearly tax and 191.625 as monthly tax.

**7. Tax (-130000)**

| | A | B | C | D | E | F |
|---|---|---|---|---|---|---|
| 1 | Salary | -130000 | | | | |
| 2 | Deduction | | | | | |
| 3 | Providient Fund | | | | | |
| 4 | CIT | | | | | |
| 5 | Life Insurance | | | | | |
| 6 | Taxable Income | -130000 | | | | |
| 7 | | | | | | |
| 8 | Tax bracket | | Tax slab | Tax Rate | Tax Amount | Amount left after tax |
| 9 | 0 | 100,000 | 100,000 | 15% | -19500 | 0 |
| 10 | 100,000 | 350,000 | 250,000 | 30% | 0 | 0 |
| 11 | 350,000 | over | 350,000 | 40% | 0 | |
| 12 | | | | Total Tax | -19500 | |
| 13 | | | | Monthly Tax | | |
| 14 | | | | | | |
| 15 | | | | | | |
| 16 | | | | | | |
| 17 | | | | | | |

**error**
Salary cannot be negative

*Figure 8: Calculation for -130000*

The above table shows error because the value of salary is less than 0. The salary of a person cannot be negative, so the error message is displayed while validation.

# Problem 2

## Part A

Jack and Bro's company ltd. makes three types of decorative lamps; Model A, model B and model C. The raw material requirement for all lamps is the same, but the cost of production differs due to different labor requirements. Each model A lamp requires 0.1 hour of assembly time, 0.2 hour of wiring time and 0.1 hour of packaging time. Model B lamp requires 0.2 hour of assembly time, 0.3 hour of wiring time and 0.1 hour of packaging time. Model C lamp requires 0.3 hour of assembly time, 0.4 hour of wiring time and 0.1 hour of packaging time. The Company makes a profit of £120 on each model A lamp , £190 on each model B lamp and £210 on each model C lamp .The company can schedule up to 80 hours of assembly labor ,120 hours of wiring labor and 100 hours of packaging labor.

**Questions**

You should answer the following questions and incorporate your answers into a word-processed report to form part of your final pdf. The sections of your report should correspond to the individual questions following.

a) Formulate the problem as a linear programming model, clearly defining the variables, the objective function and the constraints.

b) Solve the problem using Simplex method and find the optimum quantity of each model so that the company can make maximum profit.

c) Solve the problem using the Excel Solver and interpret the results.

d) For the final part of your report, in your capacity as an Adviser, you should present a memorandum to the Jack and Bro's company. Describe your main conclusions in simple, non-technical English; i.e. do not use technical terms like variable, objective function or dual price. Don't worry about repeating some or all the points that you have already made in answer to earlier questions. The aim is to communicate your conclusions clearly to someone who is knowledgeable about the combination of products to maximize the profit, but who knows nothing about the subject of linear programming. You may use tables and charts if you wish.

**A. Formulating the problem as linear programming model.**

**Solution,**

The above question has asked to find optimum quantity of each model A, B, and C. So, that the company can make maximum profit.

<u>For Decision Variable</u>

Let $X_1$, $X_2$ and $X_3$ be the quantity of model A, model B and Model C respectively of decoration lamps that Jack and Bro's Makes.

<u>For Objective Function</u>

Total Profit = $120X_1 + 190X_2 + 210X_3$

Let Total profit = Z

$Z_{max} = 120X_1 + 190X_2 + 210X_3$

<u>For constraints</u>

$0.1X_1 + 0.2X_2 + 0.3X_3 <= 80$ [Assembly time constraints]

$0.2X_1 + 0.3X_2 + 0.4X_3 <= 120$ [wiring time constraints]

$0.1x_1 + 0.1X_2 + 0.1X_3 <= 100$ [packaging time constraints]

$X_1, X_2, X_3 >= 0$ [default/nonnegative constraints]

Let $S_1$, $S_2$ and $S_3$ be the stack variable

$0.1X_1 + 0.2X_2 + 0.3X_3 + S_1 = 80$

$0.2X_1 + 0.3X_2 + 0.4X_3+S_2 = 20$

$0.1X_1 + 0.1X_2 + 0.1X_3 + S_3 = 100$

Standard equation for revised simplex

$Z - 120X_1 - 190X_2 - 210X_3 + 0*S_1 + 0*S_2 + 0*S_3 = 0$

$0*Z + 0.1X_1 + 0.2X_2 + 0.3X_3 + S_1 + 0*S_2 + 0*S_3 = 80$

$0*Z + 0.2X_1 + 0.3X_2 + 0. 4X_3 + 0*S_1 + S_2 + 0*S_3 =120$

$0*Z + 0.1X_1 + 0.1X_2 + 0.1X_3 + 0*S_1 +0*S_2 + 0*S_3 =100$

**B. Solving problem with simplex method**

**Solution,**

For Decision Variable

Let $X_1$, $X_2$ and $X_3$ be the quantity of model A, model B and Model C respectively of decoration lamps that Jack and Bro's Makes.

For Objective Function

Total Profit = $120x_1 + 190x_2 + 210x_3$

Let Total profit = Z

$Z_{max} = 120X_1 +190X_2 + 210X_3$

<u>For constraints</u>

$0.1X_1 + 0.2X_2 + 0.3X_3 <= 80$ [Assembly time constraints]

$0.2X_1 + 0.3X_2 + 0.4X_3 <= 120$ [wiring time constraints]

$0.1x_1 + 0.1X_2 + 0.1X_3 <= 100$ [packaging time constraints]

$X_1, X_2, X_3 >= 0$[default/non negative constraints]

Let $S_1$, $S_2$ and $S_3$ be the stack variable

$0.1X_1 + 0.2X_2 + 0.3X_3 + S_1 = 80$

$0.2X_1 + 0.3X_2 + 0.4X_3 + S_2 = 20$

$0.1X_1 + 0.1X_2 + 0.1X_3 + S_3 = 100$

Standard equation for revised simplex

$Z - 120X_1 - 190X_2 - 210X_3 + 0*S_1 + 0*S_2 + 0*S_3 = 0$

$0*Z + 0.1X_1 + 0.2X_2 + 0.3X_3 + S_1 + 0*S_2 + 0*S_3 = 80$

$0*Z + 0.2X_1 + 0.3X_2 + 0. 4X_3 + 0*S_1 + S_2 + 0*S_3 =120$

$0*Z + 0.1X_1 + 0.1X_2 + 0.1X_3 + 0*S_1 +0*S_2 + 0*S_3 =100$

**Revised simplex table I**

| R | Z | $X_1$ | $X_2$ | $X_3$ | $S_1$ | $S_2$ | $S_3$ | constraints | Common ratio |
|---|---|---|---|---|---|---|---|---|---|
| R0 | 1 | -120 | -190 | -210 | 0 | 0 | 0 | 0 | ~ |
| R1 | 0 | 0.1 | 0.2 | 0.3 | 1 | 0 | 0 | 80 | 80/0.3=800/3 |
| R2 | 0 | 0.2 | 0.3 | 0.4 | 0 | 1 | 0 | 120 | 120/0.4=300 |
| R3 | 0 | 0.1 | 0.1 | 0.1 | 0 | 0 | 1 | 100 | 100/0.1=1000 |

R1=key row

$X_3$=key column

Therefore, key element =0.3

**Now, New R1= old R1/0.3**

$Z = 0/0.3 = 0$, $X_1 = 0.1/0.3 = 1/3$, $X_2 = 0.2/0.3 = 2/3$, $X_3 = 0.3/0.3 = 1$, $S_1 = 1/0.3 = 10/3$,

$S_2 = 0/0.3 = 0$, $S_3 = 0/0.3 = 0$, Constraints = 80/0.3 = 800/3.

| R | Z | $X_1$ | $X_2$ | $X_3$ | $S_1$ | $S_2$ | $S_3$ | constraints |
|---|---|---|---|---|---|---|---|---|
| R1 | 0 | 1/3 | 2/3 | 1 | 10/3 | 0 | 0 | 800/3 |

**New R0= old R0-(-210) *New R1**

Z = 1+210 *0 = 1, $X_1$ = -120+210*1/3 = -50, $X_2$ = -190+210*2/3 = -50, $X_3$ = -210+210*1 = 0, $S_1$ = 0+210*10/3 = 700, $S_2$ = 0+210*0 = 0, $S_3$ = 0+210*0 = 0, Constraints = 0+210*800/3 = 56000.

| R | Z | $X_1$ | $X_2$ | $X_3$ | $S_1$ | $S_2$ | $S_3$ | constraints |
|---|---|---|---|---|---|---|---|---|
| R0 | 1 | -50 | -50 | 0 | 700 | 0 | 0 | 56000 |

**New R2= old R2-(0.4) *New R1**

Z = 0-0.4*0 = 0, $X_1$ = 0.2-0.4*1/3 = 1/15, $X_2$ = 0.3-0.4*2/3 = 1/30, $X_3$ = 0.4-0.4*1 = 0, $S_1$ = 0-0.4*10/3 = -4/3, $S_2$ = 1-0.4*0 = 1, $S_3$ = 0-0.4*0 = 0, Constraints = 120-0.4*800/3 = 40/3.

| R | Z | $X_1$ | $X_2$ | $X_3$ | $S_1$ | $S_2$ | $S_3$ | constraints |
|---|---|---|---|---|---|---|---|---|
| R2 | 0 | 1/15 | 1\30 | 0 | -4/3 | 1 | 0 | 40/3 |

