Workshop on

Spreadsheet in Engineering

Session: Calculations Using Spreadsheet

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P. K. Yadav & C. Gupta
chhavi.gupta@sharda.ac.in.

Department of Civil Engineering

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Solving Engineering Problem with Spreadsheet

The **data organization** is one aspect of **Spreadsheet**.

The real power of the **Spreadsheet** is on solving **Engineering Problems**.

Problem solving involves: **Application of Formula** and very often also **Plotting**.

Plotting requires **Several Results**- and is time consuming process otherwise, e.g. using calculator.

Spreadsheet **speeds-up** generation of several results.

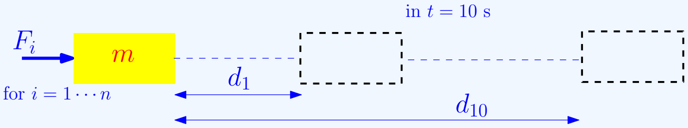
Let us get motivated from solving a simple problem using **Spreadsheet**.

Motivation II

The Classical Physics Problem: $F = ma$

Assume that m is to be obtained from $F = ma$; and that your lab has device to measure F, d and t. How will we calculate m

We really need to set-up an experiment. Where we apply several forces F_i with $i = 1 \cdots 10$ and measure different d_i over a fixed t.



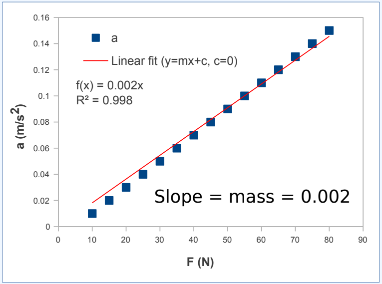
Once we get all the d_i, we set up the **Spreadsheet** to obtain $v = d/t$ and then $a = v/t = d/t^2$.

We then plot a_i against F_i.

Motivation III

The Classical Physics Problem: $F = ma$

Finally we fit the plot with the straight line equation $y = mx + c$ with $c = 0$, to find m as a slope of the fit line.



$$R^2 = \frac{\sum(\hat{a}_i - \bar{a})^2}{(a_i - \bar{a})^2}$$

for $i = 1 \cdots 10$, with $\bar{a}$ = average a, and $\hat{a}$ = a on the fit line corresponding to the observed a_i.

This all will require more time if done without **Spreadsheet**.

Calculations in Spreadsheet I

Operators and computation

Calculation mode is activated on placing **“=”** in the cell.

Operator	Name
+	Addition
-	Subtraction
$*$	Multiplication
/	Division
$\wedge$	Exponential
$<$ / $>$	less/greater than
$<=$ / $>=$	less/greater than or equal to

Spreadsheet uses conventional **mathematical operators** and **operators precedence**.

The operators can be used in a single cell, in a row or row-wise, in a column or column-wise or in any combination of all of them.

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Operators Precedence and Calculation

Calculations requiring several operators, the following **operator precedence** is followed in the **Spreadsheet** computation.

Symbol	Precedence
$\wedge$	1
/ or $*$	2
$*$	2
+ or -	3
&	4
$<$ or $>$	5

Of course! the operators within brackets have higher precedence. The innermost bracket have the highest precedence.

Functions

Ability to apply **Functions** is the most useful aspect of **Spreadsheet** for Engineers.

Function basically is relationship between an input providing an output.

The following are the most important functions:

1. Algebraic Function (e.g. Polynomial, Square root, Rational, Constant function)
2. Elementary transcendenta Functions (e.g. Exponential, Logarithmic, Trignometric, Power)

Spreadsheet provide an easy method to use these function or set of functions. Ideally, it is like doing “NUMERICALS” in a computer.

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Functions

In **Spreadsheet** the function can be used by:

$$= \textbf{Function name(INPUT)}$$

where,

The Function Name are single worded mathematical function names such as:
`log`, `sin`, `exp`, `sum`, `average`, and many hundreds of them.

`INPUT` can be a single value in a **cell** or the range of values row-wise or column-wise.

E.g., Placing `=log(10)` in any cell will provide an **output** 1 and `PI()` provides the value of π

Let us try these -

Link to list of **Spreadsheet** functions

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A simple Engineering Formula

A **Formula** is a combination different variables using different operators and/or functions.

