

Abstract:

The main objective of this project is to design a program that will provide the user with the Moment Magnitude and the Richter scale magnitude of the earthquake under scrutiny, the average amount of TNT needed for that same amount of seismic energy yield, and an example of an occurrence or famous earthquake of similar magnitude. The program should help to emphasize the past consequences of earthquakes and varying degrees civil engineers should take to prepare future designs of structures.

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Introduction:

A common problem faced by many civil engineers is the risk involved with the occurrence of earthquakes. An unexpected earthquake can easily compromise the integrity of the structure, thus leaving the responsibility of damage assessment up to the civil engineer. Before damage assessment, one must first have a basic understanding of the meanings of earthquake movements and magnitudes. With the number of catastrophic earthquakes on the rise around the world, many numbers are thrown around with little regard or understanding of the true meaning of their effects on not only the people, but also the infrastructure and urbanization of the area. In order to broaden the basic understanding of this analytic part of the earthquake, a program must be created with a more subjective view in mind. With a few pieces of input, several types of analysis will be given. The main objective in the project is to provide a simple way to understand and use program that will provide the user with the Moment Magnitude and the Richter scale magnitude of the earthquake under scrutiny, the average amount of TNT needed for that same amount of seismic energy yield, and an example of an occurrence or famous earthquake of similar magnitude. The only input required will be the shear modulus of crustal volume containing the fault (also known as the rock rigidity), the fault area undergoing the slip, and the relative slip along the ruptured fault. This report contains information on the theory behind the various scales of earthquake magnitudes and how they are calculated. From this information, the program will be created and implemented. Once the program is running correctly, the report will outline the proper way to use and read the program. The program in addition to this report should allow not only civil engineers but also any other person to grasp a better comprehension of the magnitude of earthquakes and their effect on society.

Method:

In order to be able to effectively handle the abundance of data associated with earthquake occurrences, we created a program that would easily output information on the earthquake being studied. The user inputs the shear modulus of crustal volume (μ , better known as the rock rigidity) in $\text{dyne}/(\text{cm}^2)$, the fault area undergoing the slip in cm^2 (A), and the relative slip along the ruptured fault (cm)(d). This information

can be found from the basic geological information measured after the occurrence of the fault. This empirical data is measured directly from the earthquake site based on the amount of displacement, the depth of the earthquake and the rock type at the site. From this information, the moment magnitude (M_0) is calculated from the following equation:

$$M_0 = u * A * d$$

This value is based upon a measure of the three-dimensional volume of the slipped fault. Even though the Richter scale is still the more widely known magnitude scale, the moment magnitude is quickly emerging as the preferred magnitude scale since it is the most accurate in the magnitude range above 6 and it is independent of the measuring instrument unlike the Richter magnitude scale.

The Richter magnitude scale was created originally in order to assign a single numerical value to an earthquake that represents an absolute measurement of its size based on the local values for southern California. The moment magnitude is based on the same idea, but it does not depend on the instrument. However, the Richter scale is based on the log base-10 of the maximum amplitude of the seismic wave. Hence, in the Richter scale, a single point increase in the magnitude means a tenfold increase in earthquake magnitude. This information coupled with the following equation leads to the second calculation of the program of converting the moment magnitude to the Richter scale.

$$M_n = (2/3) * ((\log (M_0) / \log (10)) - 1.6)$$

Based on the value of the Richter scale, the final step was to make it in a more subjective language that could be understood by the human mind. Since people usually have a hard time visually quantifying numerical values, the program also outputs the amount of TNT needed to create movement of that magnitude as well as output common occurrences or famous earthquakes of that magnitude and their notable consequences.

A final scale that was left out of the program, but is important to make note of it is the Mercalli Intensity scale. It is a very subjective way to classify earthquakes based on the movement felt by people, the effects on buildings and infrastructure, and the alteration of landforms. The main downside of this scale is that it can vary greatly for any given earthquake depending on the location. In a rural area, an earthquake of very high Richter or moment magnitude would have a very low intensity, as there is little to have impact on. On the other hand, even the smallest of earthquakes can have a very catastrophically high intensity when put in the middle of a highly industrial, urbanized area not originally designed for earthquakes.

