Assignment 4: VBA Programming

Solution Instructor: Trani

Problem 1

A train engineer finds that the basic train resistance of a high-speed train (see Figure 1) to be:

$$R = A + BV + CV^2$$

Where:

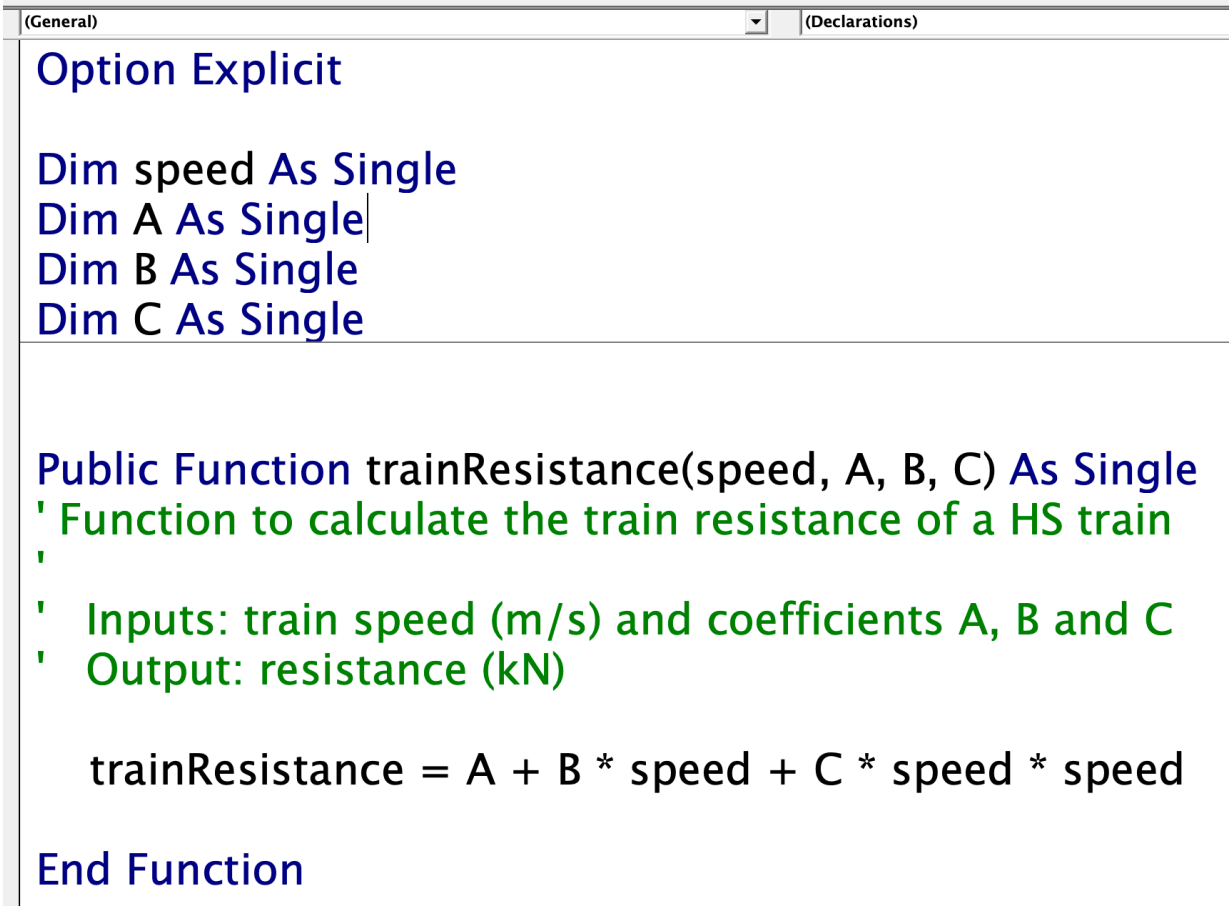
R is the basic train resistance in kiloNewtons

V is the train speed in meters/second

A, B, C are empirical constants derived from wind tunnel test. The values of A, B, C are 8.2, 0.107, and 0.0119, respectively.

1) **Create a public function in Excel/VBA** to estimate the value of the basic train resistance (R) given a value of train speed (V).
2) Apply the Excel function created above using a table of speeds ranging from 0 to 90 m/s.
3) Use Excel to make a plot of train resistance (y-axis) versus speed (x-axis). Label accordingly.

