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LIMITATIONS OF EXISTING THEORIES; AND AN ALTERNATE THEORY ON RISING, FALLING AND FLOATING BODIES

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In the existing literature there are no equations which may explain the natural motion (when no external forces act on the system, and medium has sufficiently large magnitude and at rest) of falling and rising bodies (i.e. 0.1 mg m or less, 50 gm, 50 kg or more; and spherical, flat, thin foil or distorted shaped may have holes or twists at the surfaces such that density remains precisely the same) quantitatively i.e. distance travelled in certain time in various fluids. Thus bodies may move with constant velocity, constant acceleration and variable acceleration. To explain such phenomena Archimedes' principle, Stokes' law and drag force are used. The drag force is applicable if relative velocity of body is high and constant. According to Archimedes' principle in fluids the bodies rise or fall with constant acceleration or variable velocity. So the body will only move with high and constant velocity, if high external force is applied judiciously on the body. But in natural motion of bodies no external force is applied, so drag force is not applicable in such phenomena. Stokes' law has been put forth under five postulates in 1845; and has been experimentally verified with an accuracy of a few tenths of 1% by Arnold in 1910 in case of falling spheres of rose metal of radii 0.002 cm or $V = 33.524 \times 10^{-9}$ c.c. in water. Thus it is applicable in extremely narrow range. Stokes' law, is regarded as to hold good in rising bodies (if velocity is negative), but no experiments have been conducted to confirm it. According to Archimedes' principle if D_m and D_b remains the same then theoretically all bodies should fall or rise in fluids (the principle sets no specific constraints on maximum magnitude of medium) with CONSTANT ACCELERATION. This prediction so far has not been quantitatively confirmed. However, bodies also move with constant velocity (Stokes' law). It is equally possible that bodies may also fall with VARIABLE ACCELERATION under suitable conditions. Further Archimedes' principle can be used to explain the motion of rising and falling bodies under limiting situations only i.e. if bodies rise or fall with CONSTANT ACCELERATION. According to Archimedes' principle, bodies of steel of masses 10 gm (flat or distorted) and 10 gm (spherical) should fall down in water through equal distances in equal intervals of time; but it has not been justified even at macroscopic level. According to Archimedes' principle the body floats if its density is precisely equal to that of medium; and shape has no role to play. But in case of floating balloons in water, the mass which balloon supports is found to depend upon the shape of balloon in first stage observations. In such phenomena mass, shape, distortion and angle at which body is dropped; magnitude of medium, shape of its container and state of motion of medium along with other factors like temperature and viscosity etc. are very significant. But Archimedes' principle takes in account D_m and D_b only. Thus an alternate or complete theory has been formulated taking all the factors in account; some sensitive experiments are required to confirm it.

1.0 THE LIMITATIONS OF EXISTING THEORIES: In the existing literature there are no equations which may explain the natural motion of rising and falling bodies irrespective of mass and shape (i.e. 0.1 gm or less, 50 gm, 50 kg or more; and spherical, flat, thin foil or distorted shape may have twists or holes at the surface such that density remains the precisely same) quantitatively i.e. displacements travelled by bodies in particular time in various fluids. Here by natural motion it is meant that medium is at rest and sufficiently large in magnitude; and no external forces act on the system of body and medium. The quantitative inadequacy and

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conceptual limitations of existing relevent doctrines in this regard are discussed below. Similar work of the author on Stokes' law[1] (i.e. it is unconfirmed in case of rising bodies), Archimedes' principle[2] (does not account for shape of body) and Aristotles' assertion[3] (it is as useful as Stokes' law in falling bodies if interpretted on the basis of equation rather than proportionality) useful in this regard.

1.1 STOKES' LAW: Stokes in 1845 put forth that under five postulates[2,6] small spheres of radius r, in fluid of coefficient of viscosity n fall with Constant Velocity c or Zero Acceleration, which is given by

$$c = 2\,(1 - D_m / D_b)\, D_b r^2\, g / 9n \quad ...(1)$$

In 1910 Arnold verified Eq. (1) in water with an accuracy of a few tenths of 1% for sphere of rose metal of radii 0.002 cm i.e. $V = 33.524 \times 10^{-9}$ cc. Thus it is applicable in extremely narrow range. Thus sphere of radii more than 0.002 cm fall with a variable velocity or motion is accelerated. Similarly equation for rising bodies with constant velocity in fluids can be written as

$$c = 2\,(D_m / D_b - 1)\, r^2 D_b\, g / 9n \quad ...(2)$$

The Eq. (2) can be used to determine the viscosity of fluids, purposely a method has been described by the author[1].

1.2. ARCHIMEDES' PRINCIPLE: The equations based upon the principle became derivable, after 1935 years of its enunciation i.e. in 1685 when Newton published the Principia[2]. According to it the resultant weight (weight in fluid if fluid is at rest) w, of body of density D_6 and volume V in medium of density D_m is

$$w = (1 - D_m / D_b)\, V D_b\, g \quad ...(3)$$

Due to the resultant weight w, the body is accelerated downwards[4]; and Arnold[6] has confirmed that sphere of radii 0.002 cm fall with variable velocity i.e. motion is accelerated. Niebauer[5] has confirmed that bodies fall with maximum acceleration g in vacuum (in medium where density of air has been negligible). So in fluids resultant downward acceleration G (acceleration in fluid) can be determined from w as,

$$G = (1 - D_m / D_b)\, g \quad ...(4)$$

In vacuum $D_m = 0, \quad G = g$ ...(5)

Likewise resultant upthrust u and resultant upward acceleration are,

$$u = (1 - D_m / D_b)\, V D_b\, g \quad ...(6)$$

and $$H = (D_m / D_b - 1)\, g \quad ...(7)$$

Thus according to Archimedes' principle if D_m and D_b are the same; then all bodies irrespective of mass and shape (defined earlier) should fall or rise with precisely constant acceleration. But this prediction has not been experimentally confirmed yet.

So purposely experiments are required to be conducted to draw distinct boundary about characteristics of bodies (mass and shape etc.) and media for which Archimedes' principle (i.e. bodies fall with constant acceleration) and Stokes' law (i.e. bodies fall with constant velocity) hold good. It is just possible that Eqs. (4, 7) may be justified under certain conditions (as in case of Stokes' law). For certain typical mass and shape bodies may fall with variable acceleration; then it will be accounted for by none of two.

