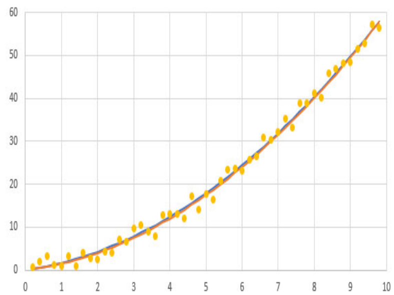


24-780 B—ENGINEERING COMPUTATION

Assigned: Wed. Sept. 8, 2021
Due: Tues. Sept. 14, 2021, 11:59pm

Problem Set 2: Regression and Bounce

PS2-1 Least Squares Method for Quadratic Curve Fit (35%)

In engineering, we are often required to covert experimental data to more usable mathematical expressions. For this assignment, you are asked to use the *least squares* approach to curve fitting (to be discussed in lecture, but you may also look it up or ask for further clarification) to find and output the coefficients a_1 and a_2 of a quadratic spring curve of the type:

$$F = a_1 x + a_2 x^2$$

A sample set of experimental data is provided in the attached txt file (partially shown at right, and charted above, with solution a1 = 1.1607, a2 = 0.48501), but your program should be able to provide the values of a_1 and a_2 for any data set in the given format. Your program should ask the user for the input filename.

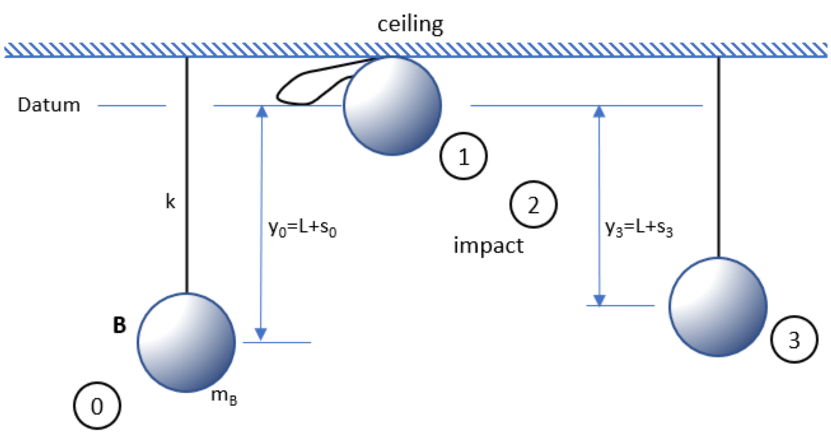
```
0.2    0.657
0.4    1.914
0.6    3.235
0.8    1.213
1      0.809
1.2    3.150
1.4    0.960
1.6    4.045
1.8    2.660
2      2.403
2.2    4.246

. . .
```

It is likely you will need to work this out "on paper" before you try to code it.

PS2-2 Ball up-bounce Quiz (65%)

Write a program that randomly creates a *unique* kinetics problem of the type shown in the attached example. Allow your program to generate reasonable random values for the problem parameters (mass, cord stiffness, coefficient of restitution, cord length, and initial stretch) as indicated below. Then, present your problem to the user and ask for the resulting final cord stretch (s_3). Assume that the user has access to the following diagram showing all parameter labels:



Where:

→ Cord has an unstretched length L and stiffness of k.

→ Ball has mass m_B and is pulled down a distance of s_0 before being let go.

→ The coefficient of restitution between ball and ceiling is e.

→ s_3 is the final maximum stretch of the cord after impact.

Let the value of the mass be a uniformly distributed random number varying from 1.0 to 2.5 kg, rounded to one decimal place. Similarly, let L vary from 0.8 to 1.5 meters, rounded to one decimal place, and s_0 be a length that varies from 15% to 40% of the selected L value, rounded to two decimal places. Let k vary from 500 to 1000 N/m, rounded to 50 N/m. The coefficient of restitution should vary from 0.6 to 0.9, rounded to two decimal places. Note that with some parameter combinations, the ball not actually hit the ceiling like it does in the example (which makes the answer a bit boring, but that's life).

Your program needs to present the problem to the user using language very similar to that used in the attached example, with the unique values substituted accordingly, then ask the user to enter the answer for s_3. Then, the program determines if the answer is correct, also providing a measure of error.

Deliverables

2 files, very appropriately named:

ps02leastsquares_yourAndrewID.cpp

ps02upbounce_yourAndrewID.cpp

Upload the files to the class Canvas page before the deadline (Tuesday, Sept.14, 11:59pm).

Hint: Even if you name your file appropriately, be sure to include your full name within the code itself (perhaps as a comment block at the top of the file). It is also appropriate to include date and course info, plus a short description of what the program does. (Think about what part of the text in the assignment write-up can be copy/pasted or adapted for this purpose.)

Learning Objectives

Developing simple algorithms

Making use of console input/output

Using functions effectively

Searching references (online and/or textbook) for C++ library functions.