**New R3= old R3-(0.1) *New R1**

Z = 0-0.1*0 = 0, $X_1$ = 0.1-0.1*1\3 = 1/15, $X_2$ = 0.1-0.1*2/3 = 1/30, $X_3$ = 0.1-0.1*1 = 0, $S_1$ = 0-0.1*10/3 = -1/3, $S_2$ = 0-0.1*0 = 0, $S_3$ = 1-0.1*0 = 1, Constraints = 100-0.1*800/3 = 220/3.

| R | Z | $X_1$ | $X_2$ | $X_3$ | $S_1$ | $S_2$ | $S_3$ | constraints |
|---|---|---|---|---|---|---|---|---|
| R3 | 0 | 1/15 | 1\30 | 0 | -1/3 | 0 | 1 | 220/3 |

**Revised simplex Table II**

| R | Z | $X_1$ | $X_2$ | $X_3$ | $S_1$ | $S_2$ | $S_3$ | constraints | Common ratio |
|---|---|---|---|---|---|---|---|---|---|
| R0 | 1 | -50 | -50 | 0 | 700 | 0 | 0 | 56000 | ~ |
| R1 | 0 | 1\3 | 2/3 | 1 | 10/3 | 0 | 0 | 800/3 | 800/3*3/1=800 |
| R2 | 0 | 1\15 | 1/30 | 0 | -4/3 | 1 | 0 | 40/3 | 40/3*15/1=200 |
| R3 | 0 | 1\15 | 1/30 | 0 | -1/3 | 0 | 1 | 220/3 | 220/3*15/1=1100 |

Key row=R2

Key column=$X_1$

Therefore, key element =1/15

Again**, New R2= 0ld R2 / (1/15)**

Z = 0/1/15 = 0, $X_1$ = 1/15/1/15 = 1, $X_2$ = 1/30/1/15 = 1/2, $X_3$ = 0/1/15 = 0, $S_1$ = -4/3/1/15 = -20, $S_2$ = 1/1/15 = 15, $S_3$ = 0/1/15 = 0, Constraints = 40/3/1/15 = 200.

| R | Z | $X_1$ | $X_2$ | $X_3$ | $S_1$ | $S_2$ | $S_3$ | constraints |
|---|---|---|---|---|---|---|---|---|
| R2 | 0 | 1 | 1\2 | 0 | -20 | 15 | 0 | 200 |

**New R0= old R0-(-50) *New R2**

Z = 1+50*0 = 1, $X_1$ = -50+50*1 = 0, $X_2$ = -50+50*1/2 = -25, $X_3$ = 0+50*0 = 0, $S_1$ = 700+50*(-20) = -300, $S_2$ = 0+50*15 = 750, $S_3$ = 0+10*0 = 0, Constraints = 56000+50*200 = 66000.

| R | Z | $X_1$ | $X_2$ | $X_3$ | $S_1$ | $S_2$ | $S_3$ | constraints |
|---|---|---|---|---|---|---|---|---|
| R0 | 1 | 0 | -25 | 0 | -300 | 750 | 0 | 66000 |

**New R1= old R1-(1/3) *New R2**

Z = 0-1/3*0 = 0, $X_1$ = 1/3-1/3*1 = 0, $X_2$ = 2/3-1/3*1/2 = 1/2, $X_3$ = 1-1/3*0 = 1, $S_1$ = 10/3-1/3*(-20) = 10, $S_2$ = 0-1/3*15 = -5, $S_3$ = 0-1/3*0 = 0, Constraints = 800/3-1/3*200 = 200.

| R | Z | $X_1$ | $X_2$ | $X_3$ | $S_1$ | $S_2$ | $S_3$ | constraints |
|---|---|---|---|---|---|---|---|---|
| R1 | 0 | 0 | 1/2 | 1 | 10 | -5 | 0 | 200 |

**New R3= Old R3-(1/15) *New R2**

Z = 0-1/15*0 =0, $X_1$ = 1/15-1/15*1 = 0, $X_2$ = 1/30-1/15*1/2 = 0, $X_3$ = 0-1/15*0 = 0, $S_1$ = -1/3-1/15*(-20) = 1, $S_2$ = 0-1/15*15 = -1, $S_3$ = 1-1/15*0 = 1, Constraints = 220/3-1/15*200 = 60.

| R | Z | $X_1$ | $X_2$ | $X_3$ | $S_1$ | $S_2$ | $S_3$ | constraints |
|---|---|---|---|---|---|---|---|---|
| R3 | 0 | 0 | 0 | 0 | 1 | -1 | 1 | 60 |

**Revised simplex table III**

| R | Z | $X_1$ | $X_2$ | $X_3$ | $S_1$ | $S_2$ | $S_3$ | constraints | Common ratio |
|---|---|---|---|---|---|---|---|---|---|
| R0 | 1 | 0 | -25 | 0 | -300 | 750 | 0 | 66000 | ~ |
| R1 | 0 | 0 | 1/2 | 1 | 10 | -5 | 0 | 200 | 200/10=20 |
| R2 | 0 | 1 | 1/2 | 0 | -20 | 15 | 0 | 200 | 200/-20= -10 |
| R3 | 0 | 0 | 0 | 0 | 1 | -1 | 1 | 60 | 60/1=60 |

Key row =R1 and

key column= $S_1$

Therefore, key element=10

Again**, New R1=Old R1/10**

$Z = 0/10 = 0$, $X_1 = 0/10 = 0$, $X_2 = 1/2/10 = 1/20$, $X_3 = 1/10 = 1/10$, $S_1 = 10/10 = 1$, $S_2 = -5/10 = -1/2$, $S_3 = 0/10 = 0$, Constraints = 200/10 = 20.

| R | Z | $X_1$ | $X_2$ | $X_3$ | $S_1$ | $S_2$ | $S_3$ | constraints |
|---|---|---|---|---|---|---|---|---|
| R1 | 0 | 0 | 1/20 | 1/10 | 1 | -1/2 | 0 | 20 |

**New R0=Old R0-(-300) * New R1**

Z = 1+300*0 = 1, $X_1$ = 0+300*0 = 0, $X_2$ = -25+300*1/20 = -10, $X_3$ = 0+300*1/10 = 30, $S_1$ = -300+300*1 = 0, $S_2$ = 750+300*(-1/2) = 600, $S_3$ = 0+300*0 = 0, Constraints = 66000+300*20 = 72000.

| R | Z | $X_1$ | $X_2$ | $X_3$ | $S_1$ | $S_2$ | $S_3$ | constraints |
|---|---|---|---|---|---|---|---|---|
| R0 | 1 | 0 | -10 | 30 | 0 | 600 | 0 | 72000 |

**New R2=Old R2-(-20) * New R1**

Z = 0+20*0 = 0, $X_1$ = 1+20*0 = 1, $X_2$ = 1/2+20*1/20 = 3/2, $X_3$ = 0+20*1/10 = 2, $S_1$ = -20+20*1 = 0, $S_2$ = 15+20*(-1/2) = 5, $S_3$ = 0+20*0 = 0, Constraints = 200+20*20 = 600.

| R | Z | $X_1$ | $X_2$ | $X_3$ | $S_1$ | $S_2$ | $S_3$ | constraints |
|---|---|---|---|---|---|---|---|---|
| R2 | 0 | 1 | 3/2 | 2 | 0 | 5 | 0 | 600 |

**New R3=Old R3-New R1**

Z = 0-0 = 0, $X_1$ = 0-0 = 0, $X_2$ = 0-1/20 = -1/20, $X_3$ = 0-1/10 = -1/10, $S_1$ = 1-1 = 0, $S_2$ = -1+1/2 = -1/2, $S_3$ = 1-0 = 1, Constraints = 60-20 = 40.

| R | Z | $X_1$ | $X_2$ | $X_3$ | $S_1$ | $S_2$ | $S_3$ | constraints |
|---|---|---|---|---|---|---|---|---|
| R3 | 0 | 0 | -1/20 | -1/10 | 0 | -1/2 | 1 | 40 |

**Revised simplex table IV**

| R | Z | $X_1$ | $X_2$ | $X_3$ | $S_1$ | $S_2$ | $S_3$ | Constraints | Common ratio |
|---|---|---|---|---|---|---|---|---|---|
| R0 | 1 | 0 | -10 | 30 | 0 | 600 | 0 | 72000 | ~ |
| R1 | 0 | 0 | 1/20 | 1/10 | 1 | -1/2 | 0 | 20 | 20/1/20=400 |
| R2 | 0 | 1 | 3/2 | 2 | 0 | 5 | 0 | 600 | 600/3/2=400 |
| R3 | 0 | 0 | -1/20 | -1/10 | 0 | -1/2 | 1 | 40 | 40/(-1/20)= -800 |

Key row =R1 and

key column =$X_2$

Therefore, Key element=1/20

Again**, New R1=Old R1/(1/20)**

Z = 0/1/20 = 0, $X_1$ = 0/1/20 = 0, $X_2$ = 1/20/1/20 = 1, $X_3$ = 1/10/1/20 = 2, $S_1$ = 1/1/20 = 20, $S_2$ = -1/2/1/20 = -10, $S_3$ = 0/1/20 = 0, Constraints = 20/1/20 = 400.

| R | Z | $X_1$ | $X_2$ | $X_3$ | $S_1$ | $S_2$ | $S_3$ | constraints |
|---|---|---|---|---|---|---|---|---|
| R1 | 0 | 0 | 1 | 2 | 20 | -10 | 0 | 400 |