A simple example :

Volume of a Cylinder:

$$V = \frac{\pi D^2 h}{4}$$

We get the **output**, (V), with **inputs** D, π and h. The inputs are required to be multiplied, squared and then divided (**operations**). In short: $V = f(D, h)$

Let us try in **Spreadsheet** $V = f(D, h)$.

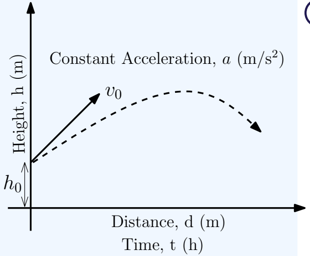
A simple Engineering Formula

Let us now try the classical physics projectile formula.

At constant acceleration ***a***, at any time (t):

Height, $h = \frac{1}{2}at^2 + v_0 t + h_0$

and Velocity, $v = at + v_0$

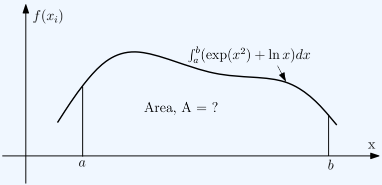


Let us try in **Spreadsheet** to obtain h and v.

Complex Calculations I

Integration

Finding area under simple directly integrable curves are straight-forward.
We find area under the curve that is not directly integrable .



$I = \int_a^b f(x)dx$ = area under curve

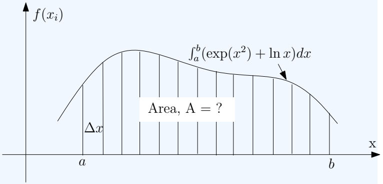
$I = \int_a^b (\exp(x^2) + \ln x)dx$

Integration

We divide the area under the curve with a increment Δx. Let us fix $a = 1$ and $b = 2$.

$$I = \int_1^2 f(x)dx \approx \Delta x \sum_{i=1}^{2} f(x_i)$$

$$f(x) = (\exp(x^2) + \ln x)dx$$



Let us implement the scheme in **Spreadsheet**.

You may want to try the scheme using numerical integration methods: Trapezoidal rule, Simpson's method.

Complex Calculations III

Differential Equation

We now attempt to solve differential problem in **Spreadsheet**.

Let us solve the classical Newton's falling apple problem.

$$
\begin{aligned}
ma &= F \\
m\frac{dv}{dt} &= F_D - F_U \\
&= mg - cv
\end{aligned}
$$

Or

$$\frac{dv}{dt} = g - \frac{c}{m}v$$

We will try to implement the scheme in **Spreadsheet**.

Differential Equation

The exact solution of the problem for $v = 0$ at $t = 0$ is:

$$v(t) = \frac{gm}{c}\left[1 - e^{-(c/m)t}\right]$$

The function $v(t)$ can be approximated by difference, using:

$$\frac{dv}{dt} \approx \frac{\Delta v}{\Delta t} = \frac{v(t_{i+1}) - v(t_i)}{t_{i+1} - t_i}$$

So, our equation becomes

$$\frac{v(t_{i+1}) - v(t_i)}{t_{i+1} - t_i} = g - \frac{c}{m} v$$

or $$v(t_{i+1}) = v(t_i) + \left[g - \frac{c}{m} v(t_i)\right](t_{i+1} - t_i)$$

Complex Calculations V

Differential Equation

The velocity equation can be interpreted as:

$$\underset{\text{New value}}{v(t_{i+1})} = \underset{\text{Old value}}{v(t_i)} + \left[\overset{\text{Constant}}{g} - \underset{\text{Old value*Constant}}{\frac{c}{m}v(t_i)}\right] \underset{\text{Time step-size}}{(t_{i+1} - t_i)}$$

Let us implement the above scheme in **Spreadsheet** using:

- $m = 0.15$ Kg
- $c =$ Drag Coeff. $= 0.025$ Kg/s
- $g = 9.8$ m/s^2
- $t_i = 0$
- $\Delta t = 2$ s

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That was introduction to using **Spreadsheet**. Let us get advanced

and learn to visualize maths.

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