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2-D Motion - projectile motion via "the monkey and the hunter" story. This demonstration with its story is one of the oldest and best known in physics education because it educates and entertains extremely well. Once observed and understood, it is remembered for decades. And the lesson(s) it teaches is fundamental. If you neglect air resistance, you learn that the horizontal velocity component of a projectile is a constant and independent of the vertical velocity component which is constantly changing due to gravity. (You are fore-warned, however, that air resistance on the hunter's "bullet" will be the greatest impediment to success in this demonstration.)

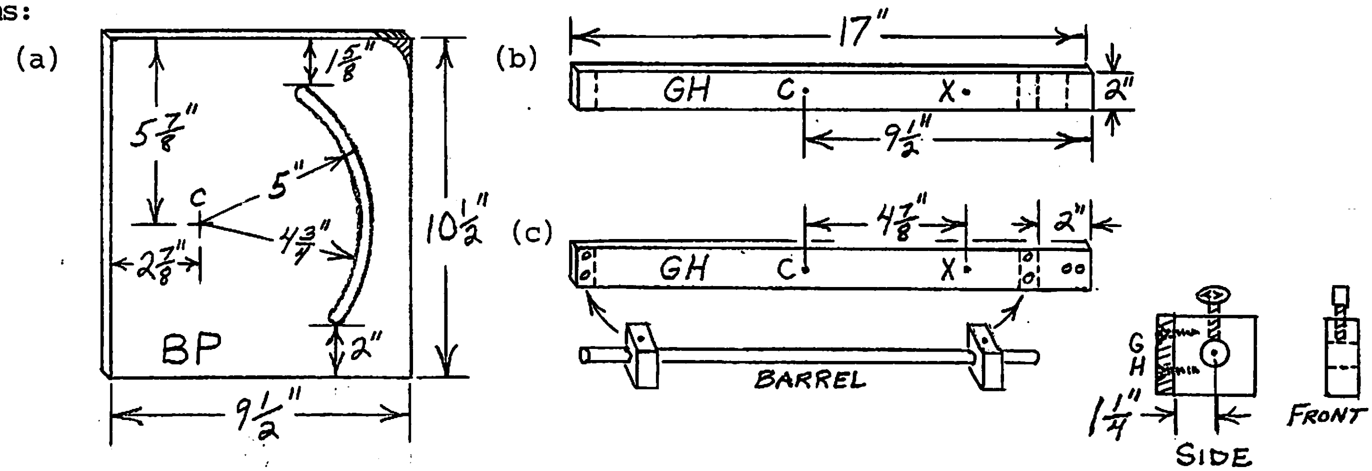
The story that is usually told involves a hunter in the jungle with a blowgun that uses darts who shoots at a monkey up in a tree. When the dart leaves the muzzle of the gun, the monkey sees it coming and decides to drop (free-fall) to a lower limb to dodge it. But the monkey doesn't know any physics, doesn't know that the dart is dropping (free-falling) at the same rate of g as he is and the time involved is the same for both. Thus, if the original aim of the hunter is accurate, the monkey makes a fatal mistake in free-falling to the lower limb; he should have jumped upward instead. At this point, see "2-D Motion - a teaching model". A study of this model is an excellent introduction to understanding this demonstration.

Many "blowguns" for this demo have been constructed (home-made) over the years with no one type dominating the field. Having seen many variations, I have come up with my own version that works quite well but is not perfect. (Maybe you can improve upon it.) First, I've tried to keep its design simple in construction, operation, and storage to encourage its use. Second, I've stayed with the original scenario of blowgun and monkey but have substituted "bullets" for darts for safety. Also, compared to other guns, I have sacrificed accuracy for increased visibility by enlarging the "bullets". To compensate, I have shortened the range. However, the students can now follow the action from start to finish in a standard classroom. The result remains convincing. Finally, I've designed it so everything is instantly adjustable, especially changes in muzzle spacing, height, and angles of elevation for different trajectories.