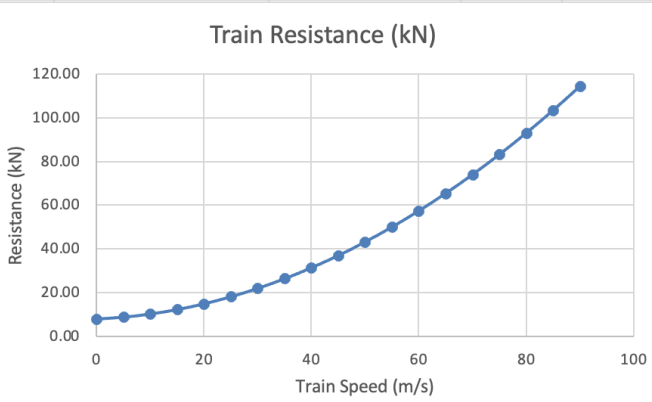
Figure 1. High-speed Train (Shinkansen 300 series). Source: Wikipedia.



Train Resistance Function. The Option Explicit statement is Needed.

Function to calculate the train resistance			
Program estimates train resistance (R in kiloNewtons) given speed (m/s)			
Programmer	Trani		
Date	2/21/24 5:55		
Formula	R=A+B V + C V^2		
Inputs to problem			
Speed	10	meters/second	
A	8.2000	kN	train resistance coefficient
B	0.1070	kN/m/s	train resistance coefficient
C	0.0119	kN/m^2/s^2	train resistance coefficient
Output			
Train Resistance (R)	10.46	kiloNewtons	

Train Speed (m/s)	Resistance (kN)
0	8.20
5	9.03
10	10.46
15	12.48
20	15.10
25	18.31
30	22.12
35	26.52
40	31.52
45	37.11
50	43.30
55	50.08
60	57.46



Excel Interface to Estimate Train Resistance.

Problem 2

Table 1 provides the California Bearing Ratios of various types of Sounds according to the Unified Soil Classification System (USCS).

Table 1. CRB Values for Typical Soils According to the Unified Soil Classification System (USCS).

Soil Type	CBR (dim)
Well-graded gravels	55
Poorly-graded gravels	45
Gravel-sand-silt	35
Clayey gravels	30
Well-graded sands	29
Silty sands	28
Clayey sands	13
Inorganic silts	12
Inorganic silty clay	5
Fine silty soils	9
Peat soil	4

Create a spreadsheet and associated VBA code to estimate the total pavement thickness (in inches) according to the empirical equation:

Pavement Thickness (inches) = sqrt (Load / (8.1 * CBR) + Area /pi)

Where:

Thickness_inches is the total pavement thickness (in inches)

Load is the single-wheel equivalent load in pounds

Area is the contact area between the tire and the pavement (square inches)

CBR is the California Bearing Ratio (dim)

The following features are needed for the spreadsheet and code:

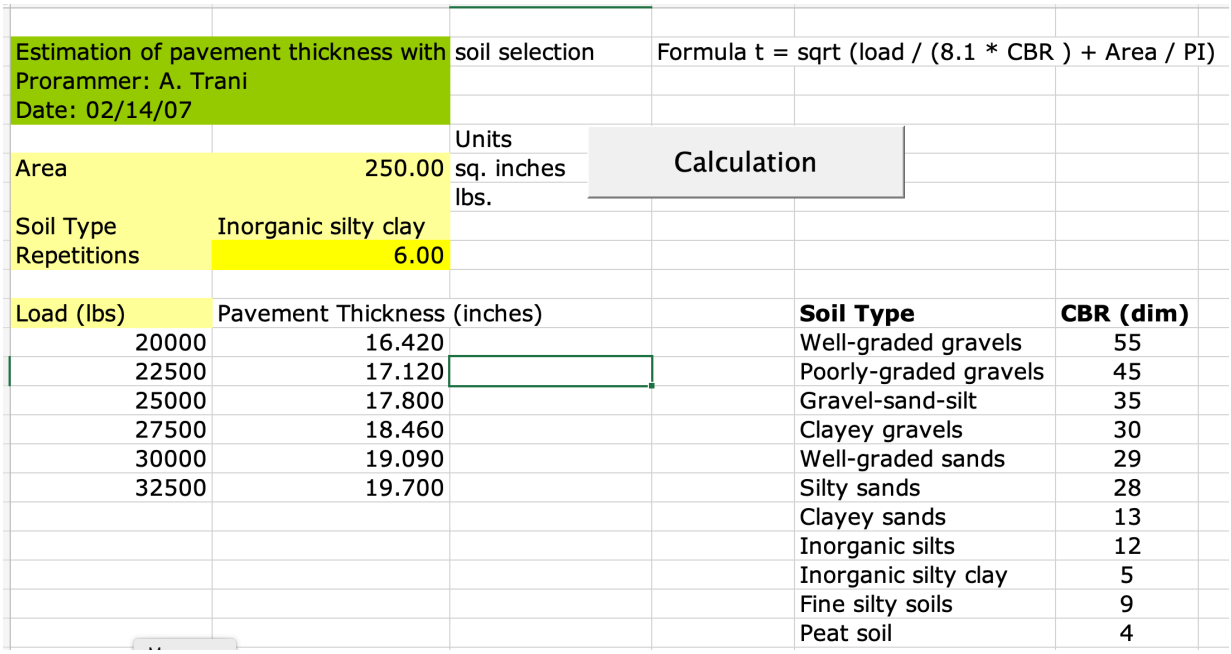
i) The user can select the soil type via a **data validation drop down menu list** containing the names of the soil type (column 1 in Table 1).

ii) The **VBA code reads the values of CBR (column 2 in Table 1) and estimates the pavement thickness**. This means Table 1 (both columns) must be inserted into the spreadsheet at a location of your choice. The VBA code reads the values of column 2 once the soil type is selected by the user.

iii) The VBA code reads the soil type from the validation drop box and reads the value of CBR from the spreadsheet (Table 1).

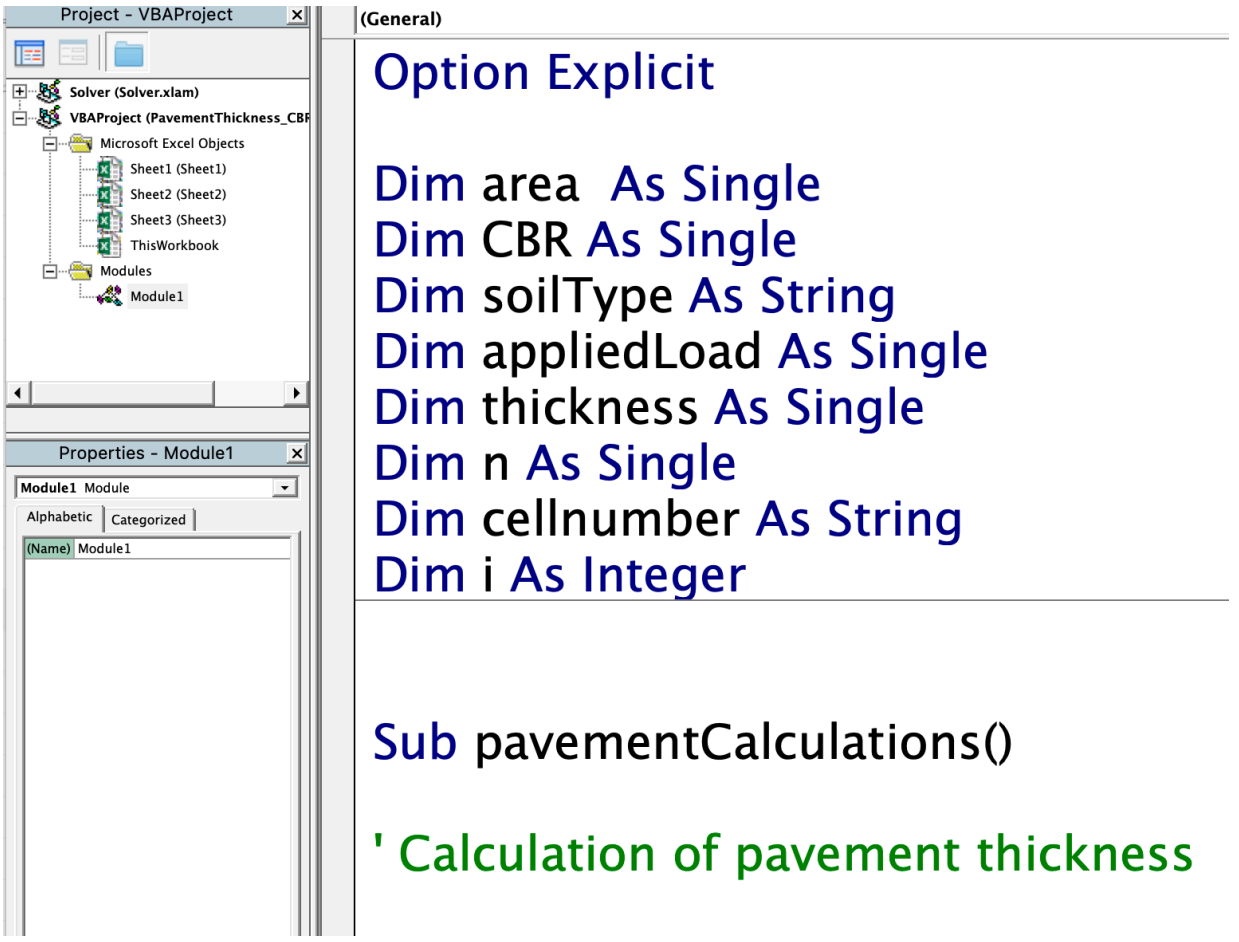
iv) The VBA code creates a table of pavement thickness solutions for 10 values of load ranging from 20,000 to 40,000 lbs. The table with pavement thickness solutions are shown on the spreadsheet. Use a contact area of 250 square inches in your analysis.