**New R0=Old R0-(-10)*New R1**

Z = 1+10*0 = 1, $X_1$ = 0+10*0 = 0, $X_2$ = -10+10*1 = 0, $X_3$ = 30+10*2 = 50, $S_1$ = 0+10*20 = 200, $S_2$ = 600+10*-10 = 500, $S_3$ = 0+10*0 = 0, Constraints = 72000+10*400 = 76000.

| R | Z | $X_1$ | $X_2$ | $X_3$ | $S_1$ | $S_2$ | $S_3$ | constraints |
|---|---|---|---|---|---|---|---|---|
| R0 | 1 | 0 | 0 | 50 | 200 | 500 | 0 | 76000 |

**New R2=Old R2-(3/2) *New R1**

Z = 0-3/2*0 = 0, $X_1$ = 1-3/2*0 = 1, $X_2$ = 3/3-3/2*1 = 0, $X_3$ = 2-3/2*2 = -1, $S_1$ = 0-3/2*20 = -30, $S_2$ = 5-3/2*(-10) = 20, $S_3$ = 0-3/2*0 = 0, Constraints = 600-3/2*400 = 0.

| R | Z | $X_1$ | $X_2$ | $X_3$ | $S_1$ | $S_2$ | $S_3$ | constraints |
|---|---|---|---|---|---|---|---|---|
| R2 | 0 | 1 | 0 | -1 | -30 | 20 | 0 | 0 |

**New R3=Old R3-(-1/20) * New R1**

Z = 0+1/20*0 = 0, $X_1$ = 0+1/20*0 = 0, $X_2$ = -1/20+1/20*1 = 0, $X_3$ = -1/10+1/20*2 = 0, $S_1$ = 0+1/20*20 = 1, $S_2$ = -1/2+1/20*(-10) = -1, $S_3$ = 1+1/20*0 = 1, Constraints = 40+1/20*400 = 60.

| R | Z | $X_1$ | $X_2$ | $X_3$ | $S_1$ | $S_2$ | $S_3$ | constraints |
|---|---|---|---|---|---|---|---|---|
| R3 | 0 | 0 | 0 | 0 | 1 | -1 | 1 | 60 |

**Revised simplex table V**

| R | Z | $X_1$ | $X_2$ | $X_3$ | $S_1$ | $S_2$ | $S_3$ | constraints |
|---|---|---|---|---|---|---|---|---|
| R0 | 1 | 0 | 0 | 50 | 200 | 500 | 0 | 76000 |
| R1 | 0 | 0 | 1 | 2 | 20 | -10 | 0 | 400 |
| R2 | 0 | 1 | 0 | -1 | -30 | 20 | 0 | 0 |
| R3 | 0 | 0 | 0 | 0 | 1 | -1 | 1 | 60 |

From above table, we have

Total profit $Z_{max}$ = **76000**

Model A ($X_1$) = **0**

Model B ($X_2$) = **400**

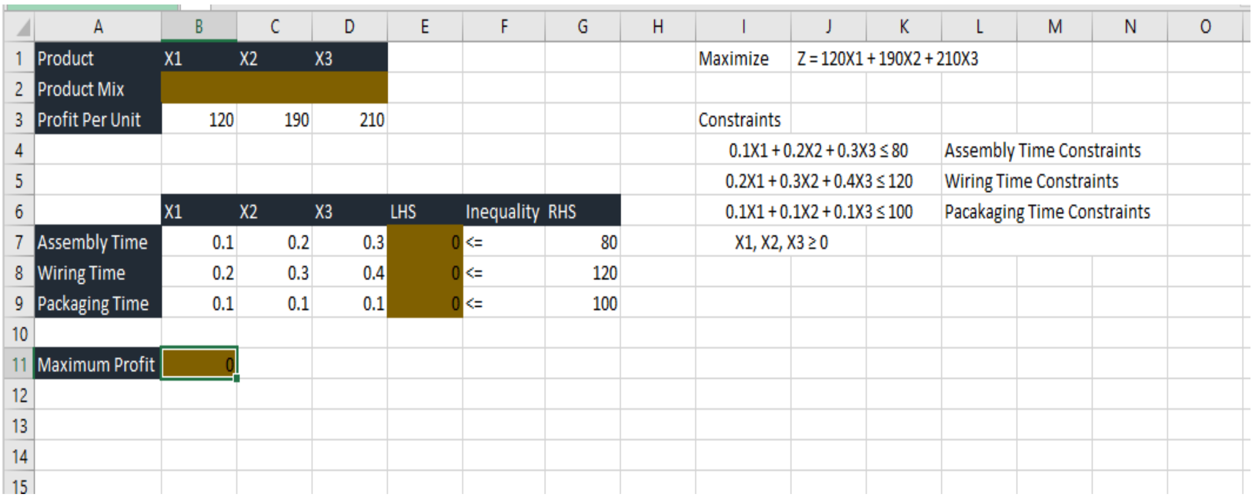
Model C ($X_3$) = **0**

Therefore, the value of $Z_{max}$ is **76000** at $X_1$ =**0**, $X_2$ = **400** and $X_3$ = **0**.

## C. Solving the problem using excel solver method

Solution,

The above simplex problem can also be solved using excel solver. The above simplex method is solved using excel solver which is shown below:



| | A | B | C | D | E | F | G | H | I | J | K | L |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Product | X1 | X2 | X3 | | | | | Maximize | Z = 120X1 + 190X2 + 210X3 | | |
| 2 | Product Mix | | | | | | | | | | | |
| 3 | Profit Per Unit | 120 | 190 | 210 | | | | | Constraints | | | |
| 4 | | | | | | | | | 0.1X1 + 0.2X2 + 0.3X3 ≤ 80 | | | Assembly Time Constraints |
| 5 | | | | | | | | | 0.2X1 + 0.3X2 + 0.4X3 ≤ 120 | | | Wiring Time Constraints |
| 6 | | X1 | X2 | X3 | LHS | Inequality | RHS | | 0.1X1 + 0.1X2 + 0.1X3 ≤ 100 | | | Pacakaging Time Constraints |
| 7 | Assembly Time | 0.1 | 0.2 | 0.3 | 0 | <= | 80 | | X1, X2, X3 ≥ 0 | | | |
| 8 | Wiring Time | 0.2 | 0.3 | 0.4 | 0 | <= | 120 | | | | | |
| 9 | Packaging Time | 0.1 | 0.1 | 0.1 | 0 | <= | 100 | | | | | |
| 10 | | | | | | | | | | | | |
| 11 | Maximum Profit | 0 | | | | | | | | | | |

*Figure 9: Using excel solver for simplex*

In the above figure the decision variable are X1, X2, and X3. RHS shows constraints values.

**Procedure for calculation**

| Product | X1 | X2 | X3 |
|---|---|---|---|
| Product Mix | | | |
| Profit Per Unit | 120 | 190 | 210 |

| | X1 | X2 | X3 | LHS | Inequality | RHS |
|---|---|---|---|---|---|---|
| Assembly Time | 0.1 | 0.2 | 0.3 | =SUMPRODUCT(B7:D7,B2:D2) | <= | 80 |
| Wiring Time | 0.2 | 0.3 | 0.4 | =SUMPRODUCT(B8:D8,B2:D2) | <= | 120 |
| Packaging Time | 0.1 | 0.1 | 0.1 | =SUMPRODUCT(B9:D9,B2:D2) | <= | 100 |

| | |
|---|---|
| Maximum Profit | =SUMPRODUCT(B3:D3,B2:D2) |

*Figure 10: Procedure for calculation with excel solver*

The formula used to solve the simplex linear programming problem using excel solver is shown in the table above. The alphabetical letter represents the column whereas the numeric value represents the row. The LHS is calculated by multiplying the time taken from model A with product mix value and adding it with the multiplication of time taken by other model B with product mix value also adding it with the multiplication of time taken by other model C with product mix value. The maximum profit is calculated by multiplying profit per unit of model A with product mix value and adding it with the multiplication of profit per unit of model B with product mix value also adding with the multiplication of profit per unit of model C with product mix value. In, this way the calculation was done using excel solver.