EXAMPLE 15–10

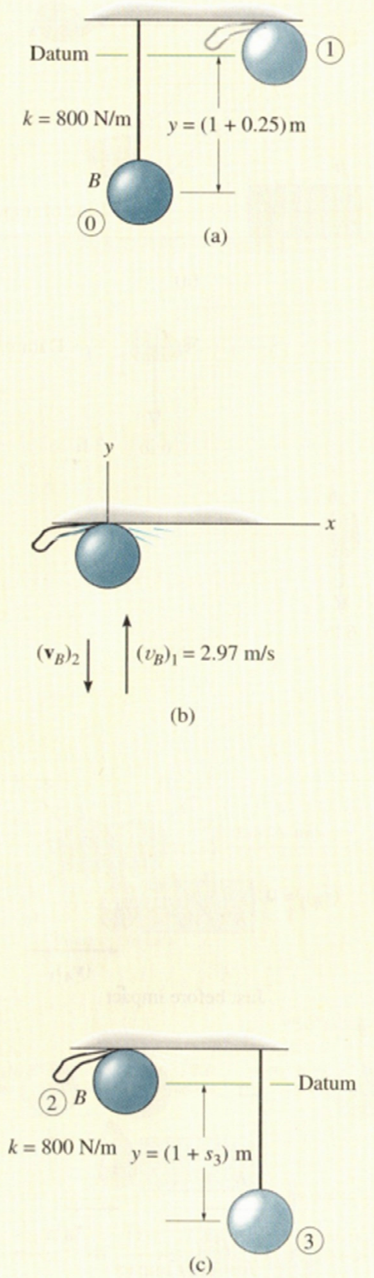


Fig. 15–17

The ball B shown in Fig. 15–17*a* has a mass of 1.5 kg and is suspended from the ceiling by a 1-m-long elastic cord. If the cord is *stretched* downward 0.25 m and the ball is released from rest, determine how far the cord stretches after the ball rebounds from the ceiling. The stiffness of the cord is $k = 800$ N/m, and the coefficient of restitution between the ball and ceiling is $e = 0.8$. The ball makes a central impact with the ceiling.

Solution

First we must obtain the velocity of the ball *just before* it strikes the ceiling using energy methods, then consider the impulse and momentum between the ball and ceiling, and finally again use energy methods to determine the stretch in the cord.

Conservation of Energy. With the datum located as shown in Fig. 15–17*a*, realizing that initially $y = y_0 = (1 + 0.25)\text{ m} = 1.25\text{ m}$, we have

$$T_0 + V_0 = T_1 + V_1$$
$$\tfrac{1}{2}m(v_B)_0^2 - W_B y_0 + \tfrac{1}{2}ks^2 = \tfrac{1}{2}m(v_B)_1^2 + 0$$
$$0 - 1.5(9.81)\text{ N}(1.25\text{ m}) + \tfrac{1}{2}(800\text{ N/m})(0.25\text{ m})^2 = \tfrac{1}{2}(1.5\text{ kg})(v_B)_1^2$$
$$(v_B)_1 = 2.97\text{ m/s}\uparrow$$

The interaction of the ball with the ceiling will now be considered using the principles of impact.* Since an unknown portion of the mass of the ceiling is involved in the impact, the conservation of momentum for the ball–ceiling system will not be written. The "velocity" of this portion of ceiling is zero since it remains at rest *both* before and after impact.

Coefficient of Restitution. Fig. 15–17*b*.

$$(+\uparrow)\; e = \frac{(v_B)_2 - (v_A)_2}{(v_A)_1 - (v_B)_1};\quad 0.8 = \frac{(v_B)_2 - 0}{0 - 2.97\text{ m/s}}$$
$$(v_B)_2 = -2.37\text{ m/s} = 2.37\text{ m/s}\downarrow$$

Conservation of Energy. The maximum stretch s_3 in the cord may be determined by again applying the conservation of energy equation to the ball just after collision. Assuming that $y = y_3 = (1 + s_3)$ m, Fig. 15–17*c*, then

$$T_2 + V_2 = T_3 + V_3$$
$$\tfrac{1}{2}m(v_B)_2^2 + 0 = \tfrac{1}{2}m(v_B)_3^2 - W_B y_3 + \tfrac{1}{2}ks_3^2$$
$$\tfrac{1}{2}(1.5\text{ kg})(2.37\text{ m/s})^2 = 0 - 9.81(1.5)\text{ N}(1\text{ m} + s_3) + \tfrac{1}{2}(800\text{ N/m})s_3^2$$
$$400s_3^2 - 14.72s_3 - 18.94 = 0$$

Solving this quadratic equation for the positive root yields

$$s_3 = 0.237\text{ m} = 237\text{ mm} \qquad \textit{Ans.}$$

*The weight of the ball is considered a nonimpulsive force.