The entire apparatus is made up of three parts: the gun "platform", the "target" (electromagnet, "monkey", etc.), and the "trigger" (electrical system). Putting each part together will require an effort, but maintenance thereafter is minimal.

Construction: These are suggestions only; change the design and/or dimensions as you see fit. Follow the diagrams as you build.

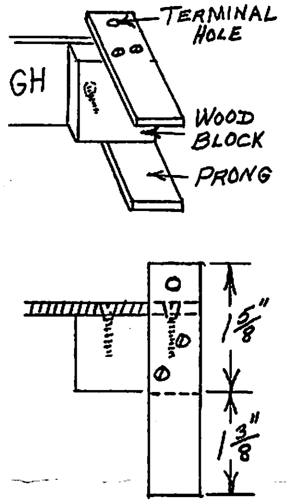
Diagrams:



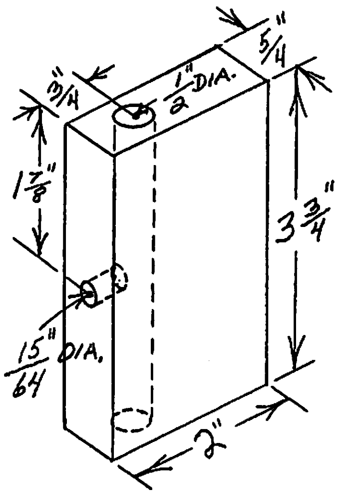
the gun "platform" - (a) Cut out a piece of 1/8" masonite as a back plate (BP) and locate its center C. With a compass, draw circular curves on the BP and cut out the ¼" circular groove with a jig saw (router?).
(b) Cut out a 1/8" masonite strip for the gun holder (GH). Mark the hole positions to be drilled as in (b) and drill them accordingly; note that the center C is a pivot point requiring a 3/16" dia. hole for both BP and GH. At point X, a 3/16" dia. hole is also required. A portion of the upper right corner of BP may be removed later if necessary.

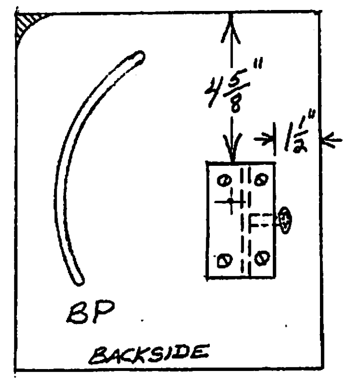
(c) Cut out two 2" x 2" 5/4" pine blocks for the gun barrel holders. Drill 3/4" dia. holes near the blocks' centers on a drill press and 15/64" dia. holes on top for ¼" x 20 x 3/4" (self-threading) thumbscrews which will "lock" down the gun barrel. Cut a 3/4" O.D. alum. pipe (copper, PVC?) 18" long for the barrel. With the barrel inserted in the blocks (thus aligned), attach the blocks to the strip with small flathead (FH) screws that must be countersunk.

(d)



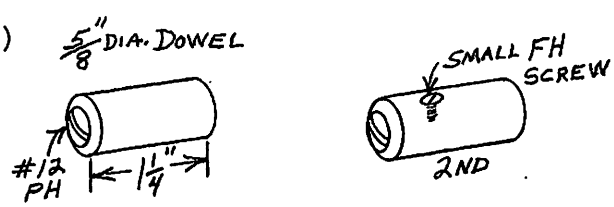
(e)