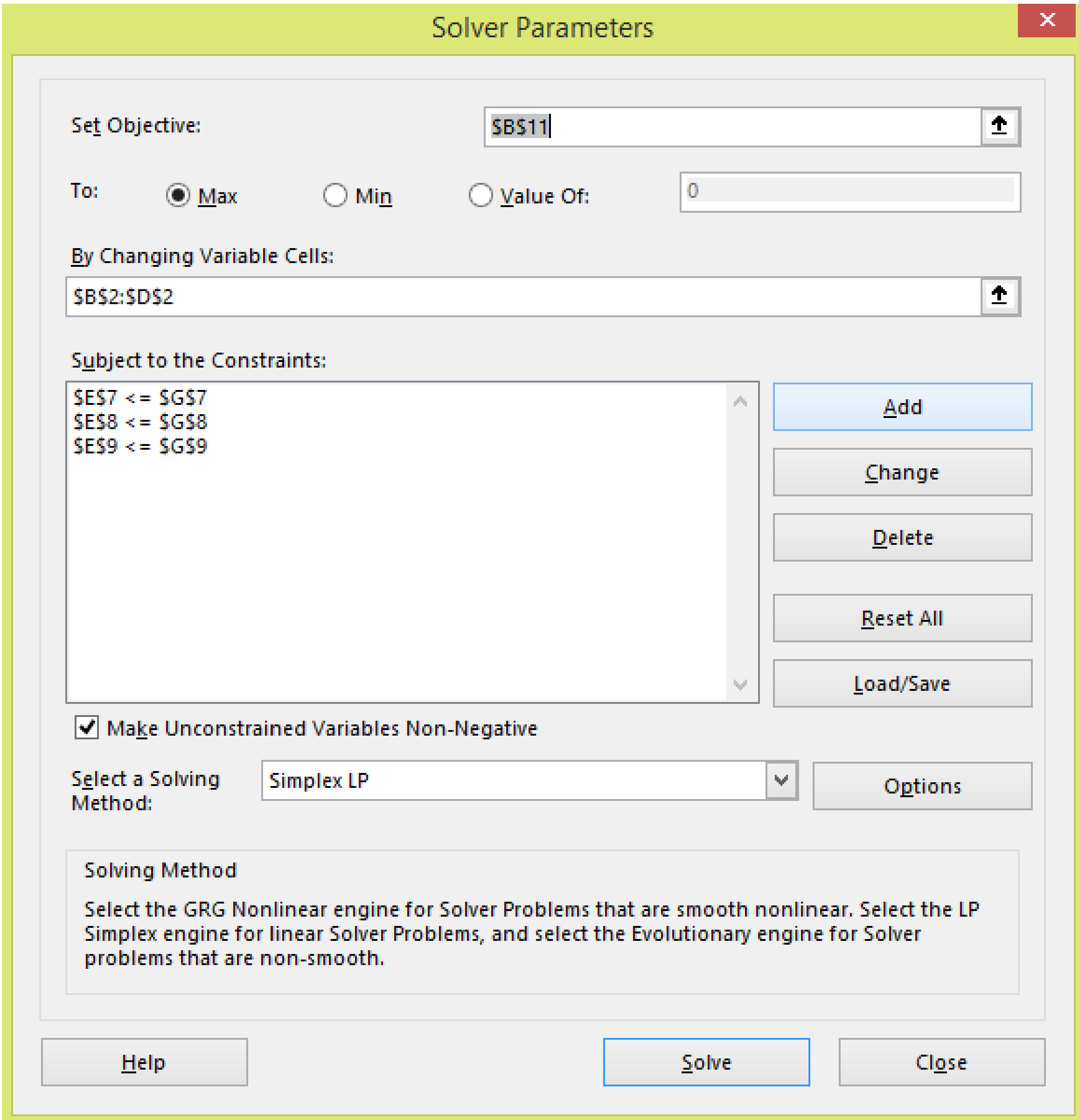



*Figure 11: Adding parameters in excel solver*

The above figures show the selected objective function also selecting maximum to find maximum profit according to question. Constraints values are added, and the problem is selected to be solve through simples linear programming as asked by the question. At last after adding all the values to be added the solve button is clicked to solve the problem using excel solver.

| | A | B | C | D | E | F | G | H | I | J | K | L | M | N |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Product | X1 | X2 | X3 | | | | | Maximize | $Z = 120X1 + 190X2 + 210X3$ | | | | |
| 2 | Product Mix | 0 | 400 | 0 | | | | | | | | | | |
| 3 | Profit Per Unit | 120 | 190 | 210 | | | | | Constraints | | | | | |
| 4 | | | | | | | | | $0.1X1 + 0.2X2 + 0.3X3 \le 80$ | | | Assembly Time Constraints | | |
| 5 | | | | | | | | | $0.2X1 + 0.3X2 + 0.4X3 \le 120$ | | | Wiring Time Constraints | | |
| 6 | | X1 | X2 | X3 | LHS | Inequality | RHS | | $0.1X1 + 0.1X2 + 0.1X3 \le 100$ | | | Pacakaging Time Constraints | | |
| 7 | Assembly Time | 0.1 | 0.2 | 0.3 | 80 | <= | 80 | | $X1, X2, X3 \ge 0$ | | | | | |
| 8 | Wiring Time | 0.2 | 0.3 | 0.4 | 120 | <= | 120 | | | | | | | |
| 9 | Packaging Time | 0.1 | 0.1 | 0.1 | 40 | <= | 100 | | | | | | | |
| 10 | | | | | | | | | | | | | | |
| 11 | Maximum Profit | 76000 | | | | | | | | | | | | |

*Figure 12: Maximum profit value through excel solver*

After solving the value obtained in maximum profit is similar to the value obtained solving from simplex method. The maximum profit obtained is 76000.

The excel solver also shows the answer report, sensitivity report and limit report which are shown below:

## Answer Report

**Microsoft Excel 16.0 Answer Report**
**Worksheet: [excel solver.xlsx]Sheet1**
**Report Created: 8/19/2019 7:06:02 AM**
**Result: Solver found a solution.  All Constraints and optimality conditions are satisfied.**
**Solver Engine**
Engine: Simplex LP
Solution Time: 0.031 Seconds.
Iterations: 4 Subproblems: 0
**Solver Options**
Max Time Unlimited,  Iterations Unlimited, Precision 0.000001, Use Automatic Scaling
Max Subproblems Unlimited, Max Integer Sols Unlimited, Integer Tolerance 1%, Assume NonNegative

Objective Cell (Max)

| Cell | Name | Original Value | Final Value |
|---|---|---|---|
| $B$1: | Maximum Profit X1 | 0 | 76000 |

Variable Cells

| Cell | Name | Original Value | Final Value | Integer |
|---|---|---|---|---|
| $B$2 | Product Mix X1 | 0 | 9.09495E-13 | Contin |
| $C$2 | Product Mix X2 | 0 | 400 | Contin |
| $D$2 | Product Mix X3 | 0 | 0 | Contin |

Constraints

| Cell | Name | Cell Value | Formula | Status | Slack |
|---|---|---|---|---|---|
| $E$7 | Assembly Time LHS | 80 | $E$7<=$G$7 | Binding | 0 |
| $E$8 | Wiring Time LHS | 120 | $E$8<=$G$8 | Binding | 0 |
| $E$9 | Packaging Time LHS | 40 | $E$9<=$G$9 | Not Binding | 60 |

*Figure 13: Answer report of excel solver solution*

Sensitivity Report

**Microsoft Excel 16.0 Sensitivity Report**
**Worksheet: [excel solver answersheet.xlsx]Sheet1**
**Report Created: 8/19/2019 7:08:51 AM**

Variable Cells

| Cell | Name | Final Value | Reduced Cost | Objective Coefficient | Allowable Increase | Allowable Decrease |
|---|---|---|---|---|---|---|
| $B$2 | Product Mix X1 | 9.09495E-13 | 0 | 120 | 6.666666667 | 25 |
| $C$2 | Product Mix X2 | 400 | 0 | 190 | 50 | 10 |
| $D$2 | Product Mix X3 | 0 | -50 | 210 | 50 | 1E+30 |

Constraints

| Cell | Name | Final Value | Shadow Price | Constraint R.H. Side | Allowable Increase | Allowable Decrease |
|---|---|---|---|---|---|---|
| $E$7 | Assembly Time LHS | 80 | 200 | 80 | 3.03165E-14 | 20 |
| $E$8 | Wiring Time LHS | 120 | 500 | 120 | 40 | 4.54747E-14 |
| $E$9 | Packaging Time LHS | 40 | 0 | 100 | 1E+30 | 60 |

*Figure 14: Sensitivity report for excel solver solution*

Limit Report

**Microsoft Excel 16.0 Limits Report**
**Worksheet: [excel solver answersheet.xlsx]Sheet1**
**Report Created: 8/19/2019 7:08:51 AM**

| Cell | Objective Name | Value |
|---|---|---|
| $B$11 | Maximum Profit X1 | 76000 |

| Cell | Variable Name | Value | Lower Limit | Objective Result | Upper Limit | Objective Result |
|---|---|---|---|---|---|---|
| $B$2 | Product Mix X1 | 9.09495E-13 | 0 | 76000 | 7.81597E-13 | 76000 |
| $C$2 | Product Mix X2 | 400 | 0 | 1.09139E-10 | 400 | 76000 |
| $D$2 | Product Mix X3 | 0 | 0 | 76000 | 4.73695E-14 | 76000 |

*Figure 15: Limit report for excel solver solution*

## D. Memorandum to Jack and Bro’s Company

Date: August 14, 2019

To: Jack and Bro’s company ltd.

From: Archit Thapa, Mamta Chauhan, Girija Tamang

Subject: to maximize the profit special lamps should be produced and labor cost should be decreased.

Respected Managing Director,

After studying the company, we knew that the requirement for raw materials for all model lamps is the same, but manufacturing costs vary because of distinct labor demands. The company earns profit £ 120, £ 190, £ 210 respectively per model A lamp, B lamp and C lamp. Knowing that the enterprise can plan up to 80 hours of installation work, 120 hours of cabling and 100 hours of packaging. We can earn more profit than previous if we produce special combination of lamps which helps in decreasing the cost of labor.

After the deep research we came to know that Jack and Bro’s company is facing problem on labor cost. Due to this company is bearing a limited profit. For maximizing this profit this company should produce an excellent lamp which consume less labor and produce more lamps. To reduce labor cost, company should provide different kinds of facilities to labor which helps them to focus in their work also helps in producing excellent products of lamps.

We all want to thank Jack and Bro’s company ltd. for giving chance to do research and give our feedbacks. If we reduce the cost of labor and problem of labor requirement this company gone make the profit of 76000 per production of lamps. So, provide different facilities to workers and treat the them in good manner which helps to solve the problem and earn maximum profit.

Looking forward to hearing you again!! Thank you.

## Part B

A factory uses three different resources for the manufacture of two different products, 20 units of resource A, 12 units of resource B and 16 units of C being available. One unit of first product requires 2, 2 and 4 units of the respective resources and 1 unit of the second product requires 4, 2 and 0 units of the respective resources. It is known that the first product gives a profit of £ 20 per unit and the second £30 per unit. Formulate the linear programming problem to find the number of units of each product that should be manufactured for maximizing the profit.

