Programming Project #2: Vehicle Fuel Economy

Background:

Fuel economy varies with the speed of a vehicle. A driver may reduce fuel costs on a trip by driving close to the speed where the vehicle has maximum fuel economy. Automobile manufacturers strive to improve fuel economy, but it can still be affected significantly by driving habits.

Modern automobiles provide the driver with many useful pieces of information related to fuel economy, including:

- Current fuel economy (average mpg)
- Distance to empty tank (based on current mpg)
- Instantaneous mpg
- Trip mpg
- etc

http://oppositelock.kinja.com/

The graph below shows the results of a 1997 study on the fuel economy statistics for various vehicles. Earlier studies indicated that many vehicles achieved maximum fuel efficiency at 35-40 mph, but more recent studies indicate that maximum fuel efficiency occurs at higher speeds.
(https://en.wikipedia.org/wiki/Fuel_economy_in_automobiles)
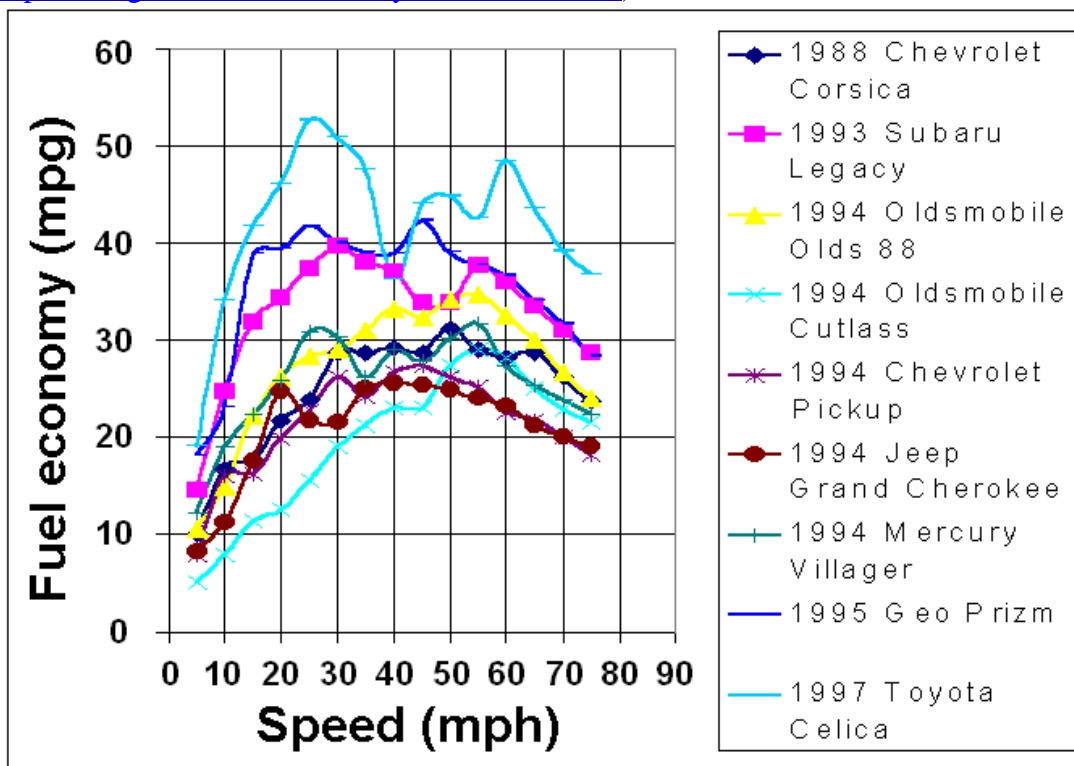
Modeling Fuel Economy

A simplified analysis of a certain vehicle indicates that its fuel economy can be modeled by a 2nd-order polynomial of the form $y = Ax^2 + Bx + C$, where

      y = fuel economy (in miles per gallon, mpg)

      x = speed (in miles per hour, mph)