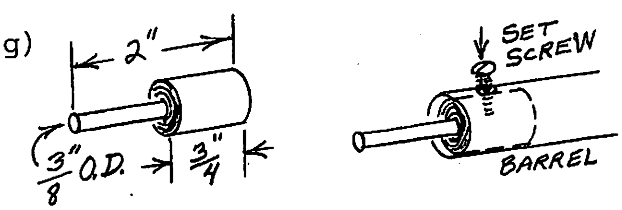


(d) Remove the barrel and make up the muzzle trigger switch (MTS) with two 3" long alum. "prongs" (1/8" x 3/4" alum. bar) and a 3/4" x 1¼" x 2" wood block. Screw the block to the GH with small FH screws. Each prong will have three holes: two for small panhead (PH) screws, one for a #6 x 32 brass bolt (elect. terminal). Screw the prongs to the block. Center the strip (GH) on the BP; the 3/16" dia. holes should line up at C and the groove. Temporarily insert 3/16" bolts at the two positions and rotate the strip (GH). Everything should fit and rotate freely; make adjustments if they don't. Remove the temporary bolts.
(e) Last, make the pine, back block (BB), 5/4" x 2" x 3 3/4". On a drill press, drill a ½" dia. hole for the ½" rod (or 17/32" if necessary), and a 15/64" dia. hole for the ¼" x 20 x 3/4" thumbscrew. Make sure that the block slides easily up and down the ½" rod for quick adjustment. Attach the block to the back of the BP with FH screws so the "pivot" (center) #10 PH screw can fasten into the block after it is attached.

(f)

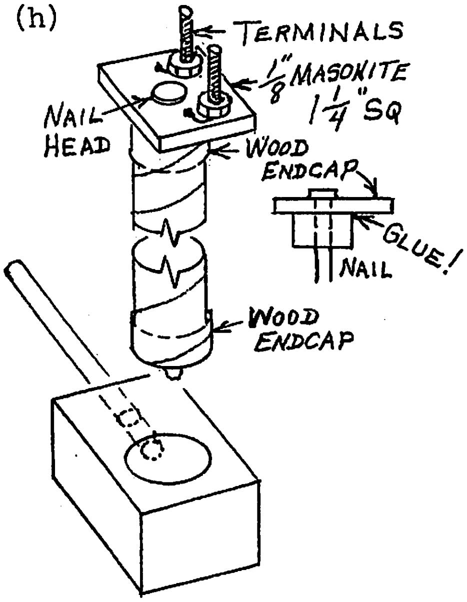


(g)

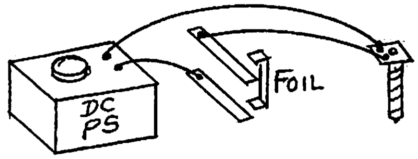


(f) The bullets are easy to make but are subject to barrel and air resistance problems so you need to experiment with them. Aluminum pipe is extruded; the inside has bumps and ridges. Thus, a bullet has to have a diameter less than most of the barrel or have a loose fit; this will decrease accuracy. The bullet may "float" or tumble in flight, slowing it down and arriving a split second late at the target due to air resistance. 5/8" dowel 1¼" long makes a visible bullet that's useful; a puff of air will easily propel it. To reduce the "float" effect during flight, a short #12 PH screw can be screwed into one end (front) of the bullet. One layer of masking tape around the dowel might make a better fit in the barrel, also. Any improvement in the bullet design will improve accuracy and reliability. Make at least two bullets. One of these must have a short steel screw inserted in its side so it can be attached to the electromagnet.
(g) Finally, the ½" O.D., 14" long rubber hose and its connector. Cut off a 2" long, 3/8" O.D. straight piece of copper tubing and wrap it with plastic tape until it fits snugly in one end of the gun barrel; add a short set screw (PH?) to secure it.

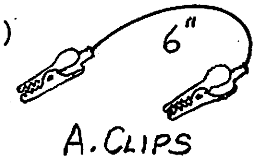
(h)



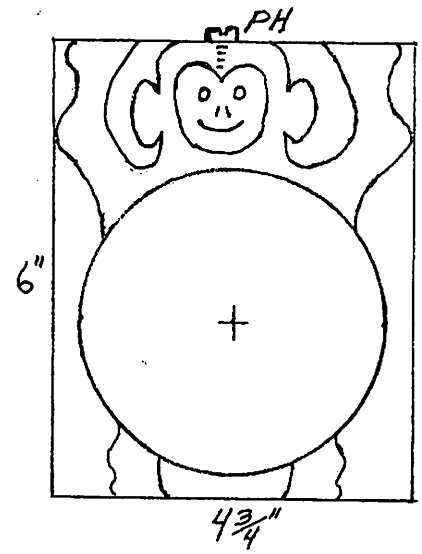
(i)



