The dynamics of an initially nonspherical liquid droplet falling in air under the action of gravity is investigated via three-dimensional numerical simulations of the Navier-Stokes and continuity equations in the inertial regime. The surface tension is considered to be high enough so that a droplet does not undergo break-up. Vertically symmetric oscillations which decay with time are observed for low inertia. The amplitude of these oscillations increases for high Galilei numbers and the shape asymmetry in the vertical direction becomes prominent. The reason for this asymmetry has been attributed to the higher aerodynamic inertia. Moreover, even for large inertia, no path deviations/oscillations are observed.

I. INTRODUCTION

A blob of fluid of density $\rho_1$, moving in a surrounding medium of density $\rho_o$, is called a bubble if $\rho_1(=\rho_1/\rho_o) < 1$ or a drop if $\rho_1 > 1$. In gas-liquid systems, bubbles in general behave differently from drops and the mechanism behind the differences were investigated by Tripathi et al. [1]. It is well known that as a result of path instability, an initially spherical air bubble rising in a liquid ($\rho_r << 1$) can either zigzag or spiral for high inertia and high surface tension [2–5]. It undergoes an unsteady shape deformation resulting in vortex shedding behind the bubble during this wobbling motion. In contrast, a solid sphere or an initially spherical liquid drop in air ($\rho_r >> 1$) falls in a straight path [6]. For a falling leaf or flat/cylindrical solid objects (i.e. non-spherical) in gas/liquid, oscillatory motion is observed due to the associated aerodynamics/hydrodynamics (see e.g [7]). A question that arises then is, can we observe path and/or shape instabilities by making the initial drop shape non-spherical in an air-liquid system. It would be interesting to study if a similar phenomenon occurs for a nonspherical liquid drop falling in air.

In liquid-liquid systems (with $\rho_r \leq 2.2$), by releasing spherical drops of organic liquids, Edge & Grant [8] experimentally found that a small liquid drop in a straight path, but a bigger drop falls in a zig-zag path (i.e., wobbling motion) in water under the action of gravity. They observed a thread-like wake for small drops, but vortex sheet for large drops falling in zigzag paths. They also observed shape oscillations (oblate-prolate deformation) in case of zigzagging drops. Later, considering liquid-liquid systems (for $\rho_r \approx 1$), Koh & Leaf [9, 10] investigated the dynamics of an initially non-spherical bubble rising in a quiescent liquid of slightly higher density by conducting numerical simulations and experiments at low Reynolds numbers ($Re < 0.01$). They found that a bubble with a small degree of nonsphericity, comes back to a spherical shape, whereas for a bubble with a large degree of nonsphericity, the deformation continues to increase with time. Specifically, they [10] experimentally showed that an oblate bubble of initial aspect ratio, $A_{r,0} \approx 2.63$ became spherical, but a bubble with $A_{r,0} \approx 5.45$ formed a skirt-like structure, which broke to form satellite bubbles, at later times. In case of an initially prolate bubble, they found that for $A_{r,0} \approx 0.89$ the bubble eventually became spherical, whereas for $A_{r,0} \approx 0.7$ a tail was formed, which got detached from the main bubble at later times. The viscosity ratios considered by them were in the range [0.026–0.74], while density ratio, $\rho_r$ was about 0.954. The first analytical correlation between the frequency of shape oscillation of a spherical drop and its physical properties in the inviscid and linear limit (for small oscillation) was given by Rayleigh [11]. Later studies focussed on the decay rate of the oscillations for a viscous drop in zero-gravity [12, 13]. The effect of initial amplitude on frequency for nonlinear inviscid oscillations was reported by Tsamopoulos and Brown [14]. Several investigations concerning the effect of viscosity on drop shape-oscillations have also been carried out [15–17]. However, to the best of our knowledge, none of the studies include the effect of gravity, i.e. in the inertia dominated regime.

To summarise, one can say that while a bubble in an air-liquid system ($\rho_r << 1$) can undergo path instabilities under some conditions, a drop in an air-liquid system ($\rho_r >> 1$) always falls in a straight path. A solid in air/liquid ($\rho_r >> 1$) also falls in a straight path if it is spherical, but may follow an oscillatory path if it is nonspherical. In liquid-liquid systems, a falling drop ($\rho_r \approx 1$, where inertia can be neglected) with a degree of nonsphericity can undergo a zig-zag path under certain conditions. Thus, we ask and attempt to answer a few questions, which motivated the present study. They are (i) Can one observe oscillatory motion in case of a falling liquid drop in air ($\rho_r >> 1$) by changing its initial shape to a nonspherical one? (ii) For situation (i), where inertia becomes important, what effect does it have on the droplet dynamics? (iii) The presence of inertia may result in vortex shedding. What is the role of vortex shedding in this case and how different is it from that observed in
case of a rising bubble? To answer these questions, three-dimensional numerical simulations are conducted to investigate the hydrodynamics of an initially nonspherical liquid droplet falling in air ($\rho_r \approx 1000$), and the effects of initial deformation (degree of obliquity) and inertia are investigated.