In the graph below, A = -0.004, B = 0.45, and C = 16. The graph indicates that the maximum fuel economy occurs at a speed of about 56 mph.
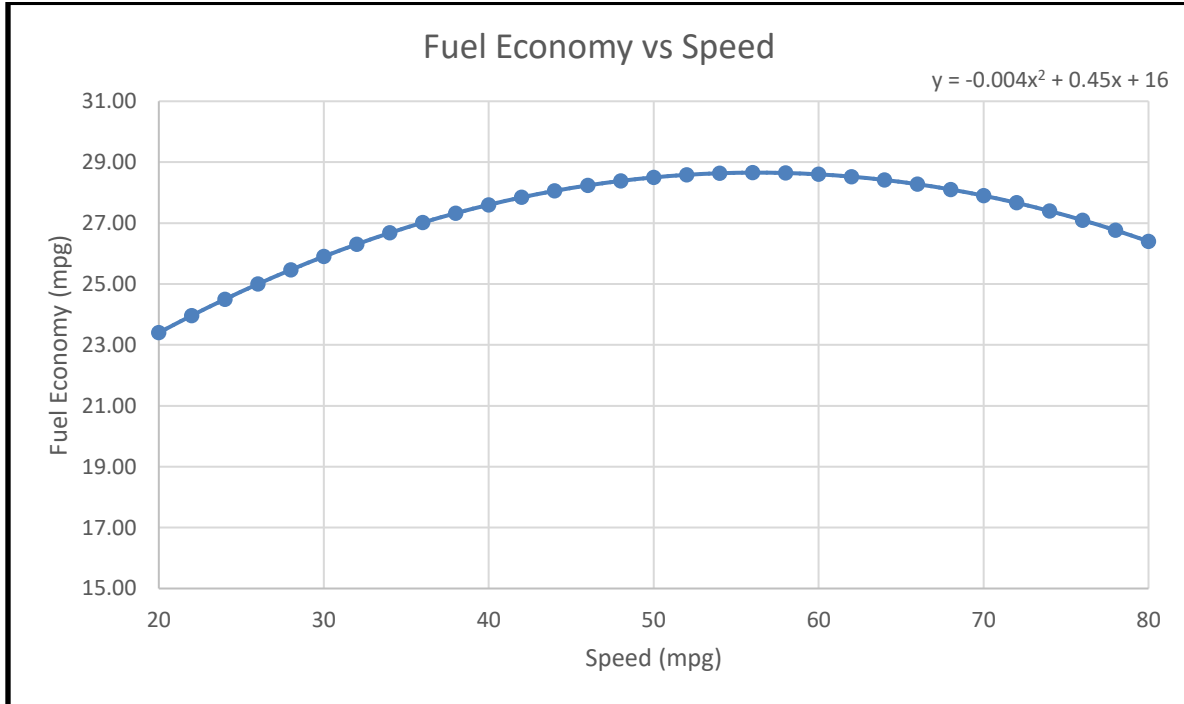
Program Requirements:

Write a C++ program to perform various calculations related to the fuel economy of a vehicle where the fuel economy is modeling using a polynomial of the form $y = Ax^2 + Bx + C$, where

      y = fuel economy in miles per gallon (mpg)

      x = speed in miles per hour (mph)

In particular:

1. ***Inputs***: The user should be prompted to input the following information.
   - The values for coefficients A, B, and C used to model the fuel efficiency
   - The capacity of the fuel tank (in gallons).
   - The current amount of fuel in the tank (in gallons).
   - The current speed of the vehicle (in mpg)
   - The distance to be travelled on the current trip (in miles)
   - The cost per gallon for gasoline
   - The minimum speed, Smin, to be used in the table of Fuel Economy vs Speed
   - The maximum speed, Smax, to be used in the table of Fuel Economy vs Speed
   - The speed increment, Sinc, to be used in the table of Fuel Economy vs Speed

2. _**Functions**_: The program should use at least 4 user-defined functions (in addition to main) as described below.
- **MPG(A, B, C, Speed)** – This function returns the fuel economy in mpg for a given speed in mph.
- **PrintTable(Smin, Smax, Sinc A, B, C)** – This function will print a table of Speed (in mpg) and Fuel Economy (in mpg).
  - Use the range of speeds indicated with the speed increment indicated.
  - This function should call the function MPG above.
  - Fuel economy should be calculated using the coefficients A, B, and C provided.
  - Include a table heading with units.
  - Display speeds as integers and fuel economy with 2 digits after the decimal point (include trailing zeros).
- **MaxEconomy(Smin, Smax, Sinc A, B, C, MaxMPG, MaxMPH)** – This function will return the maximum mpg and the corresponding speed value using the speed range and increment specified. This function should call the function MPG above.
- Use at least one more useful (user-defined) function to calculate one or more of the program outputs.
3. _**Outputs**_: The program output should include the following:
- Neatly summarize the input values
- A table of Speed and Fuel Economy values (created by the PrintTable function above).
- The maximum fuel economy (in mpg) and the corresponding speed (determined by the MaxEconomy function above).
- The fuel economy (in mpg) at the current speed
- The minimum fuel economy (in mph) and the corresponding speed. Note: This does not always occur at the minimum speed.
- For the current speed, trip distance, number of gallons currently in the tank, and cost per gallon for fuel (show the value of each), display the following:
  - The fuel economy (in mpg)
  - Speed for the trip (in mph)
  - The fuel cost for the trip.
  - The number of gallons that will be used for the trip.
  - The time to reach the destination.
  - State how many times you will need to stop for gas. Assume that the tank must be filled when it is 10% full.
  - State the number of gallons of gas will be left in the tank at the end of the trip.
  - State the number of miles until the next time the tank must be filled (after the trip).
- Repeat the above if you drive at the speed for maximum fuel economy. Also state how many gallons of gas were saved and how much money was saved by driving at the speed for maximum fuel efficiency.
- Use a suitable number of digits for all numeric outputs and include units when appropriate.
4. _**Error Checks**_: The program should check for appropriate ranges for inputs and allow the user to re-enter any incorrect inputs, including:
- Fuel tank capacity: 0 to 20 gallons
- Current amount of fuel in tank: 20% - 100% of fuel tank capacity
- Current speed of vehicle: 20 to 80 mph
- Distance to be travelled: Must be > 0
- Cost per gasoline: Must be > 0
- Minimum speed for table (Smin): Integer value where $20 \leq Smin < 50$
- Maximum speed for table (Smax): Integer value where $(Smin + 10) < Smax \leq 80$
- Speed increment for table (Sinc): Integer value where $0 < Sinc \leq (Smax - Smin)/5$
5. _**Re-running the Program**_: Include a loop that will give the user the option of re-running the program.

