Module #2 – Some Physics Engr 124 – Excel, F20	Name (LAST, First)

"Only" two problems.

Objective: To use Excel to:
- solve trajectory problems with single-value outputs;
- create a table to generate trajectory data, and plot that data;
- solve mass-ramp-friction problems with single-value outputs;
- create a table to generate friction force vs. ramp angle data, and plot that data.

Instructions
- Answer each problem on a different worksheet in <u>one</u> workbook (one Excel file).
- Rename each worksheet with a one or two-word title that is descriptive of the problem.
- Save an electronic copy of your file for reference. Name the file: Last_name_Mod_2.xlsx, e.g., Hancock_Mod_2.xlsx.
- When you have completed all the problems in the module, upload the Excel file (workbook) to the Canvas web site for ENGR 124.

Formatting
- In the first Column (A), and in the first 3 rows of each worksheet, enter your Name (in A1), the Problem Title (A2) and the Date completed (A3).
- Start all work below Row 4.
- Make sure that you format each worksheet and use appropriate text (titles, prompts, etc.) so:
    (1) someone who opens the worksheet knows what the worksheet does, and
    (2) the user can easily use the sheet.
    (3) It looks good (background fill, borders, font).

Problem 1: *The Classic Projectile Problem*

(a) Create a worksheet to solve the standard projectile problem
Make sure you label and format the spreadsheet so a user can figure out what to enter. You are creating the worksheet as a tool for someone else to use. Refer to the sample set-up in *Fig. 2.1* below. You will be provided with the equations to implement in Excel; so complete understanding of the physics is not necessary.

- The projectile will start at $x_o = 0$ and $y_o = 0$. Neglect air resistance.
  Assume the acceleration of gravity g is constant for a given problem, but could be changed (for different locations on earth, or different planets).

- You must have the following **inputs**:
    (1) initial speed of the projectile v_o (m/s)
    (2) initial angle for the projectile's velocity above the x-axis θ (degrees),
        -to get the Greek letter theta θ, enter "q". In the **Formula Bar**, select only the letter q, and then **Home Tab/Font(Format Cells)/Font**: select the **Symbol** font
    (3) the acceleration of gravity g (m/s^2).
        -to get the 2 as a *superscript*, in the **Formula Bar** select the number 2, and then **Home Tab/Font(Format Cells)/Font**: check **Superscript**

- The **outputs** must be:
  (1) initial x-velocity v_{ox} [m/s] – i.e., the initial horizontal velocity)
  (2) initial y-velocity v_{oy} [m/s] – i.e., the initial vertical velocity)
  (3) range R [m] – how far the projectile goes before returning to $y = 0$
  (4) maximum height h [m] – maximum height that the projectile reaches
  (5) time in air t_{air} [sec] – assuming a level ground, the time to return to $y = 0$
  (6) dt [sec] – the time increment to break t_{air} into 20 equal increments
  (7) a table of t-, x- and y- values
  (8) plots of x vs. t and y vs. t <u>on the same graph/chart</u> (t on horizontal axis)
  (9) plot of y vs. x – this is the **trajectory**, or path of the projectile.

Figure 2.1 Sample Projectile Worksheet. Format your own worksheet so the user knows what to input when they open the file. Do not forget to italicize your variables. The "Time and Position" displaced in Row 19 is the start of my table for the *t-x-y* data for the trajectory.

- **Equations**
  The necessary output equations are given it *Table 2.1* (see *Figure 2.2* for typical trajectory). Assume the initial position is ($x_o = 0$ and $y_o = 0$).

Table 2.1 Equations used to generate output for Trajectory Problem.

(1) $v_{ox} = v_o\cos\theta$	the angle θ in the formula must be in radians (do not forget to convert since the input in degrees)
(2) $v_{oy} = v_o\sin\theta$	
(3) $R = \dfrac{v_o^2\sin2\theta}{g}$	Range (x-direction distance that the projectile has travelled when it returns to $y=0$); note the angle in the sine function is 2θ.
(4) $h = \dfrac{v_o^2\sin^2\theta}{2g}$	Maximum height of trajectory (flight path)
(5) $t_{air} = \dfrac{2v_o\sin\theta}{g}$	Time in air (time to return to $y = 0$); see note below.