v) Declare all program the variables using Option Explicit.



Estimation of pavement thickness with		soil selection	Formula t = sqrt (load / (8.1 * CBR) + Area / PI)		
Prorammer: A. Trani					
Date: 02/14/07					
		Units	Calculation		
Area	250.00	sq. inches			
		lbs.			
Soil Type	Inorganic silty clay				
Repetitions	6.00				
Load (lbs)	Pavement Thickness (inches)			**Soil Type**	**CBR (dim)**
20000	16.420			Well-graded gravels	55
22500	17.120			Poorly-graded gravels	45
25000	17.800			Gravel-sand-silt	35
27500	18.460			Clayey gravels	30
30000	19.090			Well-graded sands	29
32500	19.700			Silty sands	28
				Clayey sands	13
				Inorganic silts	12
				Inorganic silty clay	5
				Fine silty soils	9
				Peat soil	4

Excel Interface to Estimate Pavement Thickness with Soil Selection List.



VBA Code to Estimate Pavement Thickness with Soil Selection List. Part 1 of Code.

```
(General)                                   pavementCalculations
' Programmer : A. Trani
' Date: 02/17/07

Const Pi = 3.1415

' retrieve values of constant parameters from cells b6 and b7

Sheets("Sheet1").Select

Range("b6").Select
area = ActiveCell.Value

'Code to select the value of CBR asa  function of the soil type selected

Range("b8").Select
soilType = ActiveCell.Value
```

VBA Code to Estimate Pavement Thickness with Soil Selection List. Part 2 of Code.

```
Range("b8").Select
soilType = ActiveCell.Value

If soilType = "Well-graded gravels" Then
    Range("f10").Select
    CBR = ActiveCell.Value
ElseIf soilType = "Poorly-graded gravels" Then
    Range("f11").Select
    CBR = ActiveCell.Value
ElseIf soilType = "Gravel-sand-silt" Then
    Range("f12").Select
    CBR = ActiveCell.Value
ElseIf soilType = "Clayey gravels" Then
    Range("f13").Select
    CBR = ActiveCell.Value
ElseIf soilType = "Well-graded sands" Then
    Range("f14").Select
```

VBA Code to Estimate Pavement Thickness with Soil Selection List. Part 3 of Code.

```
    Range("f18").Select
    CBR = ActiveCell.Value
ElseIf soilType = "Fine silty soils" Then
    Range("f19").Select
    CBR = ActiveCell.Value
ElseIf soilType = "Peat soil" Then
    Range("f20").Select
    CBR = ActiveCell.Value
End If

' Retrieve the value of repetitions (n) in cell B9

Range("B9").Select
n = ActiveCell.Value

' Clear the range (table) before the loop

Range("A12:B1000").Clear
```

