

FORCES-GRAVITATIONAL/INERTIAL

LAB MECH 27.CALC

INTRODUCTION

Forces are a constant reality in the dynamics of our world, the universe, and of daily living. We recognize the forces of nature as: the strong force that between nucleons of nuclei, the weak interaction force involved in such as beta decay, the electrical force which involves charge that keeps atoms themselves together and atoms to atoms in matter, and then the force of gravity or mass with respect to mass.

That matter is characterized by mass, that an attractive force exists between masses— inverse-square with distance, and that matter is a common constituent of the universe; hence gravity is the primary force of the universe—that behind stellar dynamics, makes possible the rather stable behavior of the sun, keeps the sun “positioned” providing quite a steady flow of energy that drives much of the earth’s dynamics; thus gravity provides us a relatively stable environment/living place in the universe with respect to our needs, our tolerances, our sustenance, and our relative self-dependence and security.

Further, we associate with matter that which gives rise to the force of gravity as gravitational mass and that aspect of matter resisting change of motion as inertial mass. “Evidence” seems to support that the measure of a quantity of matter’s gravitational mass and of its inertial mass is the same.

This experiment focuses on forces associated with gravitational and inertial masses. A force plate senses the measure of the force difference between its two surfaces. This results with such as the force plate at rest on a floor and a person standing on it which would measure the gravitational attraction force between a person and the earth, that is, the person’s weight given by their mass, m , times acceleration, g , of a body falling freely near the earth’s surface so gravitational force, $F_G=mg$. Further, force considerations come into play, with inertial mass involvement such as standing on the force plate: in an accelerating elevator, lowering and raising oneself vertically, jumping, throwing up/catching a mass object; and dropping a mass object on the force plate. These, generally, in addition to weight/force mg would involve a force (or forces) as a result of mass, m , being accelerated, a , or $F = ma$ and for a total force $F_{tot} = mg + ma$ (plus similar terms with more forces involved).

The calculator program, in monitoring the experimental performance with the desired forces applied, yields a force vs time graph. Various analyses of the data can be pursued.

PURPOSE

To study and measure the forces exerted on a force plate by such as a static weight, a weight with motion in an elevator, a person's weight with a pattern of vertical motions, a horizontal push and two opposing horizontal pushes.

MATERIALS

Programmable calculator
LabPro
Logger Pro
Vernier Force Plate

Elevator
Mass (for tossing)
Meter stick

PRELIMINARY QUESTIONS

1. When standing on the force plate in an elevator at rest and then as it starts to move upward; what change, if any would you expect in the measured force?
2. When jumping up-and-down (rising above it and dropping down) on a fixed force plate, what would one expect as the minimum measured force? Explain.
3. Discuss how you would expect your measured weight force to differ such as: at the equator, at the North Pole, on a high mountain, and above a large deposit of very dense magna.

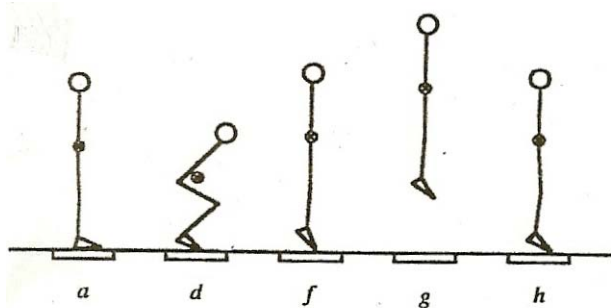
PROCEDURE/ANALYSIS

The following, Activities 5, 6, 7, 8, and 10 are rather separate experiments so choice could be made as to which or all to include. Note the DATA TABLE which provides for recording the various data/results and should be helpful in guiding analysis.

1. Connect the force plate cable to Channel 1 of the LabPro interface. Have the programmable calculator in place and connected to the LabPro. Position the force plate RANGE setting switch as desired (generally to -800/+3500 N, if forces >+850N).
2. Prepare the TI Graphing Calculator for taking data: press on, press APPS, select the DATAMATE program, and press to restart the program.
3. Now you should zero the sensor. Select SETUP from main screen. Select ZERO from setup screen. Select CH 1-FORCE (n) from the SELECT CHANNEL screen. Press

