Determination of the ratio of the principal specific heats for air

Christopher G. Deacon, and J. P. Whitehead

Citation: American Journal of Physics **60**, 859 (1992); doi: 10.1119/1.17071
View online: https://doi.org/10.1119/1.17071
View Table of Contents: https://aapt.scitation.org/toc/ajp/60/9
Published by the American Association of Physics Teachers

Determination of the ratio of the principal specific heats for air

Christopher G. Deacon and J. P. Whitehead
Department of Physics, Memorial University of Newfoundland, St. John's, Newfoundland A1B 3X7, Canada

(Received 5 February 1992; accepted 26 February 1992)

Rüchardt's method is often demonstrated in the undergraduate laboratory for determining γ, the ratio of the principal specific heats of air. Here, a metal ball is released at the top of a glass tube, which is connected to a reservoir of air, and undergoes damped harmonic oscillations. The variations of pressure and volume are presumed to be adiabatic, and, while factors that serve to determine the decay time associated with the oscillations are difficult to quantify, the period, T, of the oscillations is well approximated by the expression,

$$T^2=4\pi^2 mV/P_0A^2\gamma, \tag{1}$$

where P_0 is atmospheric pressure, m is the mass of the ball, A is the cross-sectional area of the tube, and V is the volume of air in the container.

It may also be shown that the vertical distance l which the ball falls before it begins to rise again is given by,

$$l=2mgV/P_0A^2\gamma. \tag{2}$$

Determination of γ by Eq. (2) is known as Rinkel's method. Note that the magnitude of l is twice the amplitude of the first oscillation.

The quantities in Eqs. (1) and (2) above are readily determined, and hence the ratio of the principal specific heats of air can be obtained independently from either method.

The apparatus required to perform such measurements is readily available from Central Scientific of Canada Ltd,[1] and consists of a glass tube of uniform diameter 16 mm, a stainless steel ball which is exactly the same diameter as the tube, and a glass aspirator, whose volume is about 10 liters. The aspirator is fitted with an air-tight rubber stopper, through which the tube passes.

While a single measurement will suffice to provide a reasonable estimate of γ, a considerable improvement in the precision of the experiment is obtained if the period and initial amplitude are measured as a function of the volume of air in the aspirator.

The volume of air may be easily varied with the addition of water to the container which is otherwise presumed to be empty. Writing V, the volume of air as,

$$V=V_0-V_w, \tag{3}$$

Eqs. (1) and (2) may be rewritten as

$$T^2=\frac{4\pi^2 m}{P_0A^2}\left(\frac{V_0}{\gamma}-\frac{V_w}{\gamma}\right), \tag{4}$$

$$l=\frac{2mg}{P_0A^2}\left(\frac{V_0}{\gamma}-\frac{V_w}{\gamma}\right). \tag{5}$$

Plotting either T^2 or l vs V_w therefore yields a straight line the slope of which allows for the determination of γ while the intercept provides an estimate of V_0, the volume of the aspirator. Some sample data is plotted in Figs. 1 and 2 together with the values of γ and V_0 obtained. In each case, the data give reasonable results which are consistant with both methods.

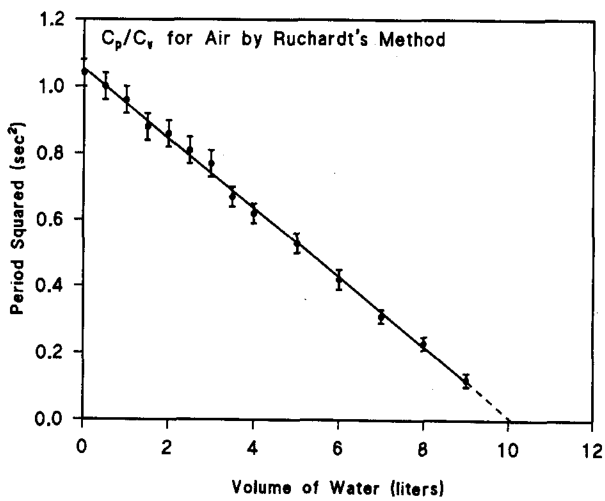

Fig. 1. Graph of (period)^2 versus volume of water to determine γ by Rüchardt's method. A least-squares fit to the data gives $\gamma=1.42\pm0.01$ and $V_0=(10.10\pm0.16)$ liter.