1.3. DRAG FORCE: The total resistance of plate (body) in direction of fluid stream is called drag force[7], and in magnitude is given by,

$$D = C D_m A U^2 \quad ...(8)$$

where C is drag coefficient, A is area of cross-section of body, and U is relative velocity (constant in magnitude) of body in medium. Thus U can be +ve or –ve or zero. The Eq. (8) has been derived by method of dimensions and is applicable if relative velocity U is HIGH and CONSTANT. It is evident from determination of drag coefficients when body is subjected to fluid stream of CONSTANT VELOCITY, air craft and submarine move with CONSTANT VELOCITY etc.

The drag force is not applicable in natural motion of bodies it can be illustrated in a practical example. According to Eq. (4) if body of Al (2700 kg/m^3) is dropped in water (998.23

kg/m^3) at rest then it will attain velocities after 1s, 3s and 5s equal to 6.17 m/s, 18.51 m/s, and 30.85 m/s respectively as it has acceleration in water 6.17 m/s^2. Thus in fluids (water) the velocities of bodies are variable i.e. not constant. The relative velocity of body can be maintained HIGH and CONSTANT (pre-condition for derivation and applicability of drag force i.e. Eq. (8); if suitable external force is applied judiciously on the body in the interval. As in natural motion (defined earlier) no external force is applied on the body so body falls with CONSTANT ACCELERATION, according to Archimedes' principle; hence drag force as given by Eq. (8) is not applicable in such phenomena.

For completeness let us consider if external force of magnitude F is applied on the body in the interval in direction opposite to motion of falling bodies. Thus body forcibly may attain CONSTANT VELOCITY relative to medium, then drag force may be applicable. So external force, drag force and upthrust all act upwards. Thus value of U (falling) in magnitude is given by

$$D_b Vg = F_e + CAD_m U^2 + VD_m g \text{ or } U = \left[\left\{ (D_b - D_m) Vg - F_e \right\} / CAD_m \right]^{1/2} \quad \text{... (9)}$$

The Eq. (9) has also been quoted by Resnick[8] in the following way,

$$U = (D_b Vg / CAD_m)^{1/2} \quad \text{... (10)}$$

Strictly speaking in Eq. (10) F_e and u have not been taken in account. Likewise constant velocity of rising body is given by,

$$U = \left[\left((D_m - D_b) Vg - F_e \right) / CAD_m \right]^{1/2} \quad \text{... (11)}$$

Then distances travelled can be calculated as $S = Ut$. But experimentally it may not be feasible to calculate accurately constant velocity U as accurate determination of F_e is quiet tedious process; and simultaneous accurate determination of C makes it further complex.

Thus it is evident that in natural motion (defined earlier) drag force is not applicable; and Stokes' law is applicable in extremely narrow range. Further in this regard applications of Archimedes' principle can be discussed; but so far in existing literature the principle has not been confirmed even at preliminary level i.e. Eqs. (4, 7) based upon fundamental law have not been quantitatively confirmed.

1.4 ARCHIMEDES' PRINCIPLE AND QUANTITATIVE DISPLACEMENTS OF BODIES. The displacements of bodies when fall with constant acceleration (the principle theoretically predicts the same) in vacuum and fluids are,

$$S = 1/2\, g t^2 \quad \text{... (12)}$$

$$S = 1/2\, G t^2 = 1/2\, (1 - D_m/D_b)\, g t^2 \quad \text{... (13)}$$

Similarly for various rising bodies displacement in fluids is,

$$S = 1/2\, (D_m / D_b - 1)\, g t^2 \quad \text{... (14)}$$

The Eqs. (13–14) are only applicable if resultant downward and resultant upward accelerations are precisely constant and medium is at rest. If the medium is set in motion (even due to falling and rising body) then energy of medium is imparted to body which has influence on its motion. It is just possible that prediction of Archimedes' principle that bodies move in fluids with constant acceleration may be true under certain conditions (as in case of Stokes' law). So the effect of magnitude of medium is likely to be the most significant, however Archimedes' principle does not specify the exact amount of medium for its confirmation. Thus in this regard for final confirmation of rising and falling bodies Eqs. (13-14) some sensitive experiments are required involving bodies of various masses, densities, and shapes in fluids of different magnitudes, densities and viscosities. According to Archimedes' principle i.e. Eq. (13) the bodies of aluminium of mass 10 gm (distorted) and 10 gm (spherical) should fall through 27.7956 m in 3s; in water but this prediction has not been experimentally confirmed, even at macroscopic level.

To confirm the prediction from Archimedes' principle about the rising bodies (a body of cork (240 kg/m^3) irrespective of mass and shape in water should rise through 139.324 m in 3s.) media of different dimensions should be considered; as magnitude of medium is likely to be very significant.

1.5. ARCHIMEDES' PRINCIPLE AND FLOATING BODIES. According to the principle the bodies (irrespective of mass and shape) float in media; if $VD_m g = VD_b g$ i.e. $D_m = D_b$. Under this condition from Eqs. (4, 7) both resultant downward acceleration G and resultant upward acceleration H are zero; and body is regarded at rest. According to it when body floats its shape is completely insignificant by all means. But it has not been found correct in first stage observations involving floating balloons in water; as mass which balloons of same volume support in water is found to depend upon shape of balloon. Thus to account for the shape of balloon, purposely upthrust is regarded as proportional to weight of fluid displaced thus the principle has been generalised[2]. The constant of proportionality thus comes in picture is regarded as to account for shape of balloon and other relevant factors. To understand the floating bodies critically or completely bodies of non-hygroscopic plastic of various shapes and densities slightly less or more than that of water should be fabricated to conduct experiments. Such experiments should be conducted in fluids of high density (mercury) and viscosity (glycerine).

1.6. THE RIGOROUS REQUIREMENT OF AN ALTERNATE THEORY: Thus it is evident that in explaining natural motion (defined in sub-section (1.0)) of rising and falling bodies the drag force is not applicable. The reason for its non-applicability is that in natural motion; the conditions of derivation and applications (the velocity should be HIGH and CONSTANT) of drag force are not satisfied. Secondly Stokes' law is applicable in extremely narrow range as confirmed by Arnold in falling bodies and regarding rising bodies it has yet to be confirmed.

Finally Archimedes' principle is left which is applicable in such quantitative phenomena of rising and falling bodies under very special or limiting conditions. The principle is only applicable if resultant upward or resultant downward accelerations of bodies in fluids are precisely constant. Furthermore in such phenomena Archimedes' principle has not been confirmed quantitatively (i.e. whether or not the bodies rise or fall with constant acceleration in fluids; if yes then what are the conditions) even at preliminary level. About the floating bodies; Archimedes' principle predicts that the shape of body is insignificant but in case of floating balloons in water in first stage observations the shape of body has been observed to play a significant role.

