PHY138 Mechanics - Written Homework

This homework assignment is due by 5PM on Friday October 14. It should be submitted in the *Drop Box* for your tutorial. The Drop Boxes are located in the basement of the Burton tower of McLennan. On the first floor of McLennan there is a stairway with a bust of Newton on the 1st floor; the Drop Boxes are at the bottom of the stairs.

You should solve the problems together in the same team that you have been working with in your tutorials. Designate one member of your team as the *coordinator*. The coordinator will be responsible for assembling the final copy of your solutions and submitting them in the Drop Box on time.

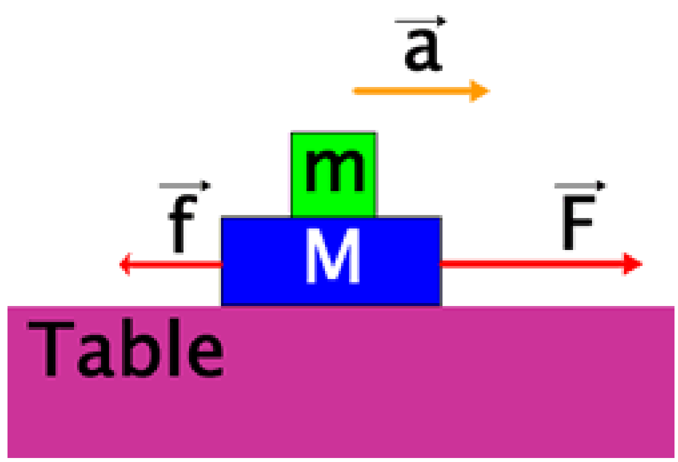
Be sure to include the following information in the submitted copy of the solutions:

- All team member names and student numbers.
- Your tutor's name
- Your tutorial section and group.

We strongly recommend that you work together to solve all the problems. It is likely that these problems will appear on the Test or the Final Exam, either verbatim or slightly modified, so be sure you know how to solve all of them.

Problem 1 (15 Points)

In class on Monday, September 26, we analysed the situation shown to the right. Two blocks of masses **M** and **m** are stacked on top of each other and are being pulled to the right on a rough table top by a force **F**. The frictional force exerted on the lower block is **f**. The acceleration of the blocks is **a**. We assumed the **F** is greater than **f**, so the direction of the acceleration is as shown.



When we considered the two blocks together as the *system* we showed that the acceleration is:

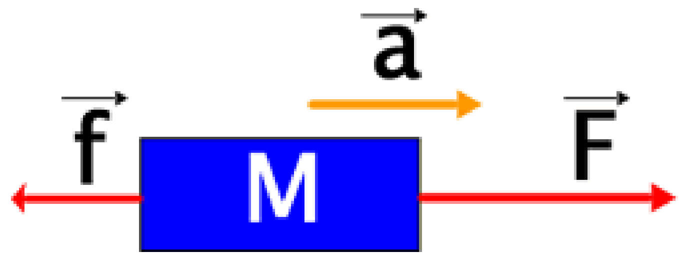
$$a = \frac{F - f}{M + m}$$

We then analysed the upper block as the system.The only horizontal force being exerted on it is the static frictional one being exerted on it by the lower block. That force points to the right and "drags" the block along with the lower one. We called that force **f '** and showed that:

$$f' = m\,a$$

Here the acceleration is just the result found above.

Now you will analyse the system of the lower block alone. In a naive analysis where one is, for example, unaware of Newton's 3rd Law, one might write down a Free Body Diagram of the horizontal forces acting on the block as shown.



Wrong!

Part A (7 Points)

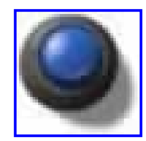
Show that this Free Body Diagram gives the wrong value of the acceleration.

Part B (8 Points)

Now draw the correct Free Body Diagram and solve for the acceleration. Compare the result to the acceleration given above: if they are the same then your answer is correct.

Problem 2 (20 Points)

A Flash animation based on the Air Track Experiment in the labs is available via the button to the right.



If you are reading this in hardcopy, the URL is:
http://faraday.physics.utoronto.ca/PVB/Harrison/Flash/ClassMechanics/AirTrack/AirTrack.html

Part A (10 Points)

Verify that the total momentum is conserved for all 6 possible collisions.

Part B (10 Points)

Leibniz, a contemporary and rival of Newton, analysed collisions in terms of the *vis viva*, literally the *living force*. It is equal to the mass times the instantaneous speed squared: $\mathbf{mv^2}$. Some of the air track collisions conserve the total vis viva and some do not. Determine which.

Problem 3 (15 Points)

In class we discussed the *ballistocardiogram*. When the heart beats it expels a mass *m* of blood into the aorta with speed *v*, and the body and platform move in the opposite direction with speed *V*. The blood velocity can be determined independently by observing the Doppler shift of ultrasound; the Doppler effect will be studied in the next quarter of PHY138.

Assume that *v* is 50.0 cm/s in one trial. The mass of the subject plus the platform is 54.0 kg. The platform moves 6 x 10^{-5} m in 0.160 s after one heartbeat.

Calculate the mass *m* of blood that leaves the heart.

Problem 4 (25 Points)

Knight Chapter 8 Problem 48.

Problem 5 (25 Points)

Knight Chapter 9 Problem 72. Assume, reasonably, that as the chair slides across the floor the force of friction on it is constant and equal to 39 N.