(6) $dt = \dfrac{t_{air}}{20}$	the time interval ("delta-t" Δt) that will give 21 evenly spaced data points from $t = 0$ to $t = t_{air}$. See note below.
(7a) $x = v_{ox}t$	x as a function of time (with $x_o = 0$)
(7b) $y = v_{oy}t - \dfrac{1}{2}gt^2$	y as a function of time (with $y_o = 0$)

- t_{air}, dt: From the input, you will calculate 21 data points for the t-x-y table. The last data point should be when the projectile returns to $y = 0$. The user should not need to determine the time t_{air} when the projectile returns to $y = 0$, nor the **time step dt** (the difference in time values in the table). The spreadsheet should be set up so that Excel will automatically calculate t_{air} and dt values from the three inputs. Do not calculate t_{air} or dt by on your calculator. Set Excel up to do it for you and use the variable quantities in the table.
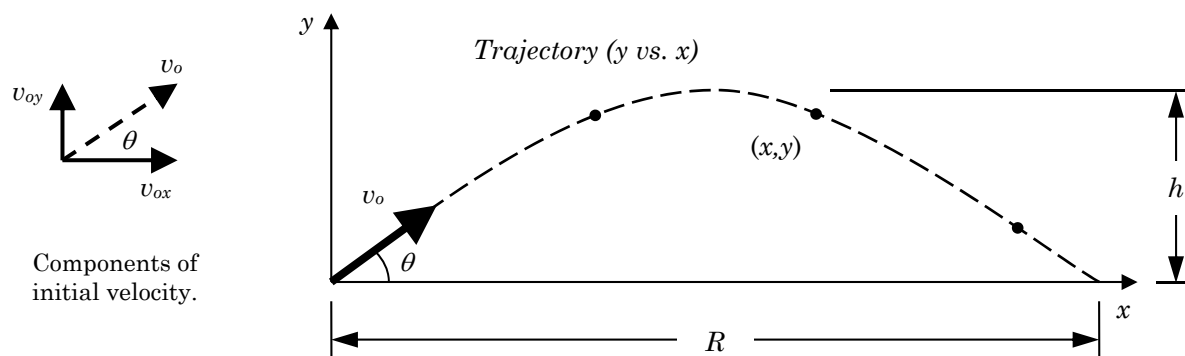

Figure 2.2 Trajectory (y vs. x) of a projectile, with initial speed v_o at angle θ.

- **All** of the t, x, y data in the table should be created using formulas, except for the first value of t, which is zero (0). Copy the formulas downward. The table should be automatically updated for any new inputs (i.e., v_o, θ and g can change, which means t_{air} and dt change, etc.).

- Remember, the last data points should correspond to the values for t, x and y of t_{air} , R and 0, respectively.

- Make sure that you use **absolute references** for formulas that need them (e.g., gravity).

- Note that every table will have 21 rows, so that every plot will have 21 data points, and thus all plots will have the same relative smoothness, not matter how large the numbers are.

(b) Outputs (8), (9): For the projectile problem, create two *x-y scatter plots*

(I) x vs. t <u>and</u> y vs. t on <u>one</u> graph/chart (*x*- and *y*-values should both be on the vertical axis), and

(II) y vs. x (the *trajectory*).

As a test case, for the initial velocity, angle and gravity, use, $v_o = 40.0$ m/s, $\theta = 30.0^\circ$, $g = 9.81$ m/s²

For these input values: $R = 141.2$ m, $h = 20.4$ m , $t_{air} = 4.08$ sec.

Experiment with different values of v_o, θ , and g. On the moon: $g = 1.63$ m/s², on Mars: 3.73 m/s²).

Properly label your graphs … graph title, axis titles and units, numbers, etc.

(c) In lab, ask your instructor to verify your worksheet (*show it off*)

Problem 2: *Mass on a Rough Inclined Plane*

(a) Create a spreadsheet that calculates the Normal Force n, the Friction Force F and the Acceleration a of a block of mass m released (let go) from rest on an inclined plane (ramp) with friction (*Fig. 2.3*).

(a)

- The **inputs** should include:
  - (1) mass m (kg)
  - (2) ramp angle θ (degrees, Symbol font "q")
  - (3) coefficient of static friction μ_s (Greek "mu"; apply the Symbol font to "m", subscript format for "s")
  - (4) coefficient of kinetic friction μ_k

(b)

- The **outputs** should include:
  - (1) **normal force** n [units: newtons, N] (the perpendicular force from the ramp on the block)
  - (2) **friction force** F [N] (parallel to the ramp; due to the roughness of the surfaces)
  - (3) **acceleration** a [m/s²] of block down ramp.