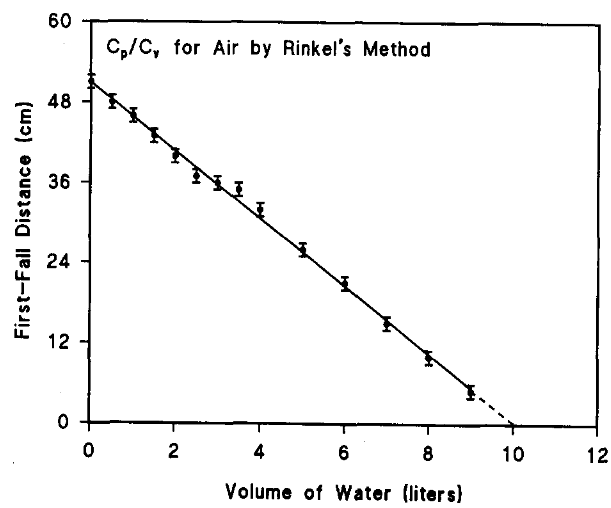

Fig. 2. Graph of first-fall distance versus volume of water to determine γ by Rinkel's method. A least-squares fit to the data gives $\gamma=1.45\pm0.03$ and $V_0=(10.06\pm0.21)$ liter.

The quantity γ is an important thermodynamic quantity since it completely specifies the thermal properties of a dilute gas. Moreover, γ may be interpreted microscopically through the equipartition of energy theorem as a measure of the number of thermally active degrees of freedom f per molecule, by virtue of the relation

$$\gamma = 1 + 2/f,$$

thus providing students with a simple but nonetheless important insight into the molecular basis of thermodynamics. In the case of a mixture of diatomic molecules such as air $f=5$ yielding $\gamma=1.4$. In addition to the significance of the experiment from the perspective of thermodynamics, it also offers an simple illustration of harmonic motion that can serve as the basis for further study and discussion.

More accurate methods for determining γ exist.[2] However, the present experiment is reasonably straightforward to do, and encourages the student to consider the wider applications of the graphical analysis of data as the method outlined above offers two independant determinations of γ as well as an independant estimate of the volume V_0.

[1]Catalog numbers: Tube (37105), Glass Aspirator (37104).
[2]D. G. Smith, "Simple C_p/C_v resonance apparatus for the physics teaching laboratory," Am. J. Phys. **47**, 593–596 (1979).

A simple demonstration of the Barkhausen effect

William Lonc
Physics Department, Saint Mary's University, Halifax, N.S. B3H 3C3, Canada

(Received 9 March 1992; accepted 23 March 1992)

In an attempt to demonstrate induced emf to a noncalculus introductory physics class, it was surmised that a simple cassette tape player could be useful. The idea was to place the player in its "play" mode—but without a tape—and then to wave a magnetized nail or screwdriver past the player's pickup head. It was expected that an audible "click" or "thump" would be heard in the loudspeaker (of course, the volume would be turned up to maximum!).

The result was as expected, but it was also noticed that there was "white" noise being generated at the same time. This noise immediately recalled a phenomenon known as the Barkhausen effect, which pertains to discontinuous domain–wall motion in a ferromagnet. To make the noise more dramatic, a magnetron magnet was brought up, somewhat slowly, to within a few centimeters of the cassette player's pickup head. As the magnet was being moved toward and away from the pickup head, the resulting white noise (discontinuous domain–wall motion) was quite noticeable.

It would be surprising if this particular implementation of demonstrating the Barkhausen effect is all that new. However, the author does not recall seeing any discussion of this implementation in this Journal during the past several decades, so the hope is that this particular discussion of the demonstration at this time will be of some interest. A convenient account of the effect is given by Feynman *et al.*[1]

[1]R. P. Feynman, R. B. Leighton, and M. Sands, *The Feynman Lectures on Physics Vol II* (Addison-Wesley, Reading, MA, 1964) Chap. 37, pp. 9–10.

HOW MANY PHYSICISTS HAVE READ *THE PRINCIPIA*?

Very few persons in London read Descartes, whose works have in fact become totally useless. Newton also has very few readers, because it requires great knowledge and sense to understand him. Everybody however talks about him.

Voltaire, quoted in *Let Newton Be*, edited by John Fauvel, Raymond Flood, Michael Shortland, and Robin Wilson (Oxford, New York, 1988), p. 3.