VBA Code to Estimate Pavement Thickness with Soil Selection List. Part 4 of Code.

```
For i = 1 To n

    cellnumber = "A" & (i + 11)                ' assign the cell to write load values
    Range(cellnumber).Select                   ' select cell assigned in previous step
    appliedLoad = 20000 + 2500 * (i - 1)       ' compute load (lb) at 2500 lb incremer
    ActiveCell.Value = appliedLoad             ' assign computed load to cells A+ (n+

    ' calculate the pavement thickness

    thickness = Round(Sqr(appliedLoad / (8.1 * CBR) + area / Pi), 2)

    cellnumber = "B" & (i + 11)                  ' assign the cell to write pavement th
    Range(cellnumber).Select                     ' select cell
    ActiveCell.Value = thickness                 ' write value of pavement thickness

Next i                                           ' next value of i
```

VBA Code to Estimate Pavement Thickness with Soil Selection List. Part 5 of Code.

Problem 3

A simple formula used in highway engineering to estimate the horizontal radius of a road is:

$$R = \frac{v^2}{g(e+f)}$$

Where:

R is the road horizontal radius (in meters)

v is the road design speed (m/s)

g is the gravitational constant (9.81 m/s^2)

e is the superelevation rate of the road (%/100). For example, a road with a superelevation rate of 0.06 implies the road of inclined at a lateral slope of 0.06 meters for each one meter in horizontal distance (see . Typical values of e vary from 0 (no superelevation) to 0.10 (high superelevation).

f is the lateral friction force coefficient developed between the vehicle tires and the pavement.

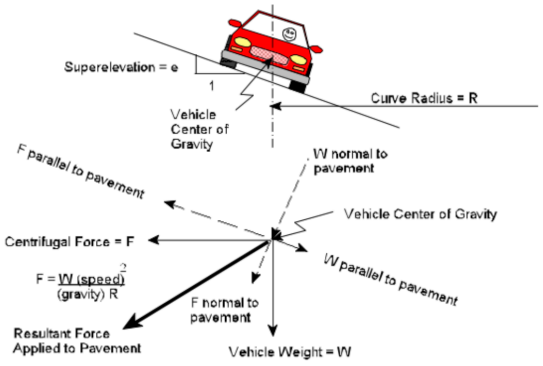
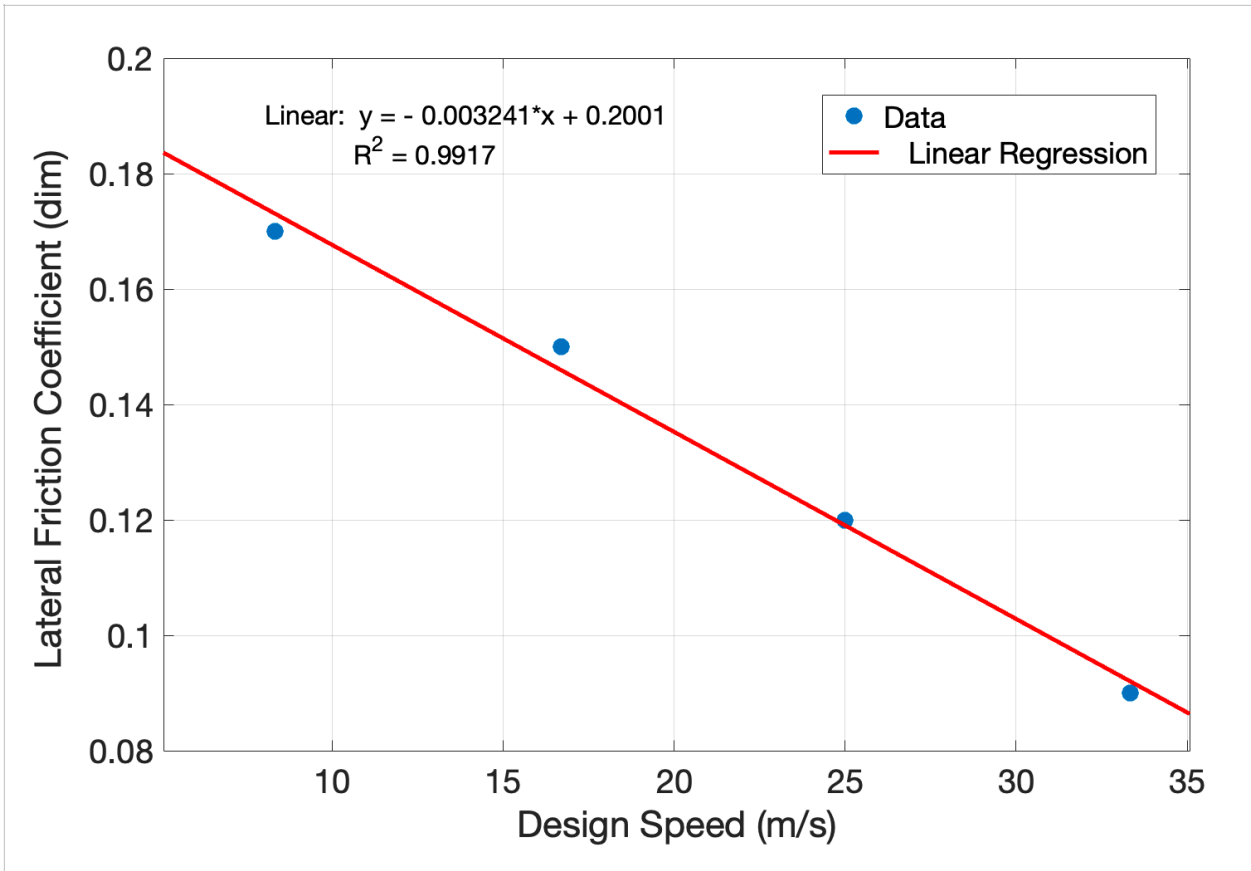