4. The time axis calibration is initially set up with time intervals between samples of 0.02 sec and 180 samples per run so a run duration of 3.6 sec. This time axis calibration seems to work well for such as standing on the force plate, raising and lowering oneself, holding a mass then tossing it up and catching it, and dropping a mass on the force plate.
5. With the force plate positioned on the floor, press and select START and promptly (after signal sounds) step onto the force plate being rather centered and standing still. Observe the resulting force vs time graph. Draw an appropriate sketch of the plotted graph. Press ; for the rather constant force region select ANALYZE; select STATISTICS; scroll cursor key to position for SELECT LEFT BOUND margin corresponding to approximate graph stepped-on position; press ; scroll cursor key to position for SELECT RIGHT BOUND margin at about end of run; press . Note and record in DATA TABLE the MEAN force value.
6. With force plate oriented vertically as against a wall resting on edge so no horizontal force, proceed to “zero” as outlined in preceding Activity 3. Hold force plate against a wall (having the handles attached would be helpful) and be prepared to push. Press ; press START and rather promptly exert a steady horizontal push and then after a bit exert a more intense steady horizontal push. Draw an approximate sketch of the plotted graph. Press and proceed as outlined in Activity 5 to obtain and record the MEAN push forces. Now with a partner to hold against one side of the force plate, be prepared to push horizontally from the other side. Press ; press START and promptly try to exert a steady horizontal force of similar magnitude as the more intense force with your partner pushing from other side holding the force plate fixed in horizontal position. As above, select a region of rather constant force and obtain and record the MEAN force.
7. With force plate resting on a horizontal surface, such as a floor, proceed to “zero” as outlined in preceding Activity 3. Holding a jug mass (gallon jug of water) steadily about chest level, with calculator prepared and standing on floor about to step on force plate, press START. Step on force plate; briefly stand steady; toss the mass vertically $\frac{1}{2}$ to 1 meter and catch it (some practice might be helpful to coordinate timing). Draw an approximate sketch of the plotted graph. Label positions/ regions of special interest such as: step-on mean force, tossing jug, catching jug,.... Record in the DATA TABLE values of interest as they are determined. Force values are obtained by scrolling with the cursor keys and to position values of interest. To obtain a mean value for a region press , select ANALYZE, select STATISTICS, with cursor key scroll to position for SELECT LEFT BOUND margin, press , then scroll to position for SELECT RIGHT BOUND margin, press . Note the MEAN; press ; select RETURN TO MAIN SCREEN; select GRAPH.

8. Prepare for the sequence of actions according to the Figure illustrating a countermovement jump. The action motions are vertical; center-of-mass is shown by a circular symbol; and key times during the jump are indicated by letters. You might check for graph zeroing by press , press START. Note data whether zeroed. Standing prepared to step on force plate press , press START; soon after signal sounds, step onto the force plate, stand briefly as position a of figure, squat as d and pause briefly, proceed with jump as f, g, and h. You likely should do a practice run or runs, particularly to synchronize the sequence of actions within the 3.6 s run time. Of course, the run time span could be expanded (note Activity 9 for time calibration procedure). In our trial runs the 3.6 s time span calibration seemed adequate. With a satisfactory graph of plotted data, draw an approximate sketch of the graph. Label on your sketch positions/regions of interest such as for a, d, f, g, h. Obtain and record in DATA TABLE force values for these positions/regions according to the analysis procedure outlined in previous Activity 7.



Figure

9. Now in preparation for the elevator ride experiment, a time axis expanded calibration is needed. Press ; select MAIN SCREEN; select SETUP; scroll to MODE: TIME GRAPH; from TIME GRAPH SETTINGS screen select CHANGE TIME SETTINGS; for ENTER TIME BETWEEN SAMPLES IN SECONDS (put in such as) 0.1 press ; for ENTER NUMBER OF SAMPLES (put in such as) 200 press . Select OK; select OK. You will note that run time span is now 20 seconds. This seemed to work well with doing the experiment in the “Hoyt smaller” elevator in moving a distance two stories. For more stories and/or slower elevators, a more expanded time span might be required.
10. With force plate, LabPro and calculator in elevator at “ground” floor; select SETUP; select ZERO; select CH 1-FORCE (n) from SELECT CHANNEL; press . Standing prepared to step on force plate, select START and rather promptly step on force plate; standing erect and steady on force plate press “second” floor elevator button. Retain your steady position through out the elevator motion until it stops. With a satisfactory graph of plotted data, draw an approximate sketch of the graph.

Indicate and label on your sketch regions of interest as: stopped before starting, starting motion, moving with constant motion, and stopping motion. Proceed to obtain the mean force for each of these regions of interest by press **ENTER**; **SELECT ANALYZE**; **SELECT STATISTICS**; scroll with cursor keys **▶** and **◀** to **SELECT LEFT BOUND** margin; press **ENTER**; scroll with cursor key **▶** to **SELECT RIGHT BOUND** margin; press **ENTER**; note and record in **DATA TABLE** the **MEAN** force. Continue this for each region of interest.

DATA TABLE

Activity 5 Standing on Force Plate

Mean Force: N

Activity 6 Vertical Force Plate with Horizontal pushes

Against Wall--Push 1, Mean Force: N

Push 2, Mean Force: N

Against Partner--Mean Force: N

Activity 7 Standing on Force Plate with Jug Mass--Tossing/Catching

Standing -- Mean Force: N

Tossing--Force: N

Tossed--Mean Force: N

Catching--Force: N

Caught--Mean Force: N

Weight of Jug Mass: N

Activity 8 Vertical Action on a Force Plate--Countermovement Jump

Figure Positions/Actions

Stand a--Mean Force : N

Squat d--Mean Force: N

Start Jump f--Force: N

Top of Jump g--Force: N

Stop Jump h--Force: N

Activity 10 Standing on Force Plate--Elevator Ride

Still Bottom--Mean Force: N

Starting Up--Mean Force: N

Acceleration: m/s^2

Steady Up--Mean Force: N

Stopping Up--Mean Force: N

Acceleration: m/s^2

FURTHER ANALYSIS

1. For the experiment Activity 5, what is the meaning of the force value as it relates to the person standing on the force plate? Compute the mass value in kg.
2. Compare and discuss the results of the Activity 6 experiment, particularly, when pushing with the wall and with your partner. Comment with respect to Newton's third law of motion.
3. For Activity 10, compute the starting and stopping elevator average accelerations corresponding to the MEAN starting and stopping incremental (+ or -) forces. The person's mass should be obtainable from the "Still Bottom" or "Steady Up" "Mean Force".