Hence to explain the phenomena over a wide range (motion may be with CONSTANT VELOCITY or CONSTANT ACCELERATION or VARIABLE ACCELERATION; taking all factors in account i.e. mass, shape and angle at which body is dropped, magnitude, characteristics motion of medium and convectional currents etc.; an alternate or complete theory on rising, falling and floating bodies has been formulated as below.

2.1. THE BACKGROUND OF AN ALTERNATE OR COMPLETE THEORY: An alternate or complete theory on rising, falling and floating bodies has been formulated taking in account the limitations of existing theories. Here approach may be initially postulate like (the same is the situaton with many other theories) as some factors are included to explain the phenomena which are not taken in account in Archimedes' principle. In this theory all effective forces exerted by body and medium on each other are compared taking all possible factors in account which may influence the results directly or indirectly.

The body may be in any fluid (which has natural tendency to flow) or medium; primarily it is under the influence of gravity i.e. body exerts force (F_b) on the fluid as attracted by the earth. As a reaction medium also exerts force (F_m) on body. The force exterted by medium (may be in motion, of any magnitude, viscosity etc.) includes upthrust and other relevant factors. The

magnitude of F_m (which includes upthrust and other factors) may be regarded as proportional to density of medium D_m mainly, (also upthrust, $u \propto D_m$).
So,

$$F_m = a_m D_m \quad \text{... (15)}$$

The coefficient a_m which is obtained by removing the sign of proportionality (like coefficient of thermal conductivity, drag coefficient etc.), it depends upon the characteristics of medium and can be expressed in one of the simplest way as,

$$a_m = x_m y_m \quad \text{... (16)}$$

where x_m accounts for magnitude and shape of medium; y_m its state of motion along with other relevant factors like temperature, viscosity, convectional currents, surface tension etc.

JUSTIFICATION OF a_m

The significance of effect of magnitude of medium (i.e. x_m) can be understood in the following way. In falling bodies Stokes' law has been reasonably well studied but in limited cases only, in this case magnitude and state of motion of medium has been clearly defined (i.e. infinite in extent; and at rest). If motion of spheres has been studied in containers then effect of walls leads to a correction factor. It is confirmed that bodies fall with constant acceleration g in vacuum only due to gravity. Also the bodies may fall with constant acceleration in fluids (but with reduced magnitude depending upon values of D_m and D_b) under certain conditions as already mentioned. But according to the principle i.e. Eq. (7) the bodies (defined earlier) also rise with constant acceleration in fluids (irrespective of depth); that too against gravity i.e. inverse square law of attraction. If this prediction is experimentally confirmed even under certain conditions; then magnitude of medium and shape of container will be significant. According to the principle a body of cork (say, $r = 1$ cm) should rise through 3.8701 m in 0.5 s. Let there be four tanks filled with water having dimensions 10 m × 10 m × 10 m, 5 m × 5 m × 5 m, 4 m × 4 m × 3.8701 m, and 0.4 m × 0.4 m × 3.8701 m. Now it has to be experimentally confirmed whether in all cases bodies rise upward through 3.8701 m in 0.5 s or not as predicted by Archimedes' principle. If the prediction is not confirmed in some cases then it would be due to magnitude of medium only. In case of falling bodies of different shapes effect of magnitude of medium can be studied at different depths. Archimedes' principle is only valid if medium is at rest. But an alternate or complete theory is applicable even if medium is in motion; and this effect is taken in account in y_m.

Due to viscous force ($F = 6\pi\, nr\, c$) bodies attain constant velocity, under the feasible conditions. At 20°C density of water is 998.23 kg/m^3 and that of glycerine nearly 1260 kg/m^3. Whereas coefficient of viscosity of water at 20°C is 0.00101 deca poise; and that of glycerine 1.069 deca poise. Thus effect of coefficient of viscosity is very significant in case of glycerine in regard to motion of bodies; as coefficient of viscosity is 1058.4 times more than that of water, and density is only 1.2622 times more. Further the effect of viscosity in motion of bodies can be understood in the following way. The maximum density of water is 1000 kg/m^3 at 4°C. Under certain conditions the density of glycerine can be 1000 kg/m^3. If densities of glycerine and water are equal (Archimedes' principle requires only densities); and motion of bodies is even if slightly different then it would be due to viscosity only as even if slightly different then it would be due to viscosity only as viscosities of water and glycerine are different. This effect can also be studied in case of rising bodies.

The surface tension is significant as small thin foil rests over the surface of water; whereas a small sphere of the same mass sinks in water. It can also be studied in highly viscous fluids like glycerine. Also both surface tension and viscosity depend upon temperature. More significantly fluidity of fluid (tendency to flow freely) also depends upon temperature e.g. as temperature tends to zero water attains solid state. Thus in an alternate or complete theory, the phenomena are discussed for simplicity at standard temperature, say at 20°C. All this discussion highlights the importance of a_m; but there is no such term in Archimedes' principle.

Likewise the magnitude of force F_b exerted by body (irrespective of mass, shape, distortion and angle at which body is dropped in medium) on the medium (includes weight and other factors) can be regarded as proportional to D_b (also weight, $w \propto D_b$). So

$$F_b = a_b D_b \qquad ... (17)$$

The coefficient a_b is obtained after removing proportionality (like coefficient of viscosity, drag coefficient etc.) depends upon characteristics of body and may be expressed in one of the way as

$$a_b = x_b y_b \qquad ... (18)$$

where x_b accounts for magnitude of body, y_b for shape or distortion of body and angle at which it is dropped and other relevant factors.

JUSTIFICATION OF a_b.

