NEWTON'S LAWS DEMONSTRATIONS

1. **Paper and More Massive Object.** Drop a heavy object (wood or metal – bundle of keys, piece of wood, etc) from one hand at the same time you drop a flat sheet of paper from the other. Then do the same thing again, except this time with the paper wadded up into a tight ball. First time, the paper will flutter slowly to the ground. Second time it will fall essentially as fast as the heavier object. In the first case, air resistance is significant for the paper, but not for the other object. In the second case, air resistance is negligible for both, and both fall with the same acceleration.

2. **Paper and Book**. Drop a piece of paper and a book (which has a cover at least as big as the piece of paper) simultaneously, one from each hand. Both should be oriented with their flat surfaces parallel to floor when dropped. Paper will flutter, book will fall rapidly. Then put the paper on top of the book, and drop them. Both will fall together.

3. **Terminal Velocity in Air.** Fold up the edges of four 3x5 cards so that the cards act like trays with small vertical edges about1/4" high. (Alternatively you can use flat-bottomed Mr. Coffee-style coffee filters as they are -- no folding necessary.) Hold one of the cards in one hand and a tightly nested stack of three in the other, a few feet off the floor, and with their bottoms parallel to the floor. Drop them simultaneously and note that the stack of three reaches the floor significantly sooner. Crumple up the single card into a tight wad and then crumple the stack into a tight wad, stuff each crumpled wad into its own film can, put the lid on, and drop each can simultaneously. Both will hit the floor at the same time. When the cards were falling flat, each accelerated for a time, but as the speed increased, so did the air resistance. When the force of air resistance became equal to its own weight, it fell the rest of the way with a constant speed called its **terminal velocity**. The single flat card reached a slow terminal velocity very quickly, and the flat stack reached a faster terminal velocity a little later, since it had to accelerate longer before travelling fast enough for the air resistance to equal its greater weight. The two film cans, on the other hand, accelerated all the way to the floor, since their smaller drag profile made air resistance essentially negligible for them. In the total absence of air resistance, falling objects would not reach a terminal velocity, but would continue to accelerate at 9.8 meters per second, per second, the gravitational acceleration typically called "g." The fact that heavy and light objects would have the same acceleration in the absence of air resistance is explained by the fact that a light object, with its small mass, does not need much gravitational force, or weight, to accelerate it, whereas a heavy object, with its larger mass, requires its larger weight, or gravitational force, to give it the same acceleration. This is summed up in Newton's Second Law, F=ma. If you change this to a=F/m, then you can get the same "a" value by using a small "F" and a small "m" or by using a large "F" and a large "m".

4. **Terminal Velocity in Karo Syrup**. Find a steel ball and a glass marble that are the same diameter. Drop them both at the same time into a tall container (at least a foot high – e.g., large graduate, clear tennis ball container, etc.) filled with Karo Syrup (Light, not Dark). Both will achieve a constant terminal velocity very rapidly, but the steel ball's

terminal velocity will be notably faster. NOTE: Karo is **STICKY! --** avoid getting it on tabletops, yourself, etc., and clean it up as soon as possible if you do.

5. **3x5 Card and Coin on Drinking Glass**. Put a 3x5 card on a drinking glass. Put a coin on top of the card. Rapidly flick the end of the card with your finger so that it flies straight out from under the coin. The coin will drop in the glass. This demonstration is an illustration of inertia, or resistance to change in motion. Mass is a measure of inertia; Newton's Second Law, F=ma, states that or a given force, the larger the mass, the smaller the acceleration, or change in motion. The flicked card applies a frictional force to the bottom of the coin, and it accelerates; but the force is small and is over so quickly that the coin doesn't move very much before the card is gone, allowing the coin to then drop into the glass.

6. **Tablecloth and Dishes**. Get some oilcloth, or a smooth plastic tablecloth. Also some dishes and/or glasses. Put them on the tablecloth, with about six inches hanging over the edge of the table. Grasp the tablecloth with both hands, and RAPIDLY jerk the cloth horizontally from under the dishes (some teachers wrap the edge around a meter stick, to provide a more uniform pull). If all goes well, the dishes should stay on the table! A little practice may be necessary, and you should be willing to possibly sacrifice a few dishes and sweep up the pieces if you don't get it to work the first time! Dishes can be usually be obtained cheaply at thrift stores if you don't have any -- or you can "cheat" and use plastic dishes, but heavier ceramic ones usually work better than lighter plastic ones. A neat variation, if you're willing to sacrifice dishes, is to begin by SLOWLY pulling the cloth – the dishes will go with it, and fall to the floor and break. It usually gets kids' attention! The explanation is essentially the same as for **3x5 Card and Coin on Drinking Glass**. See The Old Tablecoth Trick at www.raft.net/ideas for a write-up of this demo.

