SCATTERING

REFERENCES

Prowse, *Amer. Journal of Physics*, 29, 854 (1961), reports a description of the design of this experiment. (Copies available at the **R**esource **C**entre)

INTRODUCTION

The principal methods of investigating phenomena on a nuclear scale (~ 10^{-15} m) involve projecting particles into the region of the nucleus and observing what comes out. (This may be likened to investigating the contents of the centre of a hay stack by throwing golf balls at it and finding either the golf ball returned, or human screams, or whatever.) One process that is commonly seen in using these techniques is scattering, whereby the incident particle gets bounced back out, having had its momentum (and maybe its energy) changed.

This experiment is a model experiment. It is a *simulation* on a larger scale, in two dimensions, of a wide range of experiments particularly in atomic, nuclear and particle physics in which a beam of particles is scattered from a target particle at measured angles. From this information the effective area or cross-section of the target is deduced.

This lab may be used for either 1 or 2 weights according to the guidelines given below:

1 weight: check validity of equation (1). (30-40 scattering events suggested)

2 weights: check validity of equation (2). (150 or more scattering events suggested)

THE EXPERIMENT

Small ball bearings are shot from a simple air gun towards a rigid, cylindrical, plastic target. The angles at which they are scattered are found by recording the impacts of the ball on the wall of a large cylindrical tank which surrounds the target (figure 1). The scattering process in the model is a simple elastic collision and it is not difficult to show (figure 2) that

$$\cos\frac{\theta}{2} = \frac{b}{(R + r)} \qquad (1)$$

Note that in your experiment the angles $\theta \approx \phi$.

In this experiment the impact parameter *b* (figure 2) can be varied systematically, but in an atomic or nuclear scattering experiment it cannot. One can, however, predict the probable number of scattering events that have a given *b*. Try measuring θ for a number of different *b* and plot your results. Do they agree with equation (1)?

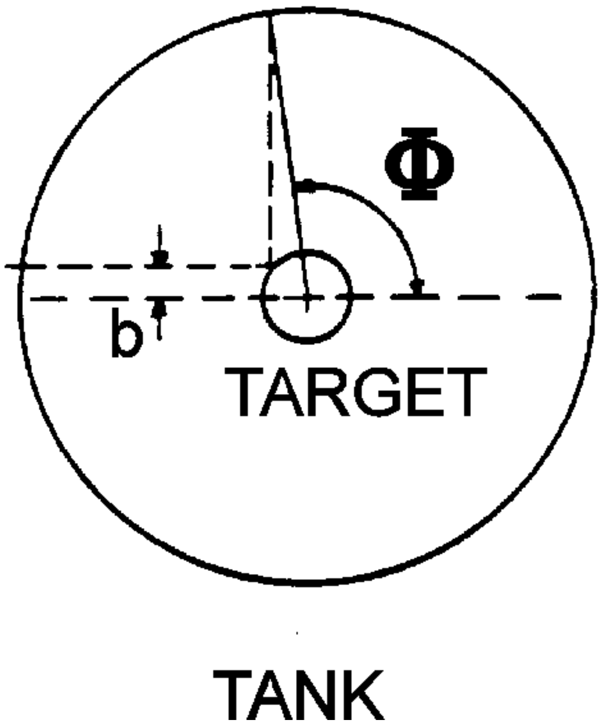

Figure 1.

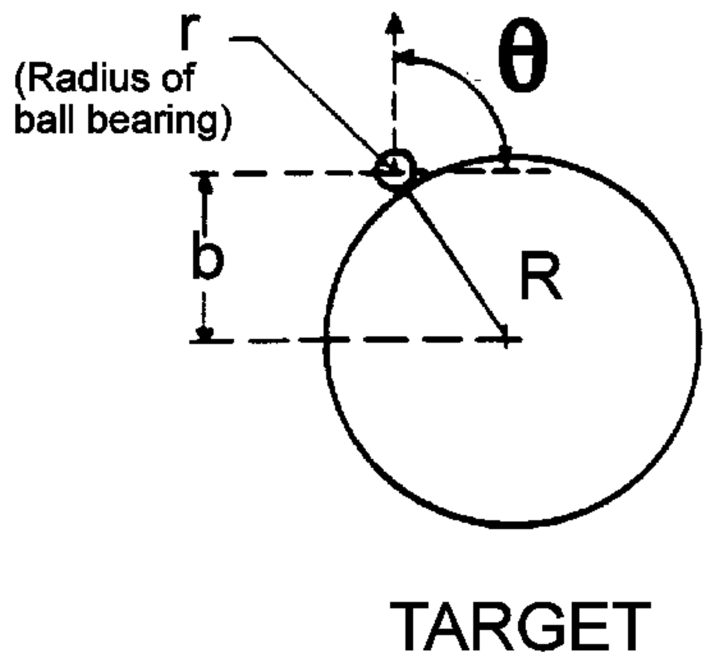

Figure 2.

When doing a real atomic or nuclear scattering experiment one cannot choose an impact parameter and study single scattering events. Instead, one must use a beam of particles (wide range of impact parameters) and measure the distribution of observed scattering angles. We can simulate this type of experiment with our apparatus by firing a large number (200-300) of ball bearings at the scatterer as we slowly move *b* through its full range of possible values.

THEORY

If the target in your experiment were situated in a uniform beam of particles for a given time duration (width *W*, total number of particles in the beam *N*) then the probable number of collisions taking place with an impact parameter value between *b* and $b + \Delta b$ would be, for a single target scatterer,

$$\left(\frac{N}{W}\right)\Delta b$$

Thus, if equation (1) is a correct description of the scattering process, the number of particles Δn scattered at angles between θ and $\Delta\theta$ will be

$$\Delta n = \frac{N}{W} \cdot \Delta b = \frac{N}{W} \frac{db}{d\theta} \cdot \Delta\theta$$

where $\frac{db}{d\theta}$ is found by differentiating (1).

$$\frac{db}{d\theta} = -\frac{1}{2} (R + r) \sin \frac{\theta}{2}$$

The minus in this formula merely indicates that θ decreases as b increases and it may be neglected. Thus:

$$\Delta n = \frac{1}{2} (R + r) \frac{N}{W} \sin \frac{\theta}{2} \cdot \Delta\theta \qquad (2)$$

You can check the validity of this equation by dividing your red wax paper into 5-10 equal angular ranges $(\Delta\theta)$ and counting the number of hits (Δn) in each range.

Then plot Δn versus $sin\frac{\theta}{2}$.

Note: As a check on (2) the total number of particles scattered by the target must be given by

$$n = \int \Delta n = \int_{-\pi}^{\pi} \frac{1}{2} (R + r) \frac{N}{W} \sin \frac{\theta}{2} \cdot d\theta = 2(R + r) \frac{N}{W}$$

which is exactly what common sense tells us: If the width of the beam is equal to the sum of the target and ball diameter ,{W=2(R+r)},all particles will be scattered (n=N).

The theory above is for a target of circular cross-section. There are also elliptical cross-section targets. You may find it interesting to derive the theory for scattering off such a target and to compare with the experimental results.

(efm - 1972, jbv - 1990, mf-95)