It has been experimentally confirmed: even in recent sensitive experiments that bodies fall with the same acceleration g in vacuum only. Thus in complete vacuum a minute particle of steel of mass a few macrogram or less and 50 kg or more (irrespective of shape) should fall through equal distances in equal intervals of time (i.e. with the same acceleration). But it is not true if the motion of bodies is observed in fluids (say, water). The small spheres (a particular shape) and of particular mass, ($33.524 \times 10^{-9} D_b$ gm.) fall in fluids with constant velocity or zero acceleration (the essence of Stokes' law). It is equally possible that bodies may fall or rise with variable acceleration depending upon the mass and distortion of body. Hence in fluids effects of mass and shape of body have to be taken account. Such experiments can be confirmed in high and viscous fluids. To understand the effect of shape (y_b) in a concrete way, consider two bodies of steel (7800 kg/m^3) having masses 62.4 gm each i.e. V =8 cc. Let one body is a cube of each side 2 cm i.e. 2 cm × 2 c m × 2 cm; and the other body be thin foil i.e. 50 cm × 16 cm × 0.01 cm. Now this flat body falls slowly in water (contrary to Archimedes' principle i.e. Eq. (13)); so this effect is accounted for by a_b in an alternate or complete theory. In case of thin foil its weight (i.e. measure of force exerted by body), and hence F_b on unit area of water decreases considerably compared to the cube of the same volume and density. But below the unit area of body water column (say, a tank of water) remains the same. The force F_m, exerted by medium (water), on effective unit area of body remains the same. So in case of thin foil F_b per unit area decreases but F_m, remains the same. Hence a thin foil compared to sphere or cube of same D_b and V falls slowly in water considerably. Thus a is very significant, but not accounted by any the principle. To draw concrete conclusions about rising bodies some specific quantitative experiments are required, which have not been conducted yet. The units of a_b and a_m are N kg^{-1}m^{-3} or m^{4}s^{-2} in SI system.

The ratio of magnitudes of F_m and F_b is called Hidden-Ratio (HR),

$$HR = F_m / F_b = a_m D_m / a_b D_b = x_m y_b D_m / x_b y_b D_b \qquad ... (19)$$

EXPLANATION FOR MOTION OF BODIES: If HR is more than one, then effective force exerted by medium dominate than that exerted by body; hence body rises in that medium. If HR is less than one then effective force exerted by body dominate than that exerted by medium and body falls in that medium. If HR is equal to unity then effective forces exerted by body and medium on each other are equal and body floats. The Falling Factor (FF) and Rising Factor (RF) are measures of tendency of body to fall or rise. Thus higher the FF and RF higher is the tendency of body to fall or rise. The FF and RF can be calculated as

$$FF = 1 - HR = (1 - x_m y_m D_m / x_b y_b D_b) \qquad .... (20)$$

$$RF = 1 - HR = (x_m y_m D_m / x_b y_b D_b - 1) \qquad ... (21)$$

2.2 STANDARD CONDITIONS: Under certain conditions (may be termed as standard conditions) the values of a_b and a_m are regarded as unity for simplicity. Thus under standard conditions HR, FF and RF become

$$HR = D_m / D_b \quad \text{.... (22)}$$

$$FF = (1 - D_m / D_b) \quad \text{... (23)}$$

$$RF = (D_m / D_b - 1) \quad \text{... (24)}$$

The standard conditions can be understood in the following way. According to the existing literature bodies fall with CONSTANT VELOCITY as in Eq. (1); and also with CONSTANT ACCELERATION (variable velocity) as in Eq. (4), however this prediction is yet to be experimentally confirmed. This prediction may be true under certain conditions. Also in some cases the bodies may fall with VARIABLE ACCELERATION. Under these three types of motion the standard conditions are different.

(i) The bodies only fall with constant velocity under five postulates as put forth by Stokes, theoretically. These postulates are regarded as standard conditions i.e. if these postulates are satisfied then values of a_m and a_b, may be regarded as unity.

(ii) If the bodies fall with constant acceleration; then in one of the ways the body may be regarded as standard if it is of steel (7800 kg/m^3) of mass 10 gm ($x_b = 1$ m^2 s^{-1}) and spherical in shape ($y_b = 1$ m^2 s^{-1}). Similarly medium may be regarded as standard in one of the ways if water is filled in cube of each side 5m ($x_m = 1$ m^{2}s^{-1}) and water is at rest ($y_m = 1$ m^2 s^{-1}). If the motion of the bodies is observed in air in closed hall, then medium may be regarded as standard (a_m = 1 m^4 s^{-2}). Also the standard conditions may be attributed in different ways. i.e. if these are justified as discussed in sub-sections (3.1 – 3.2).

(iii) It is possible if mass of body is nonuniformly distributed and is typically distorted then bodies may fall with variable acceleration. In this regard attribution of standard conditions require some tests.

About the rising bodies there is very little existing quantitative data to draw concerete conclusions. Also if the bodies are observed to rise upward with constant acceleration (agianst gravity) as in Eq. (7); then standard conditions may be attributed in the following way. Then body of wood (600 kg/m^3) of mass 10 gm ($x_b = 1$ m^2 s^{-1}) and spherical in shape ($y_b = 1$ m^2 s^{-1}) may be regarded as standard ($a_b = 1$ m^{4}s^{-2}). Similarly medium may be regarded as standard if water at 20°C is filled in cube of each side 5 m ($x_m = 1$ m^2 s^{-1}) and is at rest ($y_m = 1$m^2 s^{-1}). Thus standard conditions are similar to in case of falling bodies.

2.3. THE DISPLACEMENT IN TERMS OF FF AND RF.

(i) Falling bodies: Higher the *FF*, higher is the displacement through which body falls, in time *t*. Thus.

$$S \propto (FF)\, t \quad \text{or} \quad S = A\,(FF)\, t \quad \text{... (25)}$$

where *A* is coefficient, obtained after removal of proportionality. Its value depends upon involved experimental conditions and have units ms^{-1}. *A* is written as vector, because its magnitude directly depends upon g as in Eqs. (31, 37). With help of Eqs. (20, 23), Eq. 25 becomes

$$S = A\,(1 - x_m\, y_m\, D_m / x_b\, y_b\, D_b)\, t \quad \text{... (26)}$$

$$S = A\,(1 - D_m / D_b)\, t \quad \text{... (27)}$$

In all the cases i.e. body may fall with constant velocity, constant acceleration (variable velocity) and variable acceleration; the general Eqs. (26-27) remain the same, but only the value of *A* varies depending upon the situation. The values of *A* are determined as below.

(a) When bodies fall with constant velocity: The constant velocity of body in fluids is given by Eq. (1); also in this case the constant velocity is equal to average velocity i.e. $V_{av} = c$. Also calculating average velocity from Eq. (27) we can write,

$$V_{av} = c = A\,(1 - D_m / D_b) \quad \text{... (28)}$$

Thus comparing Eq. (28) with Eq. (1), as velocity remains constant, we get

$$A = 2r^2 D_b\, g / 9n \quad \text{... (29)}$$

So,

$$V_{av} = 2r^2 D_b\, g\,(1\ D_m / D_b) / 9n \quad \text{... (30)}$$

Arnold verified Eq. (6) for small spheres of rose metal of radii 0.002 cm in water. The value of *n* for water at 20°C is 0.01 poise then

$$A = 0.8888888 \times 10^{-4} D_b g \quad ...(31)$$

and
$$V = 0.8888888\ 10^{-4} D_b (1 - D_m / D_b) g \quad ...(32)$$

From Eq. (32) velocities for steel and aluminium bodies in water at 20°C are 0.5925 cm/s and 0.1482 cm/s. Thus there is a complete agreement between predictions of Eq. (32) based upon an alternate theory and existing experimental findings.