**Solve it graphically.**

**Solution,**

For Decision Variable

Let x and y be the number of units of two different products to be produced to maximize profit.

For Objective Function

Total Profit = 20x +30y

Let Z=20x +30y

$Z_{max}$=20x+30y

<u>For constraints</u>

$2x+4y<=20$

$2x+2y<=12$

$4x+0y<=16$

$x, y>=0$

Now, Changing the constraints inequalities into equality

2x+4y=20--------------- i

2x+2y=12---------------ii

4x=16

Therefore x=4-----------------------iii

Now, for equation I when

| | | |
|---|---|---|
| X | 0 | 2 |
| Y | 5 | 4 |

Here the equation i passes through the point (0,5) and (2,4)

Now, testing origin (0,0),

$2x+4y<=20$

Or,2*0+4*0<=20

Therefore, 0<=20(True)

For equation ii

2x+2y=12

when

| | | |
|---|---|---|
| X | 0 | 1 |
| Y | 6 | 5 |

Therefore, equation ii passes through the point (0,6) and (1,5)

Now, Origin test (0,0),

2x+2y<=12

Or, 2*0+2*0<=12

Therefore, 0<=12(True)

For equation iii

x<=4

here (x=4 and y=0)

Now, Origin test (0,0),

x<=4

0<=(True)

Therefore, equation iii passes through the point (4,0)

The equation i passes through the point (0,5) and (2,5), Equation ii passes through the point (0,6) and (1,5) and equation iii passes through the point (4,0)

Graphical Solution

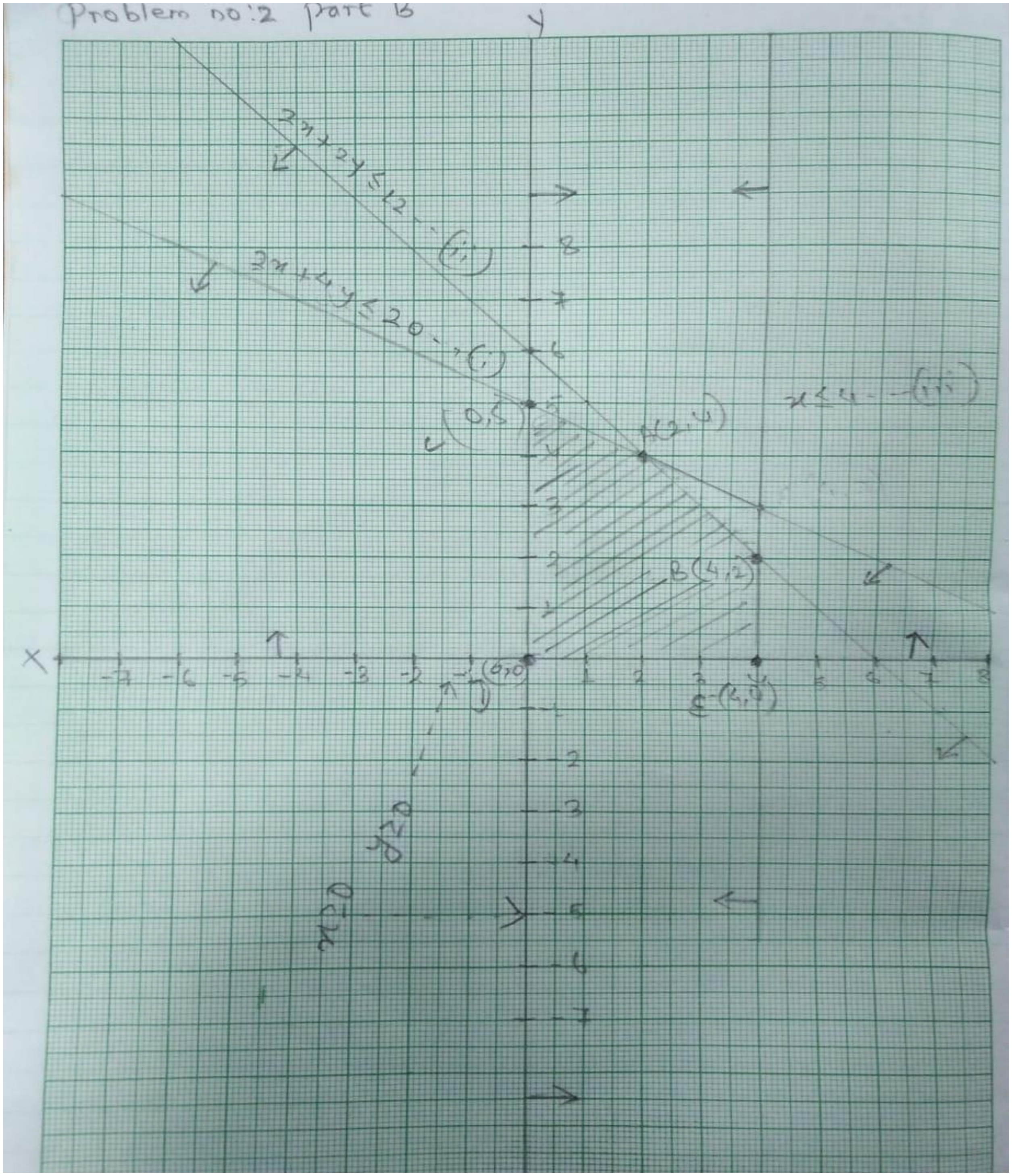



*Figure 16: Graphical Solution*

From above graph ABCDE is feasible region where

| Vertex | X | Y | Z=20x+30y |
|---|---|---|---|
| 2,4 | 2 | 4 | 160 |
| 4,2 | 4 | 2 | 140 |
| 0,5 | 0 | 5 | 150 |
| 0,0 | 0 | 0 | 0 |
| 4,0 | 4 | 0 | 80 |

From this table the maximum value of z is 160 at the vertex (2,4). So, 2 units of product x and 4 units of product y should be manufactured for maximizing the profit. (i.e. x=2, y=4and z=160).

## Problem 3

The monthly revenue R achieved by selling x items is figured to be $R(x) = 13x – 0.1x^2$. The monthly cost of selling x items is $C(x) = 4x + 60$.

**Questions**

You should answer the following questions and incorporate your answers into a word-processed report. The sections of your report should correspond to the individual questions below.

a) Find the breakeven point(s).

b) By plotting the revenue and cost functions, obtain the Break-even output levels and corresponding price (use graph paper or graphical tools).

c) Generate the profit function for the company and find,

i. The level production that maximizes the profit. ii. The maximum profit.

**Solution,**

**A. Breakeven Point:**

This point is the point where there is neither profit nor loss. The total profit at breakeven point is always zero.

Solution,

From question, Given,

Revenue $R(x) = 13x – 0.1x^2$-------------eqn(i)

Cost $C(x) = 4x + 60$----------------------eqn(ii)

At breakeven, we know,

Revenue = Cost

i.e. $R(x) = C(x)$

or, $13x - 0.1x^2 = 4x + 60$

or, $4x + 60 - 13x + 0.1x^2 = 0$

or, $0.1x^2 + 4x - 13x + 60 = 0$

or, $0.1x^2 - 9x + 60 = 0$---------eqn(iii)

The eqn (iii) is in quadratic form of eqn $ax^2 + bx + c$. comparing eqn (iii) with

$ax^2 + bx + c$. we have,

$a = 0.1$, $b = -9$, $c = 60$

Now, using formulae,

$x = \frac{-b \pm \sqrt{b^2-4ac}}{2a}$

$= \frac{-(-9) \pm \sqrt{(-9)^2-4*(0.1)*60}}{2*(0.1)}$

$= \frac{9 \pm \sqrt{81-24}}{1/5}$

$= \frac{9 \pm \sqrt{57}}{1/5}$

Taking positive(+ve) sign

Or, $X = \frac{9+\sqrt{57}}{1/5}$

Or, $X = \frac{9+7.54}{1/5}$

Or, $X = 16.549 * 5$

**X = 82.749**

If X= 82.749, then

R(x) = 13x- 0.1*$x^2$

= 13* 82.749 – 0.1*$(82.749)^2$

=1075.737 – 0.1 * 6847.397

= 1075.737 – 684.739

**R = 390.997**

Therefore, Breakeven point when x is 82.749. we know,

Breakeven point = (x, Revenue)

Breakeven point = (**82.749, 390.997**)

Taking negative(-ve) sign

X = $\frac{9-\sqrt{57}}{1/5}$

X = $\frac{9-7.54}{1/5}$

X = 1.46 * 5

**X = 7.3**

If X= 7.3, then

$R(x) = 13x- 0.1*x^2$

$= 13* 7.3 – 0.1*(7.3)^2$

=94.9 – 0.1 * 53.29

= 94.9 – 5.329

**R = 89.571**

Therefore, Breakeven point when x is 82.749. we know,

Breakeven point = (x, Revenue)

Breakeven point = (**7.3, 89.571**)

Therefore, the breakeven points are (**82.749, 390.997**) and (**7.3, 89.571**).

