Workshop Tutorials for Introductory Physics

MI4: **Newton's Laws I**

A. Review of Basic Ideas:

Use the following words to fill in the blanks:
zero, vector, newton, scalar, acceleration, constant, gravitational, velocity, non-zero, contact, forces, quantitative

Forces

How can a tugboat pull a cruise ship that's much heavier than the tug? Why does it take a long distance to stop the ship once it is in motion? Why is it harder to control a car on an icy road than on dry concrete? The answers to these and similar questions take us into the subject of dynamics, the relationship of motion to the _____ that cause it. We will use kinematic quantities - displacement, _____ and acceleration - to understand what makes bodies move the way they do.

All the principles of dynamics can be wrapped up in a neat package containing three statements called Newton's laws of motion. The first law states that when the net force on a body is _____, its motion doesn't change. The second law relates force to acceleration when the net force is not zero. The third law gives a relation between the forces that two interacting bodies exert on each other. Many other scientists before Newton contributed to the foundations of mechanics, including Copernicus, Brahe, Kepler and Galileo Galilei. Indeed, Newton himself said, "If I have been able to see a little farther than other men, it is because I have stood on the shoulders of giants."

The concept of force gives a _____ description of the interaction between a system and its environment. There are forces, including _____ and electrical forces, that act even when the bodies are separated by empty space. Force is a _____ quantity; to describe a force we need to describe the direction in which it acts as well as its magnitude. The SI unit of the magnitude of force is the _____, abbreviated N.

Discussion Questions
Can a car, with a zero net force, roll down a hill? Explain your answer.

B. Activity Questions:

1. Gaining Weight

Can you change (and hold) the reading while standing on one scale, without touching anything else?
Can you change (and hold) the reading while standing on one scale, and holding a friend? Explain.
Does your friend feel you are pushing or pulling? and in which direction?
If you stand with your weight evenly distributed over two bathroom scales, what will be the reading on each scale compared to your weight? Why?
How will the readings change as you shift your weight to your right leg?

2. Smooth variable ramp

Draw a free body diagram for the trolley.
What are the components of the forces acting parallel and perpendicular to the ramp?
Is the force on the trolley from the spring balance equal to $mg\sin\theta$? Comment on your answer.
What happens to the force needed to keep the trolley stationary on the ramp as the inclination of the ramp is increased?

3. Constant velocity
Pull the trolley along a flat surface with the spring balance.
What does the spring balance indicate?
Set the ramp so that the trolley rolls down freely.
Pull the trolley up the ramp with constant velocity. This is not easy and may take several attempts.
What is the reading on the spring balance now? Is it what you expect it to be?
Is this reading different to that when pulling the trolley on a flat surface with constant velocity?

4. Constant acceleration
Set the ramp so that the trolley rolls down freely.
When the trolley is released at the top it accelerates down the ramp. What net force is acting to accelerate the trolley?
Is the trolley in equilibrium?

5. Newton's Cradle (2 balls)
Swing one ball out and release it.
Draw a diagram showing the forces acting on the balls.
Is there an action-reaction pair here? If so, what is it?

C. Qualitative Questions:

1. Draw force diagrams (free body diagrams) for the situations described below. In which of the situations is the net force on the car zero?
a. A car cruising at a constant speed of 100 $km.h^{-1}$ on a long straight stretch of highway.
b. A car going around a curve of radius 20 m at a constant speed of 60 $km.h^{-1}$.
c. A car accelerating uniformly at 1.3 $m.s^{-2}$ on a long straight stretch of highway.

2. How can a tug boat move a cruise ship when the cruise ship exerts the same force on the tugboat as the tugboat exerts on the cruise ship? Draw a diagram showing the action-reaction force pair.

D. Quantitative Question:

Brent is trying to lift a piano of mass 150 kg using a rope and pulley as shown.
a. If the rope cannot sustain a tension of more than 2000 N, what is the maximum force with which Brent should pull?
b. What is the maximum acceleration of the piano?