(b) **When bodies fall with constant acceleration:** It has been confirmed that the bodies fall with constant acceleration equal to g in vacuum. Also according to Archimedes' principle i.e. Eq. (4) bodies fall with constant acceleration but with reduced magnitude in fluids depending upon values of D_m and D_b. So far it has not been experimentally confirmed; yet under certain conditions it may be true. Both the cases are discussed as below.

(i) When bodies fall with constant acceleration in vacuum; In this case displacement depends upon time as t^2 as in Eq. (12). Thus value of A in Eq. (25) should be of the form

$$A = k\,t \quad ...(33)$$

k can be written as k_o for vacuum. So

$$A = k_o\, t \text{ (in vacuum)} \quad ...(34)$$

In vacuum, Eqs. (26–27) become

$$S = A\,t = k_o t^2 \quad ...(35)$$

Now Eq. (12) and Eq. (35) both give displacements in vacuum, hence

$$k_o = 1/2\, g \quad ...(36)$$

The value of A and displacement S in vacuum becomes,

$$A = 1/2\, g\, t \quad ...(37)$$

and
$$S = 1/2\, g\, t^2 \quad ...(38)$$

(ii) When bodies fall with constant acceleration in fluids.

In this case also displacement depends upon time t as t. Thus value of A will be of the form ($k = k_m$ for the medium)

$$A = k\,t = k_m t^2 \text{ (in medium)} \quad ...(39)$$

Thus Eqs. (26-27) become

$$S = k_m (1 - x_m y_m D_m / x_b y_b D_b)\, t^2 \quad ...(40)$$

$$S = k_m (1 - D_m / D_b)\, t^2 \quad ...(41)$$

If the body is under standard conditions and falls with precisely with constant acceleration in fluids; then determining S corresponding to time t; then value of k_m can be determined.

(c) When body falls with variable acceleration: The displacement depends upon time t as t^2 only if it falls with constant acceleration. In this case it may depend upon time as t. Further k_m may have some complex dependence on involved factors i.e. mass, shape, distortion and angle at which body is dropped; magnitude of medium, shape of its contianer and its state of motion along with other factors like temperature, viscosity etc. In such cases the value of k_m can be established after some sensitive tests.

RISING BODIES. Similarly the displacement when bodies rise upward is proportional to the RF and time t. Hence displacements are analogous to Eqs. (26-27) and can be written as

$$S = B\,(x_m y_m D_m / x_b y_b D_b - 1)\, t \quad ...(42)$$

$$S = B\,(D_m / D_m - 1)\, t \quad ...(43)$$

where B is coefficient. Its nature and magnitude are precisely identical to A. In the existing literature there is no quantitative data about rising bodies to draw concrete conclusions. So some experiments are required to ascertain the characteristics of B.

3.1. THE FALLING BODIES AND ALTERNATE THEORY. According to alternate theory, the bodies fall down if HR is less than one i.e. effective force exerted by body is more than that exerted by medium. The measure of tendency of body to fall is Falling Factor, given by Eqs. (20, 23); thus higher the FF, higher the tendency of body to fall.

(i) In vacuum; In complete vacuum D_m can be regarded as zero and also HR is zero; which is less than one hence bodies fall down. Further FF for all bodies in vacuum is unity, hence possess

equal tendency to fail. Thus according to Eqs. (40, 41) all bodies travel equal distances in equal intervals of time. In language of existing science all bodies fall with the same acceleration.

(ii) *In air:* The *HRs* from Eq. (22) i.e. under standard conditions for bodies of aluminium (2700 kg/m^3), steel (7800 kg/m^3), silver (10500 kg/m^3) and platinum (21500 kg/m^3) in air (1.293 kg/m^3) are 0.0004788, 0.0001657, 0.0001213 and 0.0000601, which are less than one hence bodies fall down. The *FFs* for these bodies from Eq. (23) are 0.999521, 0.999834, 0.999877 and 0.999939; hence fall down. Now the values of *FFs* for these bodies in air are less than one (i.e. that for in vacuum); hence the bodies fall down in air slowly than in vacuum.

If the body of steel of mass 10 gm ($x_b = 1\ m^2\ s^{-1}$) and spherical in shape ($y_b = 1\ m^2\ s^{-1}$) is regarded as standard and it falls through distance 100 cm in time t. Let $k_m = k_{sa}$ for body of steel in air. Then for body of steel in air Eq. (41) becomes,

$$S = 100 = k_{sa}\,(0.999834)\,t^2 \quad \text{or} \quad k_{sa} = 100/0.999843\,t^2 \qquad \ldots (44)$$

Then body of aluminium in air can be regarded as standard in air in the following way. Let value of k_m for body of aluminium in air is k_{aa} and is equal to k_{sa} i.e. $k_{sa} = k_{aa}$; if fall with constant acceleration in air. Let in air the body of aluminium falls through distance S, then Eq. (41) becomes

$$S = k_{aa}\,(0.999521)\,t^2 = 99.9677 \text{ cm} \qquad \ldots (45)$$

Thus the body of aluminium spherical in shape will be regarded as standard in air which travels distance equal to 99.9687 cm in time t; in which body of steel of mass 10 gm, spherical in shape falls through 100 cm. It is just possible that this prediction may be confirmed for body of aluminium of mass precisely equal to 10 gm. or nearly 10 gm.

(iii) *In water:* The *HRs* for bodies of aluminium, steel, silver and platinum in water (998.23 kg/m^3) are 0.3697148, 0.1279782, 0.0950695 and 0.0464293 which are less than one. The *FFs* for these bodies in water from Eq. (23) are 0.630285, 0.872022, 0.904931 and 0.953571 respectively. Thus the *FFs* for same bodies are less in water than air; hence bodies fall slowly in water comparatively which is true.

