Ballistic Pendulum*

Object

To determine the accuracy of a ballistic pendulum in measuring the muzzle velocity of a gun.

Theory

If a shot of mass m is fired from a gun into a heavy pendulum bob of mass M so that the shot is lodged in the bob, total momentum of the shot and the bob is conserved immediately after impact. Hence,

$$mv = (m + M)V, \tag{1}$$

where v is the initial velocity (muzzle velocity) of the shot and V is the velocity of the bob and the shot immediately after impact.

After impact, the bob swings and rises to a maximum height of h. At this height the bob has no kinetic energy. So, using conservation of energy, the initial kinetic energy equals the change in potential energy:

$$\frac{(m + M)V^2}{2} = (m + M)gh. \tag{2}$$

Hence,

$$V = \sqrt{2gh}. \tag{3}$$

Using equation 3 in equation 1 and solving for v gives

$$v = \frac{m + M}{m}\sqrt{2gh}. \tag{4}$$

This shows that the muzzle velocity can be found from a measurement of h.

To verify the measurement of v, one may find it directly, by firing the shot horizontally at some height y from the ground and then measuring the horizontal distance x at which it drops to the ground. If t is the time taken to hit the ground, then from the equations of constant acceleration motion:

$$x = vt, \tag{5}$$

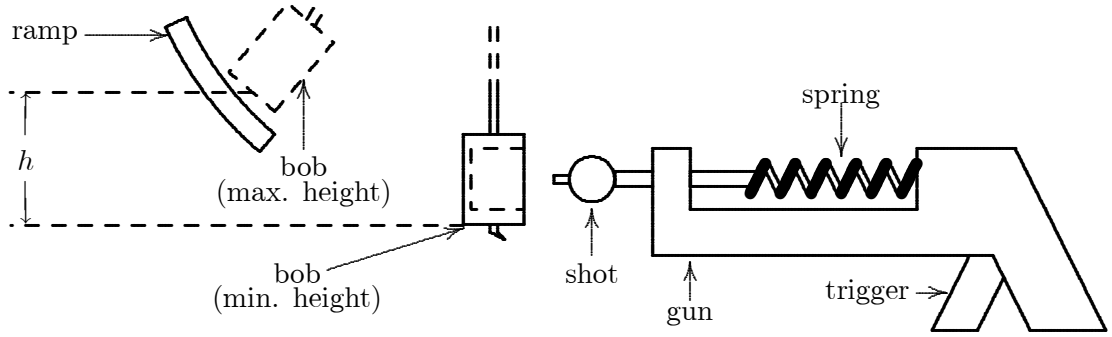
and

$$y = gt^2/2. \tag{6}$$

Solving for t in equation 5 and replacing in equation 6 gives

$$v = x\sqrt{\frac{g}{2y}} \tag{7}$$

The measurement method



The figure above shows the apparatus to be used (ballistic pendulum). The gun is spring powered. The pendulum bob has an enclosure so that the shot can get lodged in it. The point of suspension of the pendulum is outside the figure (above it). Once the shot is fired and it is lodged in the bob, the bob swings and gets caught on the ramp at the highest point it reaches (notice the hook under the bob). This allows the measurement of h. The masses of the bob and the shot are measured using a pan balance. Then equation 4 can be used to find v.

For the direct measurement of v, the bob is moved out of the way and the gun fired. This allows the shot to land on the floor. The point of contact on the floor is marked by sandwiching a carbon paper between to sheets of white paper and taping it to the floor (You may have to fire the gun once to roughly locate where the pieces of paper must be placed).

CAUTION: Make sure your line of fire is clear before every shot is fired.

The horizontal distance from the gun muzzle to the point of contact on the floor is x and the vertical distance from the gun muzzle to the floor is y. Then equation 7 is used to find v.

Some trials

Make several measurements of v using each method as described above and find the percentage difference between the two methods.

Find ways of making the measurements more accurate.

Find ways of making the measurements more safe.