APPARATUS NOTES

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This department in collaboration with the Committee on Apparatus of the AAPT will welcome the submission of brief communications reporting new equipment, techniques, or materials of interest to teachers of physics. Notes on new applications of older apparatus, measurements supplementing data supplied by manufacturers, information which, while not new, is not generally known, procurement information, and news about apparatus under development are suitable for publication in this section. Neither the *American Journal of Physics* nor the Editors assume responsibility for the correctness of the information presented. Submit materials to: Bruce G. Eaton, Department of Physics, University of Minnesota, 116 Church St. SE, Minneapolis, MN 55455.

Simple demonstration of Compton effect

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The Compton effect is one of the experimental underpinnings of the quantum relationship between momentum and wavelength, as is discussed in the last term of our introductory physics sequence. The following demonstration of the effect is simple to set up, and students find it particularly interesting in its use of modern equipment.

The apparatus consists of a 2-in.$\times$2-in. NaI scintillation detector connected to a Tracor Northern TN-1705 multichannel analyzer. We use an 8 μCi ^{137}Cs source for the γ rays. This source has a single gamma line at 0.66 MeV, which is very well suited for observation of the Compton effect. The apparatus is set up with the NaI crystal mounted about 40 cm over the table top, facing down. The analyzer gain is set to display the gamma peak at about 3/4 of full scale. The offset bias is set at zero, so there is an approximate direct correspondence between channel number and energy. The analyzer accepts counts for a 10-s interval, continually displaying the spectrum on the screen.

For the demonstration, we first show how the count rate depends on the distance to the source, and then generate a spectrum with the source placed directly under the crystal. The source is placed on a cardboard tray mounted on a ringstand to hold it about 2 cm below the endface of the detector. With the 8% resolution of our NaI crystal, the 0.66-MeV peak in the gamma spectrum is very prominent, as may be seen in Fig. 1(a). The Compton plateau is also quite distinct. We explain the origin of the plateau from Compton scattering of gamma rays within the crystal. When the scattered gamma ray escapes from the crystal, only the energy deposited by the recoiling electron is measured in the event. The high-energy edge of the Compton plateau corresponds to the most inelastic collisions, with the gamma ray scattered by 180°. The formula for gamma energies at the Compton edge is then

$$\frac{1}{E_\gamma} - \frac{1}{E_\gamma} = \frac{2}{m_e c^2}, \tag{1}$$

where E_γ is the energy of the original gamma ray, and E_γ is the energy of the scattered gamma ray. We use the cursor of

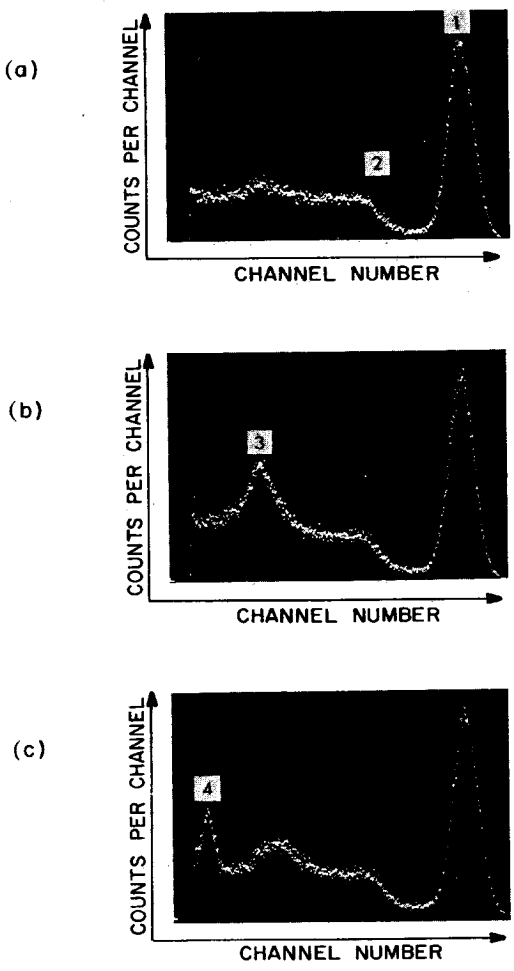

Fig. 1. Gamma spectra from a ^{137}Cs source recorded with a 2-in.$\times$2-in. NaI (Th) detector and a multichannel analyzer. (a) The source and detector are not near any solid material. The feature (1) is the full energy peak and feature (2) is the "Compton edge." (b) A 5-cm-thick aluminum block is placed directly behind the source to generate the "backscattering peak" (3). (c) The aluminum block is replaced with a lead block to generate the 80-keV Pb K x-ray peak (4).

the analyzer display to locate the channel of the main peak, which calibrates the energy scale of the analyzer. We then measure the energy of the Compton edge, which is related to the gamma energies by

$$E_e = E_\gamma - E_{\gamma'}. \quad (2)$$

Equation (1) may then be verified; typical numbers are shown in Table I.