The body of aluminium can be regarded as standard in water in the following way. For standard body of steel ($a_b = 1\ m^4\ s^{-2}$), in water ($a_m = 1\ m^4\ s^{-2}$ *i.e.* tank of water of such side equal to 5 m and water is at rest) if it travels distance 100 cm in time t, the Eq. (41) becomes

$$100 = k_{sw}\,(0.872022)\,t^2 \quad \text{or} \quad k_{sw} = 100/(0.872022)\,t^2 \qquad \ldots (46)$$

Here k_{sw} is value of k_m for body of steel in water. Let value of k_m for body of aluminium in water is k_{aw} which is equal to k_{sw} i.e. $k_{aw} = k_{sw}$, if falls with constant acceleration. If in tank of water of each side 5 m ($x_m = 1m^2\ s^{-1}$) and water is at rest ($y_m = 1\ m^2s^{-1}$), a body of aluminium falls through distance S in time t. Then the distance S from Eq. (41) becomes

$$S = k_{sw}\,(0.630285)\,t^2 = 72.2785 \text{ cm} \qquad \ldots (47)$$

Now that body of aluminium in water can be regarded as standard which falls through distance 72.2785 cm in time t, in which a body of steel of mass 10 gm spherical in shape falls through 100 cm in the same time. If this prediction is nearly confirmed for body of aluminium of mass 10 gm, then slight deviations from the spherical shape can be considered for the precise confirmation.

If this prediction is confirmed for some other body of aluminium i.e. of different mass than 10 gm and different shape than spherical; then that body can be regarded as standard. Likewise such experiments can be conducted by determining time t, taken by bodies to fall through 10 cm or 1,000 cm for various bodies in various fluids, if are more convenient experimentally.

3.2. THE RISING BODIES AND ALTERANTE THEORY: According to alternate theory the body rises upward if *HR* is more than one i.e. effective force exerted by medium is more than that exerted by body. The measure of tendency of body to rise is Rising Factor (RF) as given by Eqs. (21, 24): thus higher the *RF* higher the tendency of body to rise upward. In vacuum (D_m =0), *HR* for every body is zero, which is less than one so all bodies fall down. For rising bodies *HR* is more than one (i) *In air*: To discuss the upward motion of hydrogen and helium filled balloons in air; it is hypothetically assumed for simplicity that the densities of balloons are equal to those of gases; or the densities of balloons have to be precisely measured. The densities of hydrogen and helium gases are 0.0899 kg/m^3 and 0.1785 kg/m^3; thus for these *HRs* in air are 14.3826 and 7.2436. The *RFs* for balloons from Eq. (24) in air are 13.3826 and 6.2436; thus hydrogen filled balloon (or bubble) rise quickly than helium filled one.

According to Maxwell's law of distribution of molecular speeds[10] lighter gases escape easily from the earth's atmosphere. It can be justified on the basis of alternate theory. Here let us discuss motion of hydrogen, helium, oxygen (1.428 kg/m^3) and carbon dioxide (1.977 kg/m^3); considering each as individual body in air. In this case *HRs* for O_2 and CO_2 are less than one in air i.e. 0.905462 and 0.65402. The *FFs* for these are 0.094537 and 0.34598; hence fall down in air. Thus lighter gases (H_2 and He_2) escape easily from the earth's atmosphere due to higher RFs i.e. 13.382 and 6.24; and heavier gases (CO_2 and O_2) fall down or settle at the bottom due to higher FFs i.e. 0.34598 and 0.094537. Thus deductions from an alternate theory are consistent with Maxwell's law of distribution of molecular speeds; hence with experimental observations.

(iii) *In water:* The RFs for bodies of cork (240 kg/m^3) and wood (600 kg/m^3) from Eqs. (24) i.e. under standard conditions are 3.1593 and 0.66372, hence rise upward. As RF for cork is more than that of wood; hence cork rises upward quickly than wood.

Let standard body of wood (a_b = 1 m^4 s^{-2}), in water (tank of each side equal to 5 m and water is at rest i.e. a_m = 1 m^4 s^{-2}) travels distance 100 cm in time t. If value of B for wood in water is B_{ww} then Eq. (43) becomes

$$S = B_{ww} (0.66372)\, t \quad \text{or} \quad B_{ww} = 100/0.66372\, t \qquad \text{... (48)}$$

Then body of cork in water can be regarded as standard in the following way. Let value of B for cork in water is B_{cw} which is equal to B_{ww} i.e. $B_{cw} = B_{ww}$, if rise with constant acceleration. If in tank of water (a_m = 1 m^4 s^{-2}) a body of cork (a_b = 1 m^{4}s^{-2}) rises through distance S in time t. Then value of S for body of cork from Eq. (43) calculated as

$$S = B_{cw} (3.1593)\, t = 475.9989 \text{ cm} \qquad \text{... (49)}$$

Now that body of cork in water (a_m = 1 m^4 s^{-2}) will be regarded as standard which rises through 475.9989 cm in time t, in which body of wood rises through 100 cm. Now slight variations in shape of body of cork of mass 10 gm can be considered; if this prediction is precisely confirmed for body of mass 10 gm.

In case this prediction is justified for some other body of cork of mass other than 10 gm in tank of water of different dimensions than 5 m (water is at rest) then that body and tank is regarded as standard. Further such experiments can be conducted in highly viscous fluids like glycerine to understand the effect of viscosity in case of rising bodies.

The density of water at 20°C is 998.23 kg/m^3 and under certain conditions the density of glycerine can be made equal to 998.23 kg/m^3 (which is ordinarily 1260 kg/m^3). If the densities of both water and glycerine are made equal; and motion of bodies is found different then it can be largely due to viscosity. So in this regard some sensitive experiments are required. Likewise such experiments can be conducted by determining time t taken by bodies to fall through 10 cm or 100 cm or 1000 cm for various bodies in various fluids.

3.3. THE FLOATING BODIES AND ALTERNATE THEORY. According to this theory the body floats, if *HR* is equal to unity i.e. the magnitudes of effective forces i.e. F_m and F_b become equal. Thus in Eqs. (20–21, 23–24) both *RF* and *FF* become equal to zero; hence also the distances travelled from Eqs. (26–27 and 42–43).

(i) In air: Let hydrogen filled balloon has *RF* equal to 3 (under standard conditions), thus it rises upward. As it rises upward the density of air decreases, hence *HR*. At some stage the force exterted by balloon and medium on each other become equal, then *HR* becomes unity. Both *RF* and *FF* and distances travelled from Eqs. (23-24, 26-27; 42-43) become zero. Thus body floats at that stage i.e. neither rises nor falls.

(ii) A body of cork falls in air (*FF* = 0.994612) and rised upward in water (*RF* = 3.1593) and rests over the surface of water partially submerged. The small pins of steel sink in water due to

definite *FF* equal to 0.872022. But if these pins are pricked to cork start resting at the surface of water and system (cork and steel) is partially submerged. As pins are continuously pricked to cork; then density of system gradually increases and *HR* decreases. As soon as the force exterted by the system becomes more than that exerted by water due to gradual pricking of the pins to cork *HR* becomes less than one and body sinks.