Results:

Using the theories and equations presented in the methods behind the program, a program was created as follows:

```
Private Sub calculate_Click()

Dim Mo As Double, Mo2 As Double, u As Double, A As Double, d As Double
Dim Mn As Double, x As Double

'u= Rock Rigidity (dyne/cm^2)
'A= Fault Area Undergoing Slip (cm^2)
'd= Slip Distance (cm)

u = Text1.Text
A = Text2.Text
d = Text3.Text

'Mo = Seismic Moment in Dyne-cm

Mo = u * A * d

If Mo < 0 Then
    picoutput1.Print "Error: Negative Mo, Please End or enter numbers again."
End If

'Put Mo in terms of Newton-Meters
'1 N-m = 10^7 dyne-cm

Mo2 = Mo / (10 ^ 7)

picoutput1.Print Mo2

'To calculate the Richter Scale Value
'Mn = Richter Scale Value

Mn = (2 / 3) * ((Log(Mo) / Log(10)) - 16)

If Mn < -2 Or Mn > 13 Then
    picoutput2.Print "Error: Not a value on the Richter Scale. Please try again"
End If

picoutput2.Print Mn
```

'Next set the output for the equivalent TNT yield

x = Mn

```
If x < -2 Or x > 13 Then
    picoutput3.Print "Error: Insignificant Value, please try again."
End If
If x >= 2 And x < 2.5 Then
    picoutput3.Print "1 ton"
End If
If x >= 2.5 And x < 3 Then
    picoutput3.Print "4.6 tons"
End If
If x >= 3 And x < 3.5 Then
    picoutput3.Print "29 tons"
End If
If x >= 3.5 And x < 4 Then
    picoutput3.Print "73 tons"
End If
If x >= 4 And x < 4.5 Then
    picoutput3.Print "1,000 tons"
End If
If x >= 4.5 And x < 5 Then
    picoutput3.Print "5,100 tons"
End If
If x >= 5 And x < 5.5 Then
    picoutput3.Print "32,000 tons"
End If
If x >= 5.5 And x < 6 Then
    picoutput3.Print "80,000 tons"
End If
If x >= 6 And x < 6.5 Then
    picoutput3.Print "1 million tons"
End If
If x >= 6.5 And x < 7 Then
    picoutput3.Print "5 million tons"
End If
If x >= 7 And x < 7.5 Then
    picoutput3.Print "32 million tons"
End If
If x >= 7.5 And x < 8 Then
    picoutput3.Print "160 million tons"
End If
If x >= 8 And x < 8.5 Then
    picoutput3.Print "1 billion tons"
End If
If x >= 8.5 And x < 9 Then
    picoutput3.Print "5 billion tons"
End If
If x >= 9 And x < 10 Then
    picoutput3.Print "32 billion tons"
End If
If x >= 10 And x < 12 Then
    picoutput3.Print "1 trillion tons"
End If
If x >= 12 Then
    picoutput3.Print "160 trillion tons"
End If
```

'Next set the output for similar magnitude events

```
If x < -2 Or x > 13 Then
    picoutput4.Print "Error: Insignificant Value, please try again."
End If
If x >= 2 And x < 4 Then
    picoutput4.Print "Large Quarry or Mine Blast"
End If
If x >= 4 And x < 4.5 Then
```

```

    picoutput4.Print "Small Nuclear Weapon"
End If
If x >= 4.5 And x < 5.5 Then
    picoutput4.Print "Average Tornado (total energy)"
    picoutput4.Print "Rocky Mountain Arsenal, Denver, CO"
    picoutput4.Print "---- Over 700 earthquakes due to waste water injection into deep well"
End If
If x >= 5.5 And x < 6 Then
    picoutput4.Print "Litte Skull Mountain, NV Quake, 1992"
End If
If x >= 6 And x < 6.5 Then
    picoutput4.Print "Double Spring Flat, NV Quake, 1994"
End If
If x >= 6.5 And x < 7 Then
    picoutput4.Print "Northridge, CA Quake, 1994"
    picoutput4.Print "----Most costly earthquake in U.S. history, $20 billion"
End If
If x >= 7 And x < 7.5 Then
    picoutput4.Print "Hyogo-Ken Nanbu, Japan Quake, 1995"
    picoutput4.Print "----Over 6 thousand people killed, $300 billion damage"
End If
If x >= 7.5 And x < 8 Then
    picoutput4.Print "Landers, CA Quake, 1906"
End If
If x >= 8 And x < 8.5 Then
    picoutput4.Print "San Francisco, CA Quake, 1992 (San Andreas Fault)"
End If
If x >= 8.5 And x < 9 Then
    picoutput4.Print "Anchorage, AK Quake, 1964"
    picoutput4.Print "----damaging tsunami in CA, shoreline rise of 33 ft, excessive damage to moderately tall buildings"
End If
If x >= 9 And x < 10 Then
    picoutput4.Print "Chilean Quake, 1960"
End If
If x >= 10 And x < 12 Then
    picoutput4.Print "(San-Andreas type fault circling Earth)"
End If
If x > 12 Then
    picoutput4.Print "Fault in the center of the Earth"
End If

End Sub

Private Sub Command1_Click()

End

End Sub

```

When the user starts the program, they will see a screen like the following. In the three text boxes on the right, they will input the data corresponding to the labels to the left of each box as shown:

Earthquake Magnitude

Earthquake Analysis:

Rock Rigidity (dyne/cm²) =

Fault Area Undergoing Slip (cm²) =

Slip Distance (cm) =

Calculate!