Example: The output does not need to look exactly like this, but it should have the same information. Some results have been omitted.

A = -0.004
B = 0.45
C = 16
18.0 gallon fuel tank
17.0 gallons currently in the tank
Current speed: 40 mph
100 miles to be travelled
Gasoline cost: $2.50/gallon
Let S vary from 20 mph to 80 mph in 2 mph increments

Fuel Economy Table:

Speed (mph)	Fuel Economy (mpg)
20	23.40
22	23.96
.	
.	
80	26.60

Maximum Fuel Economy: 28.66 mpg at 56 mph
Current Fuel Economy: 27.60 mpg at 40 mph
Minimum Fuel Economy: 23.40 mpg at 20 mph

Trip Option #1:
Travelling 100 miles at 40 mph with 17.0 gallons currently in the tank and gas cost of $2.50:
- Fuel economy: 27.60 mpg
- Speed: 40 mph
- Fuel cost for the trip:
- Number of gallons that will be used for the trip:
- Time to reach the destination:
- Number of times to fill the tank:
- Number of gallons left in the tank after the trip:
- Number of miles until the next time the tank must be filled after the trip:

Trip Option #2:
Travelling 100 miles at 56 mph with 17.0 gallons currently in the tank and gas cost of $2.50:
- Fuel economy: 28.66 mpg
- Speed: 56 mph
- Fuel cost for the trip:
- Number of gallons that will be used for the trip:
- Time to reach the destination:
- Number of times to fill the tank:
- Number of gallons left in the tank after the trip:
- Number of miles until the next time the tank must be filled after the trip:
- Number of gallons saved by driving at maximum fuel economy (compared to speed in Option 1):
- Amount of money saved by driving at maximum fuel economy:

Program Testing: Print your results and include them with your report for the following four cases. Note that Case #1 is the same as the example above.

Case #	A	B	C	Fuel tank capacity (gallons)	Current fuel amount (gallons)	Current speed (mph)	Distance to be travelled (miles)	Cost per gallon	Min speed (mph)	Max speed (mph)	Speed Increment (mph)
1	-0.004	0.45	16	18.0	17.0	40	100	$2.50	20	80	2
2	-0.005	0.50	19	14.5	12.0	60	400	$2.50	20	80	4
3	-0.0025	0.32	24	16.0	5.0	65	200	$2.50	25	75	5
4	-0.006	0.51	27	15.5	14.0	76	1500	$2.50	30	80	2

Extra Credit Suggestions: (Earn up to 10 additional points. You don't need to do them all for 10 pts!)
1. Add lines to your table
2. Give the user the option of entering multiple speeds for different segments for the trip instead of a single speed for the entire trip. For example, the driver might travel on a 45 mph road for 10 miles, then a 55 mph road for 35 miles, then …
3. Give the user the option of work with US or SI units. If SI units are used, use speed in km/h, distances in km, fuel costs in $/liter. Also scale the ranges appropriately. For example, instead of 20 – 80 mph, multiply by about 1.6 and use 32 – 128 km/h. Similarly scale the fuel tank size for liters.
4. Store the values for speed and fuel efficiency in arrays.
5. Create a second table showing *cost of trip vs speed* for various gas prices (from a min value to a max value in $0.10 increments). For example (lines aren't necessary):
   Cost for trip of _____ miles:

	Cost of trip at noted price per gallon of gas				
Speed	$2.50	$2.60	$2.70	$2.80	$2.90
20					
22					
…					
80					

6. Create and use a library containing all of your functions.
7. Use your imagination!