Figure 2. Road Superelevation Diagram. NYDOT.

The lateral friction force coefficient varies according to the table below. This means, at higher speeds, the car has less grip on the road to execute a turn.

Road Design Speed (m/s)	Lateral Friction Coefficient f (dim)
8.34	0.17
16.70	0.15
25.00	0.12
33.34	0.09

First do a linear regression model to estimate the value of lateral friction (f) as a function of design speed (m/s). The figure below illustrates the analysis and the regression equation for (f).



Linear Regression Model of Lateral Friction versus Design Speed.

a) Create a spreadsheet and associated VBA code to estimate the radius of the horizontal curve (in meters) according to the equation provided.

The following features are needed for the spreadsheet and code:

b) The user can select the value of superelevation (e) from a drop-down list. Allowable values of e range from 0 to 0.10.

Calculates the Radius of horizontal curvature of a Highway		
Program estimates the lateral friction coefficient given speed		
Programmer: A. Trani		
Date	2/21/24 8:34	
Purpose:	Calcuate R given design speed	
Parameter	Value	Units
Design Speed	18	m/s
Superelevation Rate	0.010	ft/ft
Results		
Horizontal Radius	220	meters
Lateral Friction	0	dim
Speed (m/s)	Radius of Curve (mete	Lateral Friction (dim)
10	4	00.168
11	5	00.164
12	69.50	00.161
13	82.84	00.158

0
0.01
0.02
0.03
0.04
0.05
0.06
0.07
0.08
0.09
0.1

0.0

Drop Down List to Select Superelevation Rate.

vi) The user enters (directly on the spreadsheet) the value of speed (in meters/second) and the program calculates R in meters.

vii) The VBA code estimates the value of lateral friction coefficient (f) based on the value of speed entered. The estimation of f can be performed using the linear regression approximation of f versus speed (v). The regression equation should be coded in VBA.

$$f = A + Bv$$

Where:

A, B are two regression coefficients to be found using the Excel trend line of friction versus speed table data.

v is the road design speed (m/s).

viii) Declare all program the variables using Option Explicit.