7. **Hanging Masses.** Find two identical masses, approximately 200 g or greater (larger is better), that have places to tie a thread or light string to them on both the top and bottom. Hang both masses from a cross-bar, with about 6 inches of thread above them, and about 6 inches of loose thread hanging below them. Pull slowly on the bottom thread of one mass, increasing the pull until the thread breaks. Notice where the thread breaks. Jerk very quickly on the bottom thread of the other mass, and notice where the thread breaks. (Note: use some kind of cushioning – e.g., foam rubber or a jacket or a bunch of plastic shopping backs stuffed inside a single bag – on the surface where the masses hit, to protect the masses themselves and the surface.) When pulled slowly the top thread breaks. When jerked rapidly, the bottom thread breaks. When the string is pulled slowly, the lower string feels only the force you are pulling with, while the upper string feels the weight of the object in addition, and reaches its breaking strength sooner. When the bottom thread is jerked, the inertia of the relatively large mass prevents its rapid acceleration, so the full force is not felt by the upper string before the lower string reaches its breaking point.

8. **Toilet Paper Rolls**. Put two rolls of toilet paper on a horizontal rod or dowel. One roll should be a full roll. The other roll should be almost empty (about a quarter to a half inch thickness of paper still left). Tear off some paper on the full roll by jerking rapidly. Then try the same thing with the empty roll. The paper should tear off the full roll quite easily, with the roll barely moving. When the same thing is tried with the almost empty roll, the whole roll turns, and a lot of paper will unroll without tearing. A little practice may be necessary to get the feel of this. It's a great way to show that physics is everywhere! The larger mass of the full roll prevents its acceleration before the breaking strength of the paper is reached. The smaller mass of the empty roll allows the roll to accelerate before the breaking strength is reached.

9. **Hefting Masses**. Assemble two masses which have the same geometrical and textural feel, but are somewhat different in mass – e.g., two film cans, one filled with pennies, the other half-filled. Ask the student to tell you which one is most massive (or "heaviest" if that's more appropriate – this could then serve as a segue to a discussion on mass vs. weight). Students will almost always instinctively "heft" the two cans to compare them – that is, they will move their hands upward and then let them fall back, and repeat this a couple of times. They will almost always be able to tell which is "heaviest." What they are really doing is using F=ma -- they are finding which mass is easiest to accelerate with a given force. NOTE: See the separate handout from The Physics Teacher magazine, September 1986, which extends this activity with a procedure for determin ing how sensistive the method is -- i.e., the smallest diffrerence in mass that can be detected using this method.

10. **Lean Against Wall**. Identify action-reaction pair – you exert force on wall; wall exerts force on you. Discuss what happens if wall doesn't exert force!

11. **Jump Off Chair**. Stand on chair or table and identify action-reaction pairs. You exert force on chair; chair exerts force on you. You exert force on earth; earth exerts force on you. Note that the following is NOT an action-reaction pair – earth exerts force on you; chair exerts force on you. These forces do act on you, and they balance each other to keep you in equilibrium, but they are not an action-reaction pair, since an action-reaction pair never act on the same object. Then jump off the chair. Identify the action-reaction pair while you are falling – earth exerts a force on you; you exert a force on the earth (law of gravitation). Which objects are ":moving" while you fall? Both. Which "moves the most" , i.e., which has the greatest acceleration? You. Why? Your mass is far smaller than the earth's. F=ma, and since the FORCES are EQUAL (and opposite), the smaller mass will have the larger acceleration, and will do the most moving. The key idea is that if you believe physics, you have to believe that the earth is actually moving a tiny bit toward you as you fall toward it. Simple demo, but big conceptual idea here!