- There are three possible possibilities when the block is released:
  - (1) the block stays in place
  - (2) the block stay in place but is just about to slide (called *impending motion*)
  - (3) the block slides down the ramp.

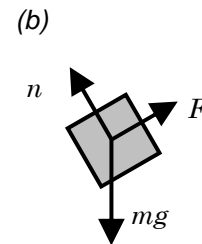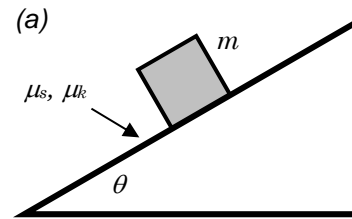 What actually happens depends on the values of $W\sin\theta$ and $\mu_s n$.

Figure 2.3 (a) Block on an inclined plane. (b) Free Body Diagram of block.

- **Equations** (remember that angles in Excel trig. functions must be in radians).

  The equations needed to set up the problem are given in *Table 2.2*. The equations that determine the response of the block are given in *Table 2.3*.

Table 2.2 Equations to Determine Response of Block on Inclined Plane Problem.

Quantity	Equation
Gravity	$g = 9.81$ m/s² (not a user input put)
Weight of Block	$W = mg$ [newtons, N]
Normal Force	$n = W \cos\theta$ [N]
Force "pulling" block down ramp	$W\sin\theta$ [N] (the object's weight tries to make it slide)

*Note: remember the angle used in the cosine and sine functions must be in radians.

Table 2.3 Equations to Determine Response of Block on Inclined Plane Problem.

Case (compare $W\sin\theta$ and $\mu_s n$)	Friction Force [N]	Acceleration [m/s²]
1. No Sliding ($W\sin\theta < \mu_s n$)	$F = W\sin\theta$	0
2. Impending Motion ($W\sin\theta = \mu_s n = F_{max}$)	$F = \mu_s n$	0
3. Sliding ($W\sin\theta > \mu_s n$; use kinetic friction coefficient)	$F = \mu_k n$	$a = g\sin\theta - \mu_k g\cos\theta$

(b) Extend the ideas of **Part (a)** to generate a table that gives Friction Force vs. Ramp Angle for ramp angles from 0 to 45 degrees. In other words, vary θ. Use $\mu_s = 0.3$, and $\mu_k = 0.25$, $m = 10.0$ kg, and $g = 9.81$ m/s². Increment the angle by one 1.0 degree ($\theta = 1, 2, 3 \ldots 44, 45°$).

- **Plot the data on an F vs. θ scatter plot.** Plot θ in degrees.
  The plot should have a shape something like *Fig. 2.4*.
  You should **title the plot, label the x-axis (σ, degrees), include numbers, etc**.
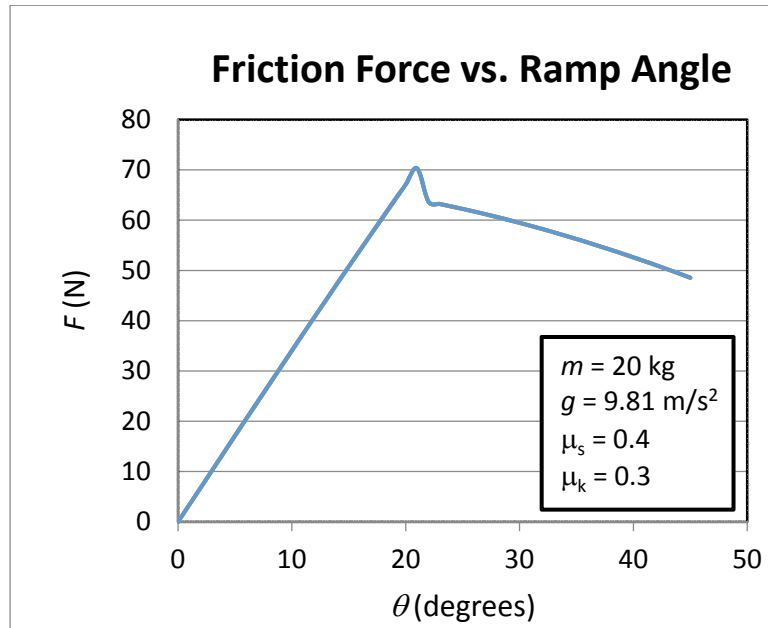 Remove or minimize the markers (points).

Figure 2.4 Example Friction Force vs. Ramp Angle graph. Note the graph is titled, the axes are labelled with variable and units, annotation box indicating key input values.