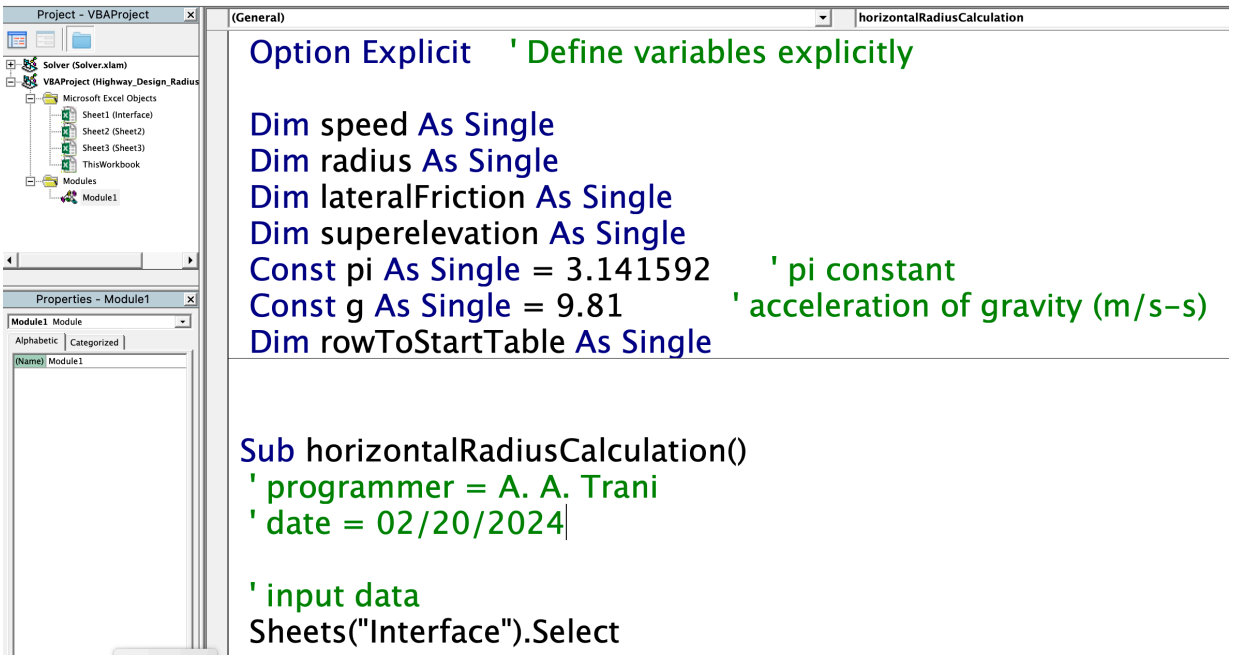
B) Test the VBA code and the spreadsheet to find the horizontal radius (R) for different speeds ranging from 10 to 30 m/s. at steps of one m/s.

	A	B	C
1			
2	Calculates the Radius of horizontal curvature of a Highway		
3	Program estimates the lateral friction coefficient given speed		
4	Programmer: A. Trani		
5	Date	2/21/24 8:20	
6	Purpose:	Calcuate R given design speed	
7			
8	Parameter	Value	Units
9	Design Speed	18	m/s
10	Superelevation Rate	0.050	ft/ft
11			
12	Results		
13	Horizontal Radius	220.071	meters
14	Lateral Friction	0.135	dim
15			
16	Speed (m/s)	Radius of Curve (meters	Lateral Friction (dim)
17	10	46.83	00.168
18	11	57.52	00.164
19	12	69.50	00.161
20	13	82.84	00.158
21	14	97.59	00.155
22	15	113.83	00.151