The reasoning presented so far is somewhat indirect, but the remainder of the demonstration convinces the class. A 5-cm-thick aluminum block is placed under the source, and another spectrum is generated. The result is shown in Fig. 1(b). The new feature in the spectrum, a peak within the Compton plateau, is due to photons that have been backscattered from the aluminum. Their energy is just $E_{\gamma'}$ and from the channel position we verify energy conservation, Eq. (2), and also have another datum for verifying Eq. (1).

Finally, we replace the aluminum block by a lead brick and generate a third spectrum. Besides the Compton backscattering peak (less prominant now), there appears a peak at about 80 keV, which we leave to the class discussion to explain. Since the class has just learned about K x rays the previous week, with a homework problem on the energy of high-Z x rays, someone usually comes up with the explanation.

Table I. Compton scattering measurement.

Spectral feature		Channel	Energy (MeV)
Primary peak	E_γ	432	(0.662)
Compton edge	E_e	311	0.48
Inferred gamma	$E_{\gamma'} = E_\gamma - E_e$		0.18
Backscattered gamma	$E_{\gamma'}$	133	0.20
Pb x ray		53	0.08

The experiment we describe is appropriate as a lecture demonstration; for laboratory use a more elaborate scattering experiment, such as described in Ref. 1, would be more suitable.

[1]R. P. Singhal and A. J. Burns, Am. J. Phys. 46, 646 (1978).

The hydrobalance

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This note describes a device for measuring the relative density of solids which the author developed about eighteen years ago while still a student. This apparatus named hydrobalance employs the buoyancy principle but is superior to the Nicholson's hydrometer in several respects. A brief description of the same had appeared in a college physics book[1] in India (in the Hindi language) and I feel that it is very desirable to bring this fact to the notice of the physics community at large, and to the AAPT in particular.

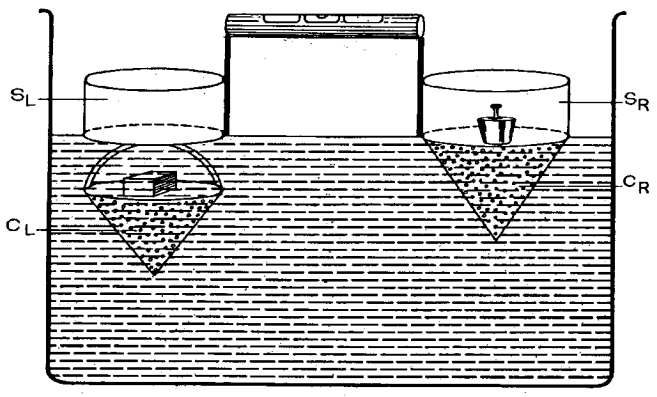

Fig. 1. A schematic diagram of hydrobalance showing the situation when the solid is placed under water on the cone C_L and the requisite known weights are placed inside the cup S_R.

This balance consists of two cups of equal diameter, volume, and weight, attached symmetrically to a spirit level. A hollow cone (C_R) is sealed to the bottom of cup S_R (Fig. 1). The other hollow cone (S_L) is closed at the top and is suspended below cup S_L. The cones are filled with lead shot so that the spirit level is horizontal when the two cups are equally immersed in water.

To determine the relative density of an unknown it is first placed in cup S_L and balanced by an appropriate weight (W_1) in the other cup. Next, the unknown solid is placed on top of cone C_L, under water, and balance restored with an appropriate weight W_2 in the opposite cup. The relative density of the solid is then found from $W_1/(W_1 - W_2)$.

There are three main advantages of this hydrobalance over Nicholson's hydrometer. There is no problem with the apparatus touching the wall of the container. Nicholson's hydrometer will tilt if the masses are not carefully centered on the pans, while this is not a problem with the hydrobalance. Nicholson's hydrometer requires three separate measurements to obtain the relative density while the hydrobalance requires only two measurements.

[1]B. L. Kulsrestha, *Madhyamik Bhowtiki* (Agra Book Store, Agra, 1968), p. 147.