Alternate theory as an extension of Archimedes' principle. As already mentioned according to Archimedes' principle the body floats if the density of body is precisely equal to that of medium i.e. $D_m = D_b$. However, according to an alternate theory the body floats if *HR* is equal to unity; thus

$$x_m\, y_m D_m = x_b\, y_b\, D_b \quad \text{or} \quad D_m = x_b\, y_b D_b / x_m\, y_m = z\, D_b\,. \qquad ..(50)$$

So according to an alternate theory the body can float if its density is different (i.e. slightly less or more) than that of medium, depending upon the value of z which depends upon x_i's. This prediction is likely to be readily verified in high viscous and dense fluids. If the value of z is unity then alternate theory simply reduces to Archimedes' principle. So an alternate theory is a general formulation and Archimedes' principle is its special case. In case of floating bodies to confirm impact of various factors (accounted for by z) other than D_m and D_b, some sensitive experiments are required.

The values of z other than unity. Bizzeti et al[9] have quoted that a solid sphere (a particular shape) of non-hygroscopic plastic (of radius r = 5 cm i.e. 523.809 cc) is allowed to float freely inside saline solution having almost the same density (but not precisely measured). In case a body of density 998.24 kg/m^3 of non-hygroscopic plastic of volume 523.809 cc (i.e. l = 500 cm, b = 209.5236 cm and t = 0.005 cm) floats in tank of suitable dimensions in which water of density (998.23 kg/m^3) is filled. This body may also have different possible shapes. Then value of z equal to 0.9999899 can be experimentally confirmed.

Now it is evident that shape of body plays a significant role in falling and rising bodies (Stokes' law); so it should be confirmed in floating bodies also. The various experiments depending upon shape, distortion of body and characteristics of medium including its magnitude some quantitative deviations from the principle can be confirmed. According to Archimedes' principle the shape of body has no role to play at all when body floats. But this prediction has not been found correct in first stage observations regarding the floating balloons in water[2]. In such experiments the mass which balloon of any shape supports in water has been found to depend upon the shape of balloon in various sets of observations. Likewise many more such tests can be conducted.

(a) If non-hygroscopic body of plastic of density 998.23001 kg/m^3 (of any possible shape) floats in water of density 998.23 kg/m^3; then value of z equal to 0.99999999 will be confirmed.

(b) If non-hygroscopic body of plastic of density 998.22999 kg/m^3 (of any possible shape i.e. spherical or cone) floats completely submerged in water of density 998.23 kg/m^3 then value of z will be 1.00000001. All such experiments cited above can be conducted in containers of water of different magnitudes; as according to alternate theory the magnitude of medium may also play a significant role.

Floating bodies in mercury and glycerine. Both an alternate theory and Archimedes' principle are equally applicable for all fluids of high and low viscosity or density. Firstly, let us discuss quantitative experiments in mercury (13,600 kg/m^3 or 13.6 gm/cc). Let us consider a body of mass 5 gm or less (flat in shape) having density 13.6001 gm per cc floats in mercury (13.6 gm per cc) then value of z will be 1.0000073.

Likewise if a body (of any possible shape) of suitable mass of density 13.5999 gm/cc floats completely submerged in mercury (13.6 gm/cc) then value of z will be 0.9999926. As mercury is not a transparent liquid then to confirm whether body floats or not some sensitive and careful experiments are required. Similar experiments can be conducted in glycerine which has very high viscosity.

In such experiments magnitude or volume of medium (of high density and viscosity) may be significant. It implies that such experiments should be conducted, in medium of volume ranging from few cubic cm to cubic m in containers of different shapes.

Thus it is evident that as far as critical and quantitative study of phenomena of rising, falling and floating bodies is concerned Archimedes' principle (which is main principle in the existing literature) takes in account only D_m and D_b. But in this regard there are also other factors which are equally significant, but not taken in account the principle. These factors have been taken account in an alternate theory or complete theory via a_m and a_b; along with D_m and D_b. Thus to confirm the predictions of an alternate theory or quantitative inadequacy of Archimedes' principle some sensitive experiments are required.

4.0. MEASUREMENT OF a_m AND a_b. So far phenomena under standard conditions are discussed. The values of x_m, x_b, y_m and y_b can be determined easily in the following way; by comparing the unknown values with known one s.

(*i*) *Measurement of* x_m : Consider a steel body of standard mass 10 gm ($x_m = 1$ m^2 s^{-1}) and spherical in shape ($y_b = 1$ m^2 s^{-1}) is dropped in tank of water of each side 5 m ($x_m = 1$ m^4 s^{-2}) and water is at rest ($y_m = 1$ m^{2}s^{-1}). Let body travels distance equal to 100 cm in time t. So Eq. (41) becomes,

$$100 = k_{sw}\,(0.872022)\,t^2 \quad \text{or} \quad k_{sw} = 100/0.872022\,t^2 \qquad \text{... (51)}$$

Let heavier body of steel of mass 10 kg or more ($x_n \neq 1$m^2 s^{-1}) and spherical in shape ($y_b = 1$ m^2 s^{-1}) travels distance 104 cm in time t (say k_{sw} remains the same). So,

$$104 = k_{sw}\,(\text{FF})\,t^2 \text{ or } FF = 0.906903 \qquad \text{... (52)}$$

Thus x_b (now body is not standard) can be determined from Eq. (20) as,

$$0.906903 = 1-0.12798/x_b \text{ or } x_b = 1.374679 \text{ m}^2 \text{ s}^{-1} \qquad \text{... (53)}$$

Thus value of a_b (x_b y_b) in this case is 1.374691 m^{4}s^{-2}.