**B. Graph for break-even output levels and corresponding price using revenue and cost functions.**

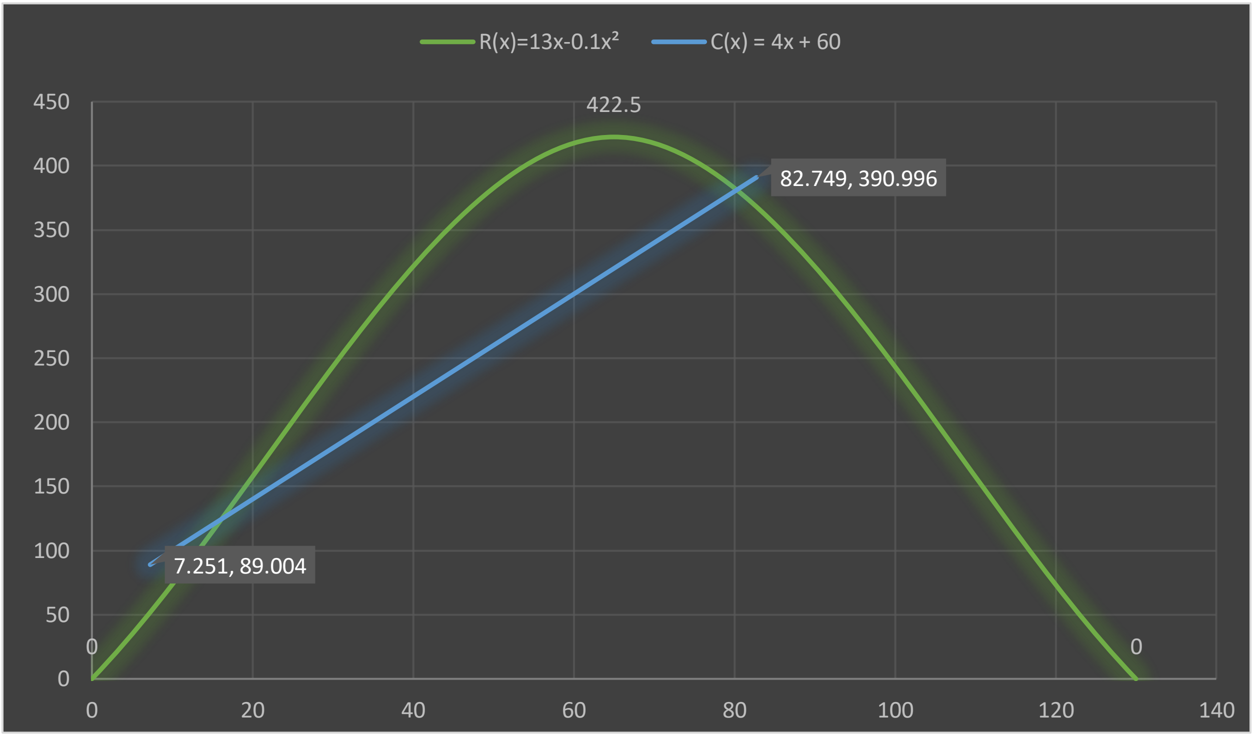



*Figure 17: Graph for breakeven point*

The graph above shows the breakeven output levels and corresponding price using revenue and cost functions. The X-axis shows the number of units whereas Y-axis shows the revenue/cost functions. The straight line shows the revenue and cost functions obtained from the quadratic equation.

**C. The profit function for the given company is given by,**

**Solution,**

Profit function = Revenue – Cost Function

Let, p be the profit function

Then,

P = R(x) – C(x)

$= 13x - 0.1x^2 - (4x + 60)$

$= 13x - 0.1x^2 - 4x - 60$

$= -0.1x^2 + 9x - 60$------eqn(i)

From above eqn x is the number of items produced monthly.

**i. The level of production that maximizes profit is given by the solution,**

X = -b/2a

Now, comparing eqn(i) $-0.1x^2 + 9x - 60$ with $ax^2 + bx + c$ , where,

a = -0.1, b = 9, c = -60

Now, for maximizing profit we have,

X = -b/2a

= -9/2*(-0.1)

= -9/-0.2

**X = 45**

Therefore, **45** items should be produced per month for maximizing the profit.

**ii. The maximum profit is given by**

**Solution,**

$Y = c - b^2/4a$

We have a = -0.1, b = 9, c = -60 from above

So, for, $y = c - b^2/4a$

$Y = -60 - 9^2/4*(-0.1)$

Y = -60 -81/-0.4

Y = -60 + 202.5

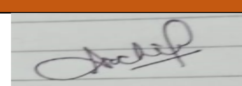
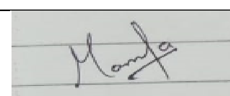
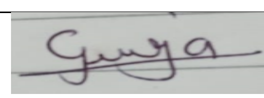
**Y = 142.5**

Therefore, maximum profit that can be generated monthly is **142.5.**

## Meeting Log

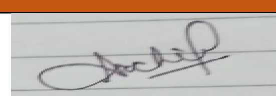
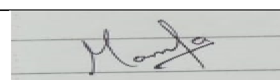
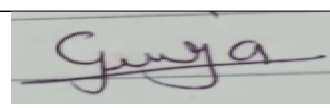
| | |
|---|---|
| Meeting | Groupwork meeting 1 |
| Date of Meeting | August 4 |
| Time | 10:00 am to 12: 00 pm |

| 1.Meeting Objectives |
|---|
| We had our first session for this group work on August 4th on college library. Our group consists of three members. Our coursework consisted of three issues in total. We all are discussing the problems and presenting our own opinions on the issue. In fact, this conference was about the discussion of questions. |

| Name | Signatures |
|---|---|
| Archit Thapa |  |
| Mamta Chauhan |  |
| Girija Tamang |  |

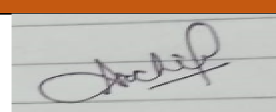
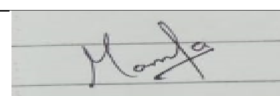
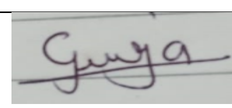
| Meeting | Groupwork meeting 2 |
|---|---|
| Date of Meeting | August 6 |
| Time | 10:00 am to 2: 00 pm |

| 2.Meeting Objectives |
|---|
| We had our second session on August 6 for this teamwork in cafeteria. We split the question into three of us. We all discussed the solution of the problem. We solved half of the problem with each other's help. And it was decided to solve the remaining of the problems at home. While solving the problems, we have to tackle different kinds of problems. |

| Name | Signatures |
|---|---|
| Archit Thapa |  |
| Mamta Chauhan |  |
| Girija Tamang |  |

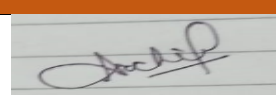
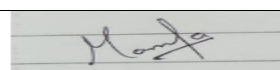
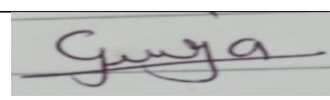
| Meeting | Groupwork meeting 3 |
|---|---|
| Date of Meeting | August 9 |
| Time | 12:00 pm to 3: 30 pm |

| 3.Meeting Objectives |
|---|
| We had our third meeting for this group work on the date of August 9th in library. All of us had brought our solution of all problems and we became busy for a few minutes to check and review all the problem solved. It was a bit difficult to plot the graph, but we were successful in completing it. We decided a 3-day period to finish the paperwork too. |

| Name | Signatures |
|---|---|
| Archit Thapa |  |
| Mamta Chauhan |  |
| Girija Tamang |  |

| Meeting | Groupwork meeting 4 |
|---|---|
| Date of Meeting | August 12 |
| Time | 12:00 am to 3:00 pm |

| 4.Meeting Objectives |
|---|
| On the date August 12 we had our fourth meeting for this group work in cafeteria. Finally, on this date, we finish our individual paperwork of each problems. we have done formatting and editing page numbers, making final pdf for submitting. On this date, we finally completed our documentation and completed our group work. Our groupwork was submitted by 11:00 am on August 19. In this way we completed our groupwork. |

| Name | Signatures |
|---|---|
| Archit Thapa |  |
| Mamta Chauhan |  |
| Girija Tamang |  |

## Appendix

### Problem 2: Part A

Problem 2: part A.

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formulating the problem as linear programming model.

The above question has asked us to find optimum quantity of each model A, B and C. so, that the Company can make maximum profit

for Descision variable.

Let $X_1$, $X_2$ and $X_3$ be the quantity of model A, model B and model C respectively of decoration lamps that Jack and Bro's make.

for objective function

Total profit $= 120X_1 + 190X_2 + 210X_3$

Let Total profit = Z

then,

$$Z_{max} = 120X_1 + 190X_2 + 210X_3$$

for Constraints.

$0.1X_1 + 0.2X_2 + 0.3X_3 \leq 80$ (Assembly time Const)

$0.2X_1 + 0.3X_2 + 0.4X_3 \leq 120$ (wiring time Const)

$0.1X_1 + 0.1X_2 + 0.1X_3 \leq 100$ (packaging time Const)

$X_1, X_2, X_3 \geq 0$ (non-neg const).

Let $S_1$, $S_2$ & $S_3$ be the slack variable.

then,

$0.1X_1 + 0.2X_2 + 0.3X_3 + S_1 = 80$

$0.2X_1 + 0.3X_2 + 0.4X_3 + S_2 = 120$

$0.1X_1 + 0.1X_2 + 0.1X_2 + S_3 = 100$

Now, standard eqn for simplex.