The rest of this paper is organised as follows. The problem is formulated in Section II. The computational method used and the validation of the numerical solver are also provided in this section. The results obtained from the study are discussed in Section III, and the concluding remarks are given in Section IV.

II. FORMULATION

The dynamics of an initially nonspherical, yet axisymmetric about the vertical axis, liquid drops (as shown in Fig. 1) falling in air under the action of gravity ($g$) is investigated via direct numerical simulations of three-dimensional incompressible Navier-Stokes and continuity equations. Two types of initial droplet shapes, namely oblate ($A_{o} > 1$) and prolate ($A_{o} < 1$) as shown in Fig. 1, are considered. The initial aspect ratio ($A_{0}$) of the droplet is varied by keeping the volume ($R_{eq}^3 = a^2b$) constant, wherein $R_{eq}$ is the volume equivalent spherical radius of the droplet. A Cartesian coordinate system ($x, y, z$) is used with the gravity ($g$) acting in the negative $z$ direction. Initially, both the droplet and surrounding air are stationary. Free-slip and no-penetration conditions are imposed on all the boundaries of the computational domain.

The governing equations, which describe the dynamics of a falling liquid droplet in air, are the equations of mass and momentum conservation. The dimensionless form of the governing equations are given by:

$$\nabla \cdot \mathbf{u} = 0,$$

$$\frac{\partial \mathbf{u}}{\partial t} + \mathbf{u} \cdot \nabla \mathbf{u} = -\nabla p + \frac{1}{Ga} \nabla \left[ \mu (\nabla \mathbf{u} + \nabla \mathbf{u}^T) \right] + \frac{\delta}{Eo} \mathbf{n} - \rho g,$$

$$\frac{\partial \mathbf{c}}{\partial t} + \mathbf{u} \cdot \nabla \mathbf{c} = 0,$$

where the dimensionless density and dynamic viscosity are given by

$$\rho = (1-c) + c \rho_r,$$

$$\mu = (1-c) + c \mu_r.$$

Here, $\mathbf{u} = (u, v, w)$ denotes the velocity field in which $u$, $v$ and $w$ represent the velocity components in the $x$, $y$ and $z$ directions, respectively. Pressure field is denoted by $p$, $t$ denotes time, $\mathbf{j}$ denotes the unit vector along the vertical direction, and $c$ is the volume fraction of the liquid phase, such that, $c = 0$ and $1$ for the air and liquid phases, respectively. $\delta$ is the Dirac delta function used to model a localized surface force at the phase interface, and $\mathbf{n}$ is the outward-pointing (away from the liquid) unit normal to the interface. The non-dimensionalisation are performed using $R_{eq}$ and $V = \sqrt{g R_{eq}}$ as the length and velocity scales, respectively. The dimensionless time is defined as $\sqrt{R_{eq}/g}$.

The various dimensionless numbers, which appear in Eqs. (2)-(5) are the Galilei number ($Ga = \rho_0 g (\rho_0 R_{eq}^3/\mu_0)$), Eötvös number ($Eo = \rho_0 g R_{eq}^2/\sigma$), density ratio ($\rho_r = \rho_{r}/\rho_0$) and viscosity ratio ($\mu_r = \mu_{r}/\mu_0$). Here, $\rho_1$, $\mu_1$ and $\rho_0$, $\mu_0$ are the density and dynamic viscosity of the inner (liquid) and outer (air) phases, respectively. $\sigma$ represents the (constant) interfacial tension for the pair of fluids considered. Note that the $Ga$ and $Eo$ defined here do not correspond to the actual ratios of buoyancy to viscous forces and the buoyancy to surface tension forces, respectively. These are utilized only for the sake of uniformity between different studies of bubbles and drops, wherein all the fluid properties are non-dimensionalized based on the outer fluid.

A Volume-of-Fluid (VOF) method that incorporates a height-function based balanced-force continuum-surface-force formulation for the inclusion of the surface force term in the Navier-Stokes equations is used [18]. A dynamic adaptive grid refinement is incorporated, which provides large number of grid points/cells in the vortical and interfacial regions. The numerical scheme is second order accurate in space and time. In order to minimise the wall effects, a sufficiently big computational domain is considered. The present numerical method is similar to the one used by Tripathi et al. [4] to investigate a rising air bubble in a quiescent liquid.

Grid convergence and choice of domain size: In Fig. 2(a), (b) and (c), the effects of height of the computation domain, $L$ and grid size on the shapes of the droplet at two time instants are investigated. The width

![Diagram showing initial shapes of liquid droplets falling in air](image75x574 to 278x740)
and breadth of the computational domain are considered to be large enough such that boundary effects can be neglected. Initially, the droplet is placed at a distance 40 below the top of the computational domain. Fig. 2(a) shows the droplet shapes at \( t = 11 \) and 12.5, obtained in a computation domain with \( L = 120 \) and with smallest grid sizes 0.058 and 0.234 in the interfacial and the vortical regions, respectively. Fig. 2(b) and (c) show the corresponding droplet shapes for the same computational height \( (L = 160) \), but obtained using different grid sizes in the interfacial and the vortical regions, respectively. The locations of centre of gravity, \( z_{CG} \) and aspect ratios of the droplet at \( t = 11 \) and 12.5 are also given in Fig. 2. The value of \( z_{CG} \) is measured from the bottom of the computational domain. It can be seen that the droplet shapes, aspect ratio and \( z_{CG} \) presented in Fig. 2(a), (b) and (c) match very well (the maximum errors for \( A_r \) and \( z_{CG} \) are less than 0.1%). In view of this, we use \( L = 160 \) and grid sizes 0.078 and 0.312 in the interfacial and the vortical regions, respectively, to generate the rest of the results presented below. Through out this study, \( E_o = 10^{-3} \) (a low value of \( E_o \), i.e., high surface tension) is chosen such that the droplet will not undergo break-up.