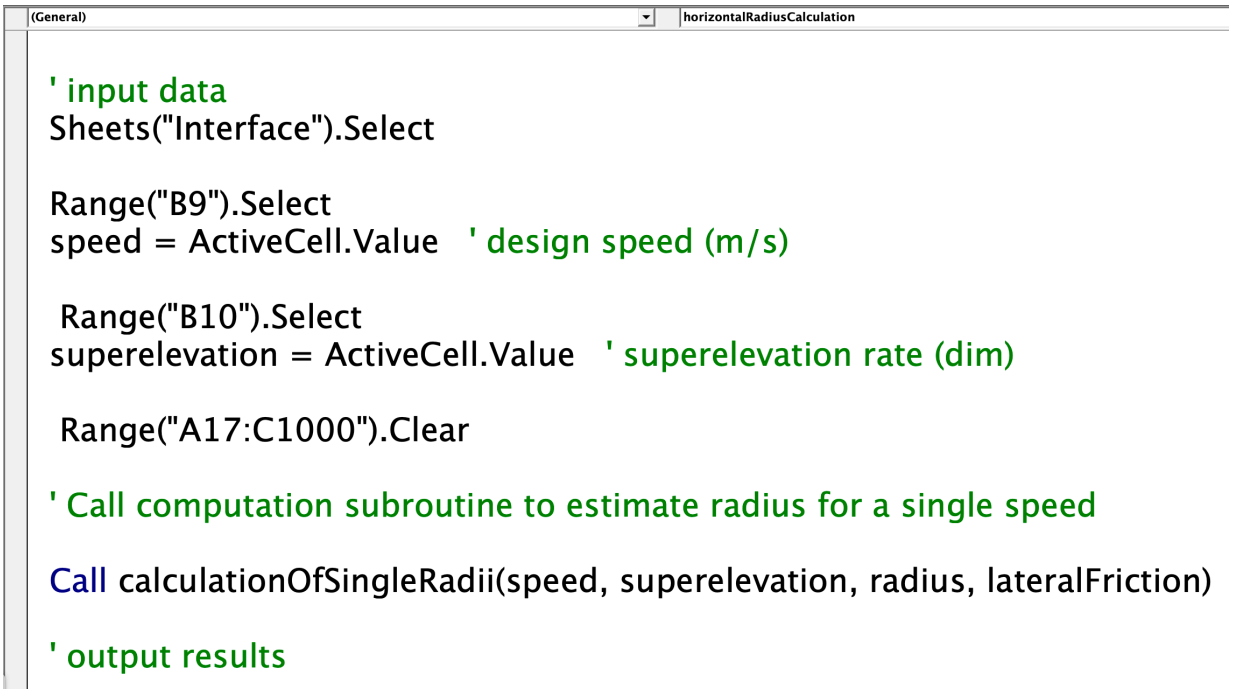
Run

0.0 Speed(m/s) 35.0

Interface of Excel Model to Estimate Horizontal Radius of a Road.



VBA Code to Estimate Horizontal Radius of the Road. Part 1.



VBA Code to Estimate Horizontal Radius of the Road. Part 2.

```
(General)                                   horizontalRadiusCalculation

 ' output results

  Range("B13").Select
  ActiveCell.Value = radius  ' meters

   Range("B14").Select
  ActiveCell.Value = lateralFriction  ' dim

' Call sub to do the calculation for multiple speeds
calculationForMultipleSpeeds

End Sub
```

VBA Code to Estimate Horizontal Radius of the Road. Part 3.

```
Sub calculationOfSingleRadii(speed, superelevation, radius, lateralFriction)

' Estimates the horizontal radius of the road in meters

lateralFriction = 0.2001 - 0.003241 * speed
radius = speed * speed / (g * (superelevation + lateralFriction))

' Things to do next:
' a) output the values of vx0 and vy0 to the worksheet,
' b) write another sub to estimate multiple values of distance and hang time

End Sub
```

VBA Subroutine to Estimate Horizontal Radius and Lateral Friction of the Road. Part 4.

```
Sub calculationForMultipleSpeeds()

' define where do you want to start the table
rowToStartTable = 16

' write down the header or the table (3 columns)
      Range("A" & rowToStartTable).Select
      ActiveCell.Value = "Speed (m/s)"   ' speed in m/s

      ActiveCell.Offset(0, 1).Select
      ActiveCell.Value = "Radius of Curve (meters"   ' radius

      ActiveCell.Offset(0, 1).Select
```

```
For speed = 10 To 35 Step 1

    lateralFriction = 0.2001 - 0.003241 * speed
    radius = speed * speed / (g * (superelevation + lateralFriction))

    Range("A" & rowToStartTable + 1).Select
    ActiveCell.Value = speed                ' speed (m/s)
    ActiveCell.NumberFormat = 0#            ' format numbers


    ActiveCell.Offset(0, 1).Select
    ActiveCell.Value = radius               ' meters
    ActiveCell.NumberFormat = "0.00"        ' format numbers

    ActiveCell.Offset(0, 1).Select
    ActiveCell.Value = lateralFriction      ' dimensionless
    ActiveCell.NumberFormat = "00.000"
```

```
      rowToStartTable = rowToStartTable + 1
 Next speed

End Sub
```

VBA Subroutine to Estimate Horizontal Radius and Lateral Friction of the Road for Multiple Speeds. Part 5.