$R_0$ $Z - 120x_1 - 190x_2 - 210x_3 + 0\cdot s_1 + 0\cdot s_2 + 0\cdot s_3 = 0$

$R_1$ $0\cdot Z + 0.1x_1 + 0.2x_2 + 0.3x_3 + s_1 + 0\cdot s_2 + 0\cdot s_3 = 80$

$R_2$ $0\cdot Z + 0.2x_1 + 0.3x_2 + 0.4x_3 + 0\cdot s_1 + s_2 + 0\cdot s_3 = 120$

$R_3$ $0\cdot Z + 0.1x_1 + 0.1x_2 + 0.1x_3 + 0\cdot s_1 + 0\cdot s_2 + s_3 = 100$

Simplex table I.

| | Z | $x_1$ | $x_2$ | $x_3$ | $s_1$ | $s_2$ | $s_3$ | Constraints. | Common Ratio |
|---|---|---|---|---|---|---|---|---|---|
| $R_0$ | 1 | -120 | -190 | -210 | 0 | 0 | 0 | 0 | — |
| $R_1$ | 0 | 0.1 | 0.2 | $\boxed{0.3}$ | 1 | 0 | 0 | 80 | $\frac{80}{0.3} = \frac{800}{3}$ |
| $R_2$ | 0 | 0.2 | 0.3 | 0.4 | 0 | 1 | 0 | 120 | $\frac{120}{0.4} = 300$ |
| $R_3$ | 0 | 0.1 | 0.1 | 0.1 | 0 | 0 | 1 | 100 | $\frac{100}{0.1} = 1000$ |

Key element.

Key column.

Key row.

Now,

$$\text{New } R_1 = \frac{\text{Old } R_1}{0.3}.$$

| | Z | $x_1$ | $x_2$ | $x_3$ | $s_1$ | $s_2$ | $s_3$ | Const. |
|---|---|---|---|---|---|---|---|---|
| $R_1$ | 0 | $\frac{0.1}{0.3} = \frac{1}{3}$ | $\frac{0.2}{0.3} = \frac{2}{3}$ | 1 | $\frac{1}{0.3} = \frac{10}{3}$ | 0 | 0 | $\frac{80}{0.3} = \frac{800}{3}$. |

$$\text{New } R_0 = \text{Old } R_0 - (-210) \times \text{New } R_1.$$

| | Z | $x_1$ | $x_2$ | $x_3$ | $s_1$ | $s_2$ | $s_3$ | Const. |
|---|---|---|---|---|---|---|---|---|
| $R_0$ | $1 + 210 \times 0 = 1$ | -50 | -50 | 0 | 700 | 0 | 0 | 56000 |

$$\text{New } R_2 = \text{Old } R_2 - (0.4) \times \text{New } R_1).$$

| | Z | $x_1$ | $x_2$ | $x_3$ | $s_1$ | $s_2$ | $s_3$ | Const |
|---|---|---|---|---|---|---|---|---|
| $R_2$ | 0 | $\frac{1}{15}$ | $\frac{1}{30}$ | 0 | $-\frac{4}{3}$ | 1 | 0 | $\frac{40}{3}$. |

New $R_3$ = Old $R_3$ − (0.1) × New $R_1$

| | Z | $X_1$ | $X_2$ | $X_3$ | $S_1$ | $S_2$ | $S_3$ | Const. |
|---|---|---|---|---|---|---|---|---|
| $R_3$ | 0 | $1/15$ | $1/30$ | 0 | $-1/3$ | 0 | 1 | $\frac{220}{3}$ |

Simplex Table (II)

| | Z | $X_1$ | $X_2$ | $X_3$ | $S_1$ | $S_2$ | $S_3$ | Const | Common Ratio |
|---|---|---|---|---|---|---|---|---|---|
| $R_0$ | 1 | −50 | −50 | 0 | 700 | 0 | 0 | 56000 | ← |
| $R_1$ | 0 | $1/3$ | $2/3$ | 1 | $10/3$ | 0 | 0 | $800/3$ | $\frac{800}{3} \times \frac{3}{1} = 80$ |
| $R_2$ | 0 | $\boxed{1/15}$ | $1/30$ | 0 | $-4/3$ | 1 | 0 | $40/3$ | $\frac{40}{3} \times 15 = 20$ |
| $R_3$ | 0 | $1/15$ | $1/30$ | 0 | $-1/3$ | 0 | 1 | $220/3$ | $\frac{220}{3} \times 15 = 110$ |

Key column. Key element.

Key row

Now,

New $R_2$ = $\frac{\text{Old } R_2}{1/15}$

| | Z | $X_1$ | $X_2$ | $X_3$ | $S_1$ | $S_2$ | $S_3$ | Const. |
|---|---|---|---|---|---|---|---|---|
| $R_2$ | 0 | 1 | $1/2$ | 0 | −20 | 15 | 0 | 200 |

New $R_0$ = Old $R_0$ − (−50) · New $R_2$

| | Z | $X_1$ | $X_2$ | $X_3$ | $S_1$ | $S_2$ | $S_3$ | Const. |
|---|---|---|---|---|---|---|---|---|
| $R_0$ | 1 | 0 | −25 | 0 | −300 | 750 | 0 | 66000 |

New $R_1$ = Old $R_1$ − (1/3) · New $R_2$

| | Z | $X_1$ | $X_2$ | $X_3$ | $S_1$ | $S_2$ | $S_3$ | Const. |
|---|---|---|---|---|---|---|---|---|
| $R_1$ | 0 | 0 | $1/2$ | 1 | 10 | −5 | 0 | 200 |

New $R_3$ = Old $R_3$ − (1/15) · New $R_2$

| | Z | $X_1$ | $X_2$ | $X_3$ | $S_1$ | $S_2$ | $S_3$ | Const. |
|---|---|---|---|---|---|---|---|---|
| $R_3$ | | | | | | | | 60 |

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Simplex Table (ii)

| | Z | $X_1$ | $X_2$ | $X_3$ | $S_1$ | $S_2$ | $S_3$ | Const | Common Ratio |
|---|---|---|---|---|---|---|---|---|---|
| $R_0$ | 1 | 0 | -25 | 0 | -300 | 750 | 0 | 66000 | — |
| $R_1$ | 0 | 0 | $1/2$ | 1 | $\boxed{10}$ | -5 | 0 | 200 | $\frac{200}{10} = 20$ |
| $R_2$ | 0 | 1 | $1/2$ | 0 | -20 | 15 | 0 | 200 | $\frac{200}{-20} = -10$ |
| $R_3$ | 0 | 0 | 0 | 0 | 1 | -1 | 1 | 60 | $\frac{60}{1} = 60$ |

key element

key Column

key row

Now, New $R_1 = \frac{\text{old } R_1}{10}$

| | Z | $X_1$ | $X_2$ | $X_3$ | $S_1$ | $S_2$ | $S_3$ | Const |
|---|---|---|---|---|---|---|---|---|
| $R_1$ | 0 | 0 | $1/20$ | $1/10$ | 1 | $-1/2$ | 0 | 20 |

New, $R_0$ = old $R_0$ - (-300) · New $R_1$

| | Z | $X_1$ | $X_2$ | $X_3$ | $S_1$ | $S_2$ | $S_3$ | Const. |
|---|---|---|---|---|---|---|---|---|
| $R_0$ | 1 | 0 | -10 | 30 | 0 | 600 | 0 | 72000 |

New $R_2$ = old $R_2$ - (-20) · New $R_1$

| | Z | $X_1$ | $X_2$ | $X_3$ | $S_1$ | $S_2$ | $S_3$ | Const |
|---|---|---|---|---|---|---|---|---|
| $R_2$ | 0 | 1 | $3/2$ | 2 | 0 | 5 | 0 | 600 |

New $R_3$ = old $R_3$ - · New $R_1$

| | Z | $X_1$ | $X_2$ | $X_3$ | $S_1$ | $S_2$ | $S_3$ | Const. |
|---|---|---|---|---|---|---|---|---|
| $R_3$ | 0 | 0 | $-1/20$ | $-1/10$ | 0 | $-1/2$ | 1 | 40 |

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Simplex Table IV

| | Z | $x_1$ | $x_2$ | $x_3$ | $S_1$ | $S_2$ | $S_3$ | Const | Common Ratio |
|---|---|---|---|---|---|---|---|---|---|
| $R_0$ | 1 | 0 | -10 | 30 | 0 | 600 | 0 | 72000 | |
| $R_1$ | 0 | 0 | $\boxed{1/20}$ | 1/10 | 1 | -1/2 | 0 | 20 | $\frac{20}{1/20} = 400$ |
| $R_2$ | 0 | 1 | 3/2 | 7 | 0 | 5 | 0 | 600 | $\frac{600}{3/2} = 400$ |
| $R_3$ | 0 | 0 | -1/20 | -1/10 | 0 | -1/2 | 1 | 40 | $\frac{40}{-1/20} = -800$ |

Key element.
Key Column
Key row.

