Acta Ciencia Indica, Vol. XXIII P, No. 1, 65 (1997)

STOKE'S LAW REVALIDATES ARISTOTLE'S ASSERTION

AJAY SHARMA

RECEIVED :

Galileo (1564 — 1642) is alleged to have contradicted about 2000 years old assertion of Aristotle (384–322 BC) by demonstrating that all bodies fall equal distances in equal times in air (one fluid) i.e. with the same acceleration (which is precisely true in vacuum only). This demonstration used Aristotle's assertion in proportionality form. But in view of current mathematical background and experimental data Aristotle's assertion is as useful in explaining the falling bodies as Stoke's law (enunciated in 1845 and largely confirmed in 1910). The reason being that mathmematical form of Aristotle's assertion simply reduces to Stoke's law under some conditions. In this regard Aristotle's assertion can be further useful if some experiments as suggested are successful.

1. INTRODUCTORY MATHEMATICAL BACKGROUND.

ARISTOTLE'S ASSERTION.

About the falling bodies[1] the assertion of Aristotle (384 – 322 B.C.) is, the falling tendency of body α mass of the body (m). According to it heavier bodies have higher tendency to fall than lighter one's. The assertion got the immediate support from the fact that a sheet of paper fall slowly than a metallic ball. In Aristotle's days the falling tendency of body can be understood to have been expressed in terms of 'average velocity'; as in this regard concept of acceleration was introduced by Galileo (1564–1642) and strengthened by Newton (1642–1727). So the above proportionality becomes

$$v_{av} \propto m$$

GALILEO'S DEMONSTRATION

Contrary to Aristotle's assertion, Galileo is alleged to have demonstrated that both one pond shot and ten pond shot (*i.e.* all bodies) travel equal displacements in equal times or in precise scientific language fall with the same acceleration. So Aristotle's assertion has been contradicted about after 2000 years of continuous use. To explain the critical observation of different motion of sheet of paper and a metallic ball (which supports Aristotle's assertion) Galileo held air resistance or upthrust responsible; but did not calculate the same due to lack of mathematical background existing at that time. But it became possible to calculate upthrust in 1685 when Newton published the Principia and defined acceleration due to gravity g and weight[2].

Thus acceptance to Galileo's idea came from the single demonstration which is not sufficient in modern scientific era. Thus Galileo should have conducted at that time experiments with various bodies and in fluids of high viscosity or density of different magnitudes to draw conclusions over a wide range. So such purposeful tests are absolutely important now.

COMMUNITY SCIENCE CENTRE, POST BOX 107
DIRECTORATE OF EDUCATION SHIMLA – 171 001 (H.P.) INDIA.

MATHEMATICAL EQUATIONS :

According to Archimedes' principle, in fluid of density d, the resultant weight w of body of density D of volume V is,

$$w = (D - d)\, V g \qquad \dots (1)$$

The resultant weight tends to accelerate the body downwards[3]; but with reduced magnitude as in fluids bodies have maximum (and constant) acceleration[4] equal to g.

In science all the scientific conclusions are drawn on the basis of exact mathematical equations; not on the basis of proportionalities as in case of Aristotle's assertion. So equation for the same can be written as,

$$v_{av} = zm \qquad \dots (2)$$

where z is constant of proportionality like Hubble's constant or coefficient, like coefficient of thermal conductivity or viscosity. The value of z depends upon experimental conditions and has been calculated in Eq. (5); and it can be measured in the similar apparatus as described in ref. (6).

1.1. THE RE-VALIDATION OF ARISTOTLE'S ASSERTION.

Stoke's in 1845, theoretically put forth that small spheres of radius r under five postulates[5] move in fluid of coefficient of viscosity n due to viscous force move with constant velocity v which is given by

$$v = (D - d)\, Vg/6\pi nr = (1 - d/D)\, mg/6\pi nr \qquad \dots (3)$$

Let motion of spheres of different masses but of the same density is considered in a medium, then D, d and n become constant so Eq. (3) becomes,

$$v = zm \qquad \dots (4)$$

So,

$$z = (1 - d/D)\, g/6\pi\, nr \qquad \dots (5)$$

If body falls with constant velocity, then both constant velocity and average velocity become equal. So Eq. (5) becomes,

$$v = v_{av} = zm \qquad \dots (6)$$

or

$$v_{av} \propto m$$

Thus Eq. (6) based upon Stoke's law is nothing but Eq. (2) which is equation for Aristotle's assertion. So Aristotle's assertion which has been abundoned after 2000 years of continuous use; in fact even now is as useful as Stoke's law in explaining the falling bodies. Aristotle's assertion in this regard can be more useful than Stoke's law if some sensitive experiments can be conducted.

Arnold confirmed Stoke's law for small spheres of rose metal of radii 0.002 cm with an accuracy of a few tenths of 1%. It implies that bodies of radii more than 0.002 cm don't move with constant velocity *i.e.* fall with variable velocity[6]. If this variable velocity is more for heavier body (even under some conditions); then under those conditions Aristotle's assertion is valid. However under these conditions Stoke's law is not valid.

Such experiments can be conducted in more viscous fluids like glycerine (n for glycerine is 1.069 deca poise and n for water is 0.00101 deca poise *i.e.* 1058. 4 times more) thus bodies of radii more than 0.002 cm may fall with constant velocity as viscous force $F = 6\pi nr\, v$ is more in case of glycerine. Thus Aristotle's assertion in case of falling bodies is at least as useful as Stoke's law; and if some experiments as suggested above are successful then it would be more useful than Stoke's law.

Thus it is evident that had Arnold's data (1910) been available in Galileo's time (1564—1642) then even now Aristotle's assertion would have been correct in this region.

2.0 CONCLUSIONS :

Thus it is evident that Galileo (1564—1642) is alleged to have contradicted Aristotle's assertion (in proportionality form) that too in an macroscopic experiment in air (one fluid). Even at that time Galileo has not been able to explain phenomena quantitatively; which has formed basis for the assertion and; in fluids no data was available (as now there is experimental data of confirmation of Stoke's law by Arnold). Thus Aristotle's assertion has been abundoned due to lack of mathematical background and experimental data. But now a days concrete conclusions are drawn on the basis of exact mathematical equations and experimental observations over a wide range. The mathematical equations of the assertion reduces to that of Stokes' law *i.e.* Eq. (2) and Eq. (6). Thus in view of current scientific status Aristotle's assertion is as useful as Stoke's law. If some experiments as suggested are successful then it will be more useful than Stoke's law in such phenomena.

ACKNOWLDGEMENTS :

The author is indebted to Prof. R.L. Balokhara, Dr. Shashi Sharma and many others for critical discussion. Also financial assistance from Community Science Centre, Shimla, is gratefully acknowldged.

REFERENCES :

1. Resnick, R. and Halliday, D., Physics Part I (Wiley Eastern Limited, New Delhi), pp. 48—49 (Fourty second reprint) (1992).
2. Sharma, A., *To be published in Speculations in Science and Technology* (accepted on 12 Feb. 1996).
3. Michel, W.C., *Foundations of Physics* (D. Van Nostrand, London, pp. 255—256 (1968).
4. Niebauer, T.M., Mchugh, M.P. and Faller, J.E., Phys. Rev. Lett. **59**, 609—612 (1987).
5. Millikan, R.A., *The Electron* (The University of Chicago Press, Chicago), pp. 93—96 (2nd Edition, 10th impression) (1980).
6. Sharma, A., *Acta Ciencia Indica*, Part–I, pp. 22–24, (1996).