(k)



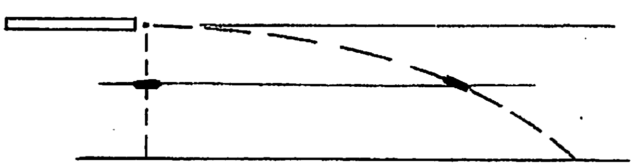
(j)



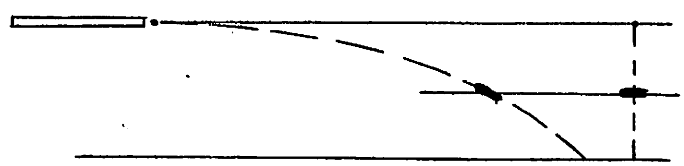
(h) For the electromagnet, I chose a twentypenny common nail and wound it with #22 insulated wire until the diameter reached 5/8". I added wood endcaps and then wrapped the wire and caps with plastic tape. One endcap holds the terminals. The whole electromagnet drops into an adjustable holder to be used with a right angle clamp on a ½" rod. The holder is a 5/4" x 1 3/8" x 2¼" pine block with a 3/4" hole drilled to hold the electromagnet. A ½" dowel 6" long is glued about 1 inch into the block.
Hardware for the elect. terminals is 2 #6 x 32 x 3/4" FH brass bolts, 2 #6 x 32 x 3/4" RH brass bolts, 2 brass washers, 4 #6 x 32 brass nuts, and 4 #6 x 32 brass thumbnuts.
(i) The electrical system is simple: a low voltage DC power supply connected to the MTS and the electromagnet. The final "connector" (circuit breaker) is a thin piece of alum. foil across the prongs that gets knocked off by the bullet when it leaves the muzzle.

Operation: The design allows the gun platform to be mounted on a ½" rod. The electromagnet "target" can be mounted, via a right angle clamp, on a separate ½" rod. The falling "monkey" can be anything that has an iron "point" that temporarily attaches to the electromagnet. (I designed a "fat monkey" (j) made of ½" plywood.) Some people use a toy, stuffed monkey with a piece of iron attached on top of its head. The amount of connecting wire (#18?) depends on the reliable range that you choose. Experiment.

(A)