Now, New $R_1 = \frac{\text{old } R_1}{1/20}$

| | Z | $x_1$ | $x_2$ | $x_3$ | $S_1$ | $S_2$ | $S_3$ | Const |
|---|---|---|---|---|---|---|---|---|
| $R_1$ | 0 | 0 | 1 | 2 | 20 | -10 | 0 | 400 |

New $R_0$ = old $R_0 - (-10) \times$ New $R_1$.

| | Z | $x_1$ | $x_2$ | $x_3$ | $S_1$ | $S_2$ | $S_3$ | Const. |
|---|---|---|---|---|---|---|---|---|
| $R_0$ | 1 | 0 | 0 | 50 | 200 | 500 | 0 | 76000 |

New $R_2$ = old $R_2 - \left(\frac{3}{2}\right) \cdot$ New $R_1$.

| | Z | $x_1$ | $x_2$ | $x_3$ | $S_1$ | $S_2$ | $S_3$ | Const. |
|---|---|---|---|---|---|---|---|---|
| $R_2$ | 0 | 1 | 0 | -1 | -30 | 20 | 0 | 0 |

New $R_3$ = old $R_3 - \left(-\frac{1}{20}\right) \cdot$ New $R_1$

| | Z | $x_1$ | $x_2$ | $x_3$ | $S_1$ | $S_2$ | $S_3$ | Const. |
|---|---|---|---|---|---|---|---|---|
| $R_3$ | 0 | 0 | 0 | 0 | 1 | -1 | 1 | 60 |

Simplex Table V

| | Z | $X_1$ | $X_2$ | $X_3$ | $S_1$ | $S_2$ | $S_3$ | Const | Common Ratio. |
|---|---|---|---|---|---|---|---|---|---|
| $R_0$ | 1 | 0 | 0 | 50 | 200 | 500 | 0 | 76000 | — |
| $R_1$ | 0 | 0 | 1 | 2 | 10 | -10 | 0 | 400 | |
| $R_2$ | 0 | 1 | 0 | -1 | -30 | 20 | 0 | 0 | |
| $R_3$ | 0 | 0 | 0 | 0 | 1 | -1 | 1 | 60 | |

from, above table, we have
Total profit $Z_{max} = 76000$
Model A $(X_1) = 0$
Model B $(X_2) = 400$ &
Model C $(X_3) = 0$

$\therefore$ The value of $Z_{max}$ is 76000 at
$X_1 = 0$, $X_2 = 400$ & $X_3 = 0$.

**Problem 3**

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Problem No: 3.

Soln Let,

Revenue $R(x) = 13x - 0.1x^2$ ---- eqn (i)

Cost $c(x) = 4x + 60$ ---- eqn (ii)

At break even, we know,

Revenue = Cost

i.e $R(x) = c(x)$

or, $13x - 0.1x^2 = 4x + 60$

or, $4x + 60 - 13x + 0.1x^2 = 0$

or, $0.1x^2 + 4x - 13x + 60 = 0$

or, $0.1x^2 - 9x + 60 = 0$ ---- eqn (iii)

The eqn (iii) is in quadratic form of eqn $ax^2 + bx + c$. Comparing eqn (iii) with $ax^2 + bx + c$, we have $a = 0.1$, $b = -9$, $c = 60$.

Now, using formulae.

$$x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$$

$$= \frac{-(-9) \pm \sqrt{(-9)^2 - 4 \cdot (0.1) \cdot 60}}{2 \cdot (0.1)}$$

$$= \frac{9 \pm \sqrt{81 - 24}}{1/5}$$

$$= \frac{9 \pm \sqrt{57}}{1/5}.$$

Taking +ve sign

$$x = \frac{9 + \sqrt{57}}{1/5}$$

$$x = \frac{9 + 7.54}{1/5}$$

$$x = 16.549 \times 5$$

$$\therefore x = 82.749$$

If $x = 82.749$, then

$$R(x) = 13x - 0.1x^2$$

$$= 13 \times 82.749 - (0.1 \times (82.749)^2)$$

$$= 1075.737 - 0.1 \times 6847.397$$

$$= 1075.737 - 684.739$$

$$\therefore R = 390.997$$

Therefore, Break Even point when $x$ is 82.749. we know,

Break Even points = ($x$, Revenue).

$\therefore$ Break Even point = (82.749, 390.997)

Taking -ve sign.

$$x = \frac{9 - \sqrt{57}}{1/5}$$

$$x = \frac{9 - 7.54}{1/5}$$

$$x = 1.46 \times 5$$

$$\therefore x = 7.3$$

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If $x = 7.3$, then

$$R(x) = 13x - 0.1x^2$$
$$= 13 \times 7.3 - 0.1 \times (7.3)^2$$
$$= 94.9 - 0.1 \times 53.29$$
$$= 94.9 - 5.329$$
$$\therefore R = 89.571$$

Therefore, Break Even point when $x$ is 7.3, we know

Break Even point = ($x$, Revenue)

$\therefore$ Break Even point = (7.3, 89.571)

b)

The profit function for the given company is given by.

profit function = Revenue − cost function.

Let $p$ be profit function.

Then,

$$p = R(x) - c(x).$$
$$= 13x - 0.1x^2 - (4x + 60)$$
$$= 13x - 0.1x^2 - 4x - 60$$
$$= -0.1x^2 + 9x - 60 \quad \ldots \text{eq}^n \text{ (i)}$$

from above eq$^n$ $x$ is the number of items produced per month.

The level of production that maximizes the profit is given by,

$$x = -b/2a$$

Now, comparing eqn (i) $-0.1x^2 + 9x + 60$ with $ax^2 + bx + c$, where,

$a = -0.1, \quad b = 9, \quad c = -60.$

Now, for, maximizing profit we have.

$$x = \frac{-b}{2a}$$

$$= \frac{-9}{2.(-0.1)}$$

$$= \frac{\cancel{-}9}{\cancel{-}0.2}$$

$$\therefore x = 45.$$

Therefore, 45 items should be produced per month for maximizing the profit.

ii) The maximum profit is given by.

$$y = c - \frac{b^2}{4a}$$

we know, $a = -0.1$, $b = 9$. $c = -60$ from above.

so, for,

$$y = c - \frac{b^2}{4a}$$

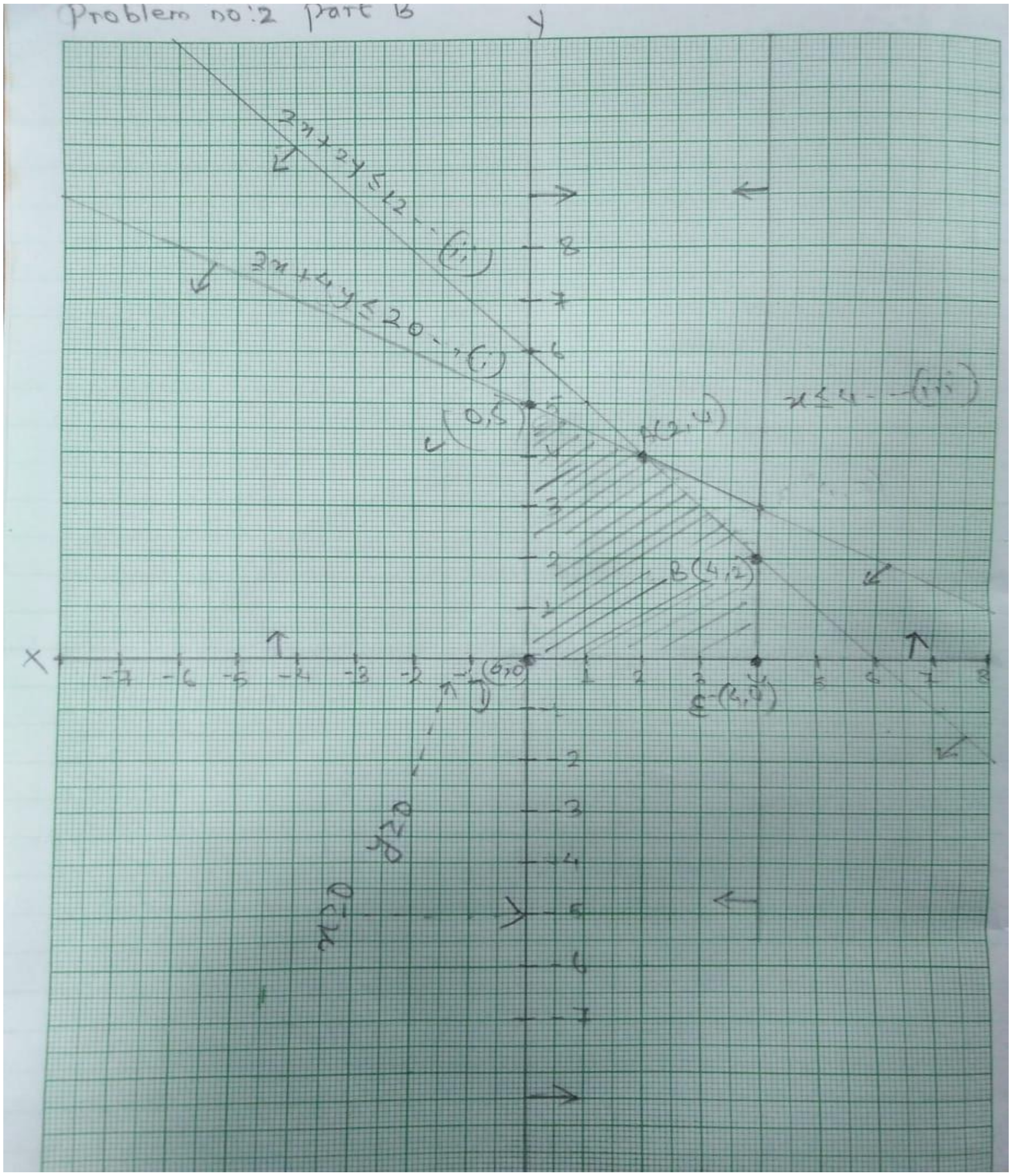
$$y = -60 - \frac{9^2}{4 \times (0.1)}$$

$$= -60 \cancel{-} \frac{81}{\cancel{-}0.4}$$

$$= -60 + 202.5$$

$$\therefore y = 142.5$$

Therefore, maximum profit that can be generated monthly is 142.5


Problem no:2 part B
2x+2y≤12
2x+4y≤20
x≤4
A(2,4)
B(4,2)
C(0,5)
(0,0)
E(4,0)
y≥0
x≥0