12. **Embroidery Hoop & Coin**. Stand hoop on edge on top of spice jar, or other container with similar size opening. Put coin on top of hoop. Hit hoop rapidly on outside of "back" edge with outstretched fingers (follow through with hand motion – you get a more effective hit this way). Hoop and coin will both go flying. Set up again and this time

hit the inside of the "front" edge. Hoop will go flying, but coin will drop into jar. Practice makes perfect. After you develop technique, you can actually grab the hoop when you hit it from the inside. First time, the hoop was deformed so that it bulged UPWARD, moving the coin both vertically (hoop pushing up), and horizontally (friction force between hoop and coin). Second time, the hoop was deformed so that it bulged HORIZONTALLY, rapidly lowering it underneath coin so that coin was "left hanging" due to its inertia, and hoop was gone before coin could fall (this is sort of a first order "get the idea" explanation –the coin doesn't actually "hang", etc. !). Coin then falls into jar.

The key concept here is inertia, or resistance to change in motion. Mass is a measure of inertia, as shown in Newton's Second Law, F=ma; for a given force, the larger the mass, the smaller the acceleration, or change in motion. The "knock out" force applied to the INSIDE of the forward edge of the hoop simultaneously gives the hoop a large acceleration, and also "flattens" it horizontally, since the hoop is "springy" rather than rigid. This causes the top of the hoop to drop as it moves under the coin, minimizing or eliminating the friction force between the hoop and the coin. Of course, as soon as the hoop starts to drop under the coin, the coin also starts to fall, but its inertia is such that the hoop is already gone before the friction force between the hoop and the coin can move the coin sideways in any significant way, and the penny just drops! When the outside of the back edge of the hoop is hit or grabbed (rather than the inside of the front edge), the deformation "flattens" the hoop vertically, causing the top of the hoop to rise; the penny gets pushed up and sideways, and goes flying into the air. See A Hole in One at www.raft.net/ideas for a write-up of this demo.

13. **Whacking Blocks**. Make a stack of 5 or 6 wood blocks, each about 5 in long, cut from a relatively smooth-surfaced 2x4. Stack the blocks neatly (large flat sides parallel to table top). Use a meter stick or other suitable "whacker" to rapidly whack back and forth just above the table top so that with each whack, another block is knocked out from the bottom of the stack. CAUTION: blocks will go flying, so make sure nobody is standing where they might get hit! This demo illustrates inertia, or resistance to change in motion. Mass is a measure of inertia, as shown in Newton's Second Law, F=ma; for a given force, the larger the mass, the smaller the acceleration, or change in motion. The "whack" force applied to the bottom block is far larger than the opposing friction forces from the table and the remaining stack, so the bottom block undergoes a large acceleration. Because of the frictional force between the bottom block and the stack above it, the stack accelerates as well; but the force is small and only occurs for a very short period of time, and therefore doesn't give the relatively massive stack much acceleration before the bottom block is gone. So the stack just drops. Notice as the blocks are knocked from the stack, the top stack moves farther; since the stack has less mass each time a block is removed from the bottom, it has less inertia. See Whack a Stack at www.raft.net/ideas for a write-up of this demo.

14. **Clapping Blocks**. Hold one of the blocks from the Whacking Blocks in each hand, and use them to hold a third block between them by pressing together on the third block (third block is the filling on a sandwich – the blocks in each hand are the slices of

bread). Then rapidly clap – move hands away and then back again fast enough to “catch” the first block before it falls very far. A very little practice will allow you to keep the third block in place for as long as you want (you’ll instinctively give it a little upward force every time you clap).

15. **Marshmallow Blowgun** (or **Puff Tube**, if you don’t like Blowgun!). Roll up half a manila file folder and tape it to make a tube that a marshmallow (large size, not mini) just fits in. Place the marshmallow in one end of the tube, and blow hard on that end. Keep blowing until the marshmallow exits the other end of the tube. The air pressure you create in the tube by blowing causes a force to be exerted on the marshmallow for its entire trip down the tube, with an accompanying acceleration in accord with Newton's 2nd Law, F=ma. Some practice may be necessary. Some tricks of the trade include letting the marshmallows dry out for a day or two before using if possible, and rolling them in flour, to keep them from sticking in the tube. See Marshmallow Puff Tube at www.exo.net/~donr for a more complete write-up.

16. **Magnetic Free Fall**. See www.exo.net/~donr for a write-up of this demo.

17. **Fan Cart**. See www.exo.net/~donr for a write-up of this demo/activity.