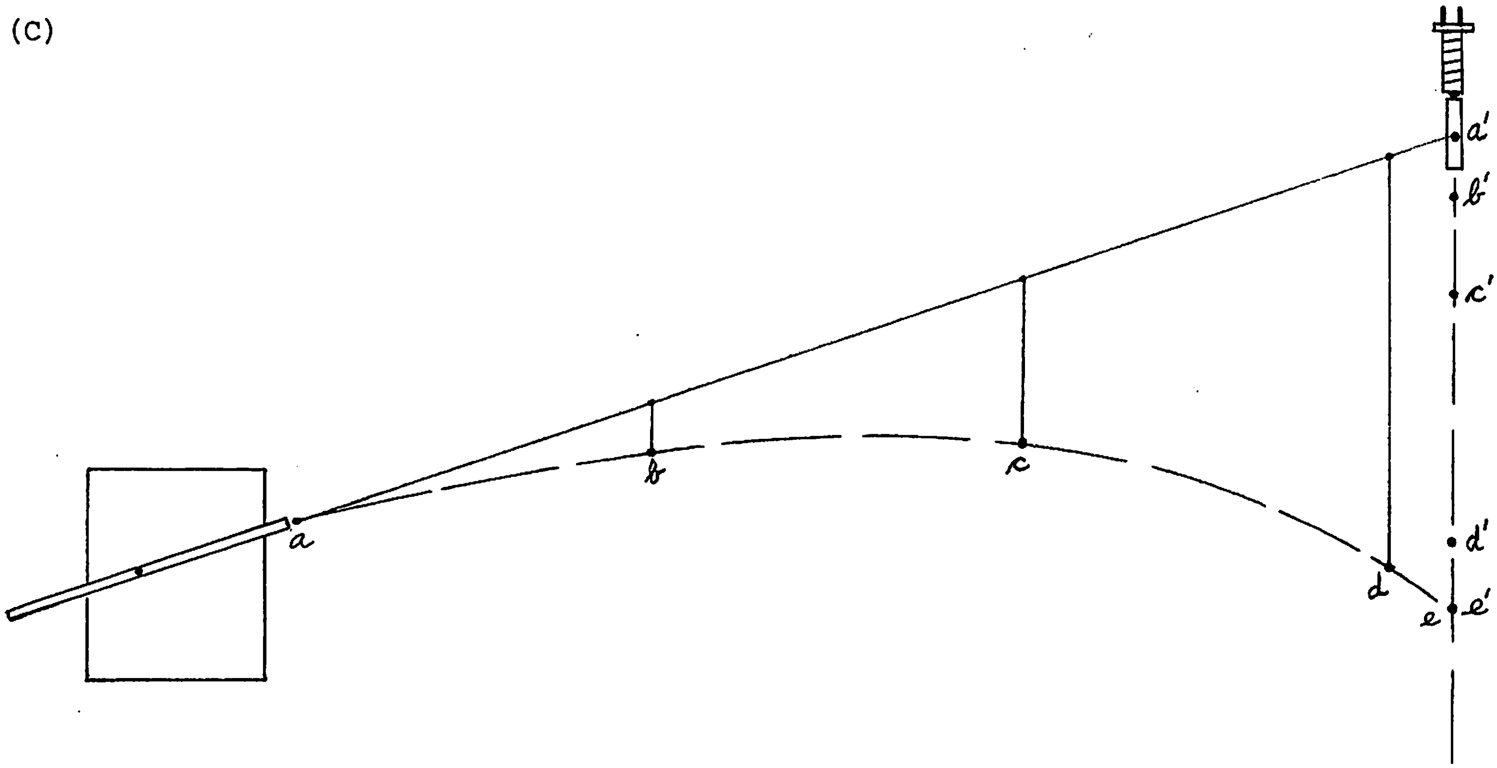
(B)



(A) Set up the platform and the "target" bullet exactly side by side. The barrel must be level; check it with a small spirit level. As best you can, space the muzzle a bullet's length from the alum. foil. Using the hose, suck the bullet to the rear of the gun. Activate the elect. system and attach the foil to the prongs. Use steelwool to polish the prongs if necessary. The foil should be attracted to the prongs. Use only enough electricity in the electromagnet to hold the "target" bullet with the screw in its side. Make sure each bullet lands on the same level surface (tabletop or floor). Puff on the hose. You should hear the two bullets hit the surface at the same time.

(B) Repeat the same procedure, but this time move the "target" bullet near where the "fired" bullet hit the surface. Of course, a puff on the hose brings the same result; the two bullets hit the surface at the same time. Keeping the electromagnet just strong enough, reduces any residual magnetic effect which might slow (hamper) the target's release.

(C)



(C) Now the real fun begins, hitting a falling target. Raise the target up and lower the platform down on their rods so there is a reasonable angle of elevation. One way to aim is through the empty barrel. Remove the hose, attach a short wire (k) between the prongs, activate the elect. system, and attach the target to the electromagnet. Make adjustments. With laser pointers available, a "modern" aiming system can be utilized instead. Complete the procedure for firing. A towel over a box or waste basket makes a good "safety net" for the falling target. If the aim is good and lady luck smiles, the target is hit and the students usually applaud. The laws of physics are upheld, and physics can be fun. If it's a miss, readjust and try again. Great experiments don't always work the first time or every time. If it succeeds on the second try, strangely, the applause may be even louder. Is this demo worth the effort? I found it so for the last 22 yrs. in my classroom career.

Note: If you look closely at (C), you will see that b and b' are the same distance from the original "aim line" of a a', as is c and c', d and d', and finally e and e' when the bullet and the target reach the same point at the same time. Neat!