(ii) *Measurement of* y_b. Let a body of steel of mass 10 gm i.e. $V = 1.282051$ cc ($x_b = 1$ m^2 s^{-1}) and flat in shape ($y_b = 1$ m^2 s^{-1} i.e. $2 \times 2 \times 0.325127$ cc or $2 \times 4 \times 0.1602563$ cc is dropped in tank of water under standard conditions ($a_m = 1$ m^{4}s^{-2}). Let this flat body (or even distorted) travels distance 98 cm in time t, then FF can be 0.854581 as in Eq. (52). Then value of y_b from Eq. (20) can be determined as,

$$0.854582 = 1-0.127978/y_b = y_b = 0.880069 \text{ m}^2 \text{ s}^{-1} \qquad \text{... (54)}$$

Thus in this case value of a_b (x_m y_m) will be 0.880069 m^4 s^{-2}

Measurement of a_m

(*iii*) *Measurement of* x_m. Let steel body of mass 10 gm ($x_b = 1$ m^{2}s^{-1}) and flat in shape ($y_b = 0.880069$ m^{2}s^{-1}) is dropped in tank of water of each side equal to 15 m ($x_m = 1$ m^{2}s^{-1}) and water is at rest ($y_b = 1$ m^2 s^{-1}). The effect of magnitude of medium (if significant) can be understood in the following way. Let at some stage in first half (0-7.5m) a body of steel travels distance 99.998 cm in time t. Then in this case FF can be calculated equal to 0.872004 as in Eqs. (52). So x_m from Eq. (20) is,

$$0.872004 = 1-0.127978\,x_m/0.880069 \text{ or } x_m = 0.8801931 \text{ m}^2 \text{ s}^{-1} \qquad \text{... (55)}$$

So in this case value of a_m will be 0.8801931 m^{4}s^{-2}.

Let at some stage the same body in second half (7.5 – 15 m) falls through distance 100.002 cm in time t, then in this case FF can be calculated as 0.872039. Thus from Eq. (20) x_m will be

$$0.872039 = 1.0\text{–}127978\,x_m/0.880069 \text{ or } x_m = 0.879952 \text{ m}^2\text{s}^{-1} \qquad \text{... (56)}$$

Thus value of a_m (x_m y_m) in this case will be 0.872039 m^4 s^{-2}.

(*iv*) *Measurement of* y_m: Consider a body of steel of mass 10 gm ($x_b = 1$ m^{2}s^{-1}) and flat in shape ($y_b = 0.880069$ m^{2}s^{-1}) as in Eq. (54). Let it is dropped in tank of water of each side equal to 5 m ($x_m = 1$ m^{2}s^{-1}) and water is in motion ($y_m \neq 1$ m^2 s^{-1}) ; may be rotated externally or shaken such that density of water remains the same. Let in this case distance travelled by body is 97 cm, then FF can be calculated equal to 0.845861. Then value of y_m can be calculated from Eq. (20) as,

$$0.845861 = 1-0.127978\,y_m\,/\,0.880069 \quad \text{or} \quad y_m = 1.05997 \text{ m}^2\text{s}^{-1} \qquad \text{... (57)}$$

TABLE 1– COMPARISON OF EXISTING THEORIES ON RISING, FALLING AND FLOATING BODIES WITH AN ALTERNATE THEORY IN NATURAL MOTION OF BODIES.

Characteristics	Existing theories	Alternate theory
	1. The Falling Bodies.	
(i) Term	Resultant downward acceleration. $G = (1-D_m/D_b)\ g$.	Falling Factor $FF = (1-x_m y_m D_m / x_b y_b D_b)$.
(ii) Displacement	$S = 1/2\ Gt^2$.	$S = A\ (FF)\ t$.
(iii) Applicable if	G is constant.	No such constraint.
(vi) Preliminary predictions	All bodies fall with constant acceleration in fluids if D_m and D_b remain the same.	All bodies may not fall with constant acceleration depending upon a_m and a_b
(v) Typical predictions	All bodies of steel of mass 10 gm (distorted) and 10 gm (sphere) should fall in fluids equal distances in equal times.	These bodies should not fall through equal distances in equal times depending upon a_i' s
(vi) Contradictions	In denser fluids	No such constraint.
(v) Reasons for contradictions	G only depends upon D_m and D_b.	Not applicable.
(vi) Stokes' law	Required, if applicable.	Not required.
(vii) Drag force	Not applicable	Not required.
	2. The Rising Bodies	
(i) Term	Resultant upward acceleration $H = (D_m / D_b - 1)g$	Rising Factor $RF = (x_m y_m D_m / x_b y_b D_b - 1)$
(ii) Displacement	$S = 1/2\ H t^2$	$S = B\ (RF)\ t$
(iii) Applicable if	H is constant.	No such constraint.
(vi) Dependence	H does not depend on mass and shape of body.	RF takes all such factors in account.
(v) Preliminary predictions	All bodies should rise with constant acceleration in fluids if D_m and D_b remain the same.	All bodies may not rise with constant acceleration depending upon a_m and a_b.
(vi) Typical predictions	A body of cork of mass 10 gm (distorted) and 10 gm (sphere) should rise in water through 3.8701 m in time 0.5 s.	These bodies may not rise through 3.8701 m in 0.5 *s* depending upon values of a_m and a_b.
(vii) Verification	Specific tests have not been conducted so far.	Quantitative tests have been suggested.
(viii) Stokes' law	Required, if applicable.	Not required.
(ix) Drag force	Not applicable	Not required.
	3. Floating bodies	
(i) Term	Resultant acceleration, G & H	RF and FF
(ii) Condition	G and H are zero	RF and FF are zero.
(iii) Equation	$D_m = D_b$	$D_m = D_b$
(iv) Typical prediction	A pallet of mass (flat) of mass 1 gm or less of density 13.60001 gm per cc should sink in mercury.	It may not sink depending upon values of values of a_m and a_b.
(v) Verification	In preliminary floating balloon tests in water it has not been found correct[1].	This has been justified in these balloons tests.

So value of a_m (x_m y_m) will be 1.05997 m^4s^{-2}. Likewise the value of a_m and a_b in other cases (including rising bodies) can be calculated.

5.0. CONCLUSIONS: Thus it is evident that to explain the natural motion of bodies quantitatively drag force is not applicable. Stokes' law is applicable in extremely narrow range. Further to explain the motion Archimedes' principle is applicable under limiting situations only i.e. if bodies rise or fall with precisely constant acceleration as predicted by Eqs. (4, 7). But so far the Eqs. (4, 7) have not been confirmed quantitatively. About floating bodies principle predicts that shape of body has no role to play; which has not been found true in case of floating balloon tests[2]. In all three cases the principle accounts for only D_m and D_b. But in this case other factors like mass, shape and angle at which body is dropped; magnitude, viscosity, surface tension, temperature and motion of medium etc. play very significant roles. Thus taking all these factors in account along with D_m and D_b, an alternate theory on rising, falling and floating bodies has been formulated. Now some sensitive experiments are required to confirm quantitative inadequacy of Archimedes' principle (a main existing theory) and establish an alternate or complete theory. The comparison of existing theories and alternate theory is shown in Table I.

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