Moment Magnitude, Mo (N-m) =

Value on the Richter Scale =

TNT for Seismic Energy Yield =

Example of Similar Magnitude Event on Richter Scale:

Exit!

The only step the user must take from here is clicking on the calculate button, which will then prompt the program to output the Richter scale equivalent, the TNT amount for equivalent movement, and the example of a similar magnitude event as shown:

Earthquake Magnitude

Earthquake Analysis:

Rock Rigidity (dyne/cm²) =

Fault Area Undergoing Slip (cm²) =

Slip Distance (cm) =

Calculate!

Moment Magnitude, Mo (N-m) =

Value on the Richter Scale =

TNT for Seismic Energy Yield =

Example of Similar Magnitude Event on Richter Scale:

Exit!

In the event that the user inputs an impossible value in the text boxes such as a negative fault area or slip distance or a number that results in an impossibly small Richter scale value, an error message will be output prompting the user to press the exit button and try again as shown:

The screenshot shows a window titled "Earthquake Magnitude" with a standard Windows-style title bar. The window contains the following elements:

- Inputs:** Three text boxes on the right side for "Rock Rigidity (dyne/cm²) = 1", "Fault Area Undergoing Slip (cm²) = 2", and "Slip Distance (cm) = 3".
- Buttons:** A "Calculate!" button in the center and an "Exit!" button on the right.
- Output Fields:**
 - "Moment Magnitude, Mo (N-m) =": 0.0000006
 - "Value on the Richter Scale =": Error: Not a value on the Richter Scale. Please try again. -15.4812324997442
 - "TNT for Seismic Energy Yield =": Error: Insignificant Value, please try again.
 - "Example of Similar Magnitude Event on Richter Scale:": Error: Insignificant Value, please try again.

Finally, when the user is done with the program, he/she can conveniently click on the exit button to end the program.

Conclusions:

By understanding the past consequences of earthquakes and varying degrees of preparation by civil engineers, future designs of structure can take into account the risk of earthquakes. Even more importantly, some of the earthquakes can even be prevented. Although most are due to natural continental drift and other uncontrollable reasons, a few have been cause by human miscalculations in well pumping, nuclear weapon testing, and reservoir filling. A major example of human error in earthquakes can be seen in the 1960s incident

where more than 700 earthquakes were started in the Denver, CO area due to the injection of wastewater in a deep well. If the people have a better understanding of the consequences of their actions, some of these catastrophic accidents can be prevented.

When researching and trying to write the program, a vast amount of data on earthquakes was presented. In the search for data on magnitude scales, we realized that there is so much more complexity in the calculations of an earthquake. The sources we used were devoted solely to the seismic effects on structures. In California especially, this remains a top concern for civil engineers. Although the program that was created worked to achieve the function specified in the problem statement, it could have been taken so much farther. For the problem of understanding the meaning of the varying magnitude scales, the program exceeded expectations. It provided not only a Richter scale conversion but also information on similar event in the past and the amount of TNT needed to create a movement of the same magnitude. This data allows even the most novice users to comprehend the power behind the earthquake they are studying.

On the other hand, after seeing how much information is available, the program could have involved more complexities if time had allowed. With the proper resources, a large database of earthquake equations and calculations could have been created. It could have included graphs of the wave propagation of the various surface and body waves. Also, in order to simplify the use of the program even more, it could also provide a calculation in the other direction from the Richter scale to the moment magnitude scale or using the aforementioned intensity scale for a more visual approach to earthquake magnitudes.

References:

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Appendix:

Richter Magnitude	TNT for Energy	Example of Equivalent Magnitude
2.0	1 ton	Large Quarry or Mine Blast
2.5	4.6 tons	
3.0	29 tons	
3.5	73 tons	
4.0	1,000 tons	Small Nuclear Weapon
4.5	5,100 tons	Average Tornado (total energy) Rocky Mountain Arsenal, Denver, CO (Over 700 earthquakes due to waste-water injection into deep well)
5.0	32,000 tons	
5.5	80,000 tons	Little Skull Mtn., NV Quake, 1992
6.0	1 million tons	Double Spring Flat, NV Quake, 1994
6.5	5 million tons	Northridge, CA Quake, 1994 (Most costly earthquake in U.S. history, \$20 billion)
7.0	32 million tons	Hyogo-Ken Nanbu, Japan Quake, 1995(Over 6,000 people killed, \$300 billion damage); Largest Thermonuclear Weapon
7.5	160 million tons	Landers, CA Quake, 1992
8.0	1 billion tons	San Francisco, CA Quake, 1906 (San Andreas Fault)
8.5	5 billion tons	Anchorage, AK Quake, 1964 (Damaging tsunami in CA, shoreline rise of 33 ft., excessive damage to moderately tall buildings)
9.0	32 billion tons	Chilean Quake, 1960
10.0	1 trillion tons	(San-Andreas type fault circling Earth)
12.0	160 trillion tons	(Fault Earth in half through center, OR Earth's daily receipt of solar energy)