III. RESULTS AND DISCUSSION

A. Effect of initial shape

The dynamics of different initial aspect ratios of oblate \((A_{r0} > 1)\) and prolate \((A_{r0} < 1)\) shaped liquid droplets falling in air is presented in Figs. 3 - 6. In Fig. 3, the variations of \((a - b)\) with time are shown for \( A_{r0} = 1.0 \) (initially spherical droplet), 1.19, 1.33 and 1.95 for \( Ga = 10, \ E_o = 10^{-3}, \mu_r = 55 \) and \( \rho_r = 998. \) The viscosity and density ratios considered correspond to the air-water system. It can be seen that an initially spherical droplet (see Fig. 3(a)) remains almost spherical (i.e., \( a - b = 0 \)) for the entire duration (upto \( t \approx 15 \)). This is due to the higher surface tension force, as compared to the aerodynamic-inertia and viscous forces (i.e., low \( E_o(= 10^{-3}) \) and low \( Ca(= \mu_o V/\sigma) \)), which prevents the deformation of the droplet. However, for a small change in initial aspect ratio \((A_{r0} = 1.19)\), the droplet undergoes an oblate-prolate-oblate oscillation, with a dimensionless time period \((T_p)\) close to 2.3 for this set of parameters. For \( A_{r0} = 1.33, \) the amplitude of oscillation \( H \left(= (a_{max} - a_{min})\right)\), wherein \( a_{max} \) and \( a_{min} \) are the maximum and minimum values of \( a \) during the oscillations) increases, but the time period of shape oscillations remains close to that observed for \( A_{r0} = 1.19 \). Increasing the initial obliquity further \((A_{r0} = 1.95)\), increases the amplitude of oscillations and also increases the time-period of shape oscillations due to dominant nonlinear effects. It is also observed (not shown) that the strength of vorticity around the droplet increases with an increase in \( A_{r0} \).

The frequency of oscillation for this mode was derived by Rayleigh [11] using a linear theory (for small oscillations) in the inviscid limit to be \( f_1 = \sqrt{2\sigma/((\pi^2 \rho R^5)}\), which yields a dimensionless frequency, \( f = \sqrt{2/[(\pi^2 \rho E_o)}\). The corresponding dimensionless time period obtained from this approximation is \( T_p \approx 2.22 \), which matches with the time period observed in the computational results with an error of less than 8% (Figs. 3 and 5).

The evolution of bubble shapes for \( A_{r0} = 1.19 \) and 1.95 are shown in Fig. 4(a) and (b), respectively. It is to be noted here that the shape oscillations of this type are not observed in case of rising oblate bubbles [9, 10]. The oblate-prolate-oblate oscillation observed in the present study (for liquid droplets falling in air) is due to the competition between the gravitational and surface tension forces. Close inspection of Figs. 3 and 4 also reveals that this shape oscillation is asymmetrical about the spherical shape \((A_r = 1)\), i.e. a droplet has a higher tendency to deform into a prolate shape than an oblate shape. This could be understood by considering the surface area of oblate and prolate drops. An oblate shape has a larger surface area as compared to a prolate shape.
shape for the same volume and the same difference in axes lengths, |a – b|. Alternatively, a spherical surface needs to be elongated/contracted more along the vertical and radial axes to obtain a prolate shape as compared to that for obtaining an oblate shape in order to generate same surface area for both the final shapes.

In Fig. 5, the variations of (a – b) of four different initially prolate shaped droplets (A_r0 = 0.857, 0.729, 0.614 and 0.512) are shown. It can be seen that all the prolate droplets also undergo prolate-oblate-prolate deformations as the time progresses, which can also be observed in the evolutions of the droplet shapes presented in Fig. 6(a) and (b) for A_r0 = 0.729 and 0.512. From Fig. 5, we also observe that in this case time period of oscillations increases with decrease in A_r0 for prolate droplets; a clear phase lag in the oscillations is also seen at later times. Fig. 7 shows the variation of an average velocity of oscillation of the droplet-air interface (defined as V_0 = 2(a_max – a_min)/T_P) with A_r0, and reveals that V_0 increases approximately linearly with an increase in the initial deformation of the droplet. However, we see some nonlinearity for large initial deformations. The more the initial deformation, the more is V_0 for both oblate and prolate shaped droplets. Due to inertia, an initially oblate droplet deforms to a prolate shape via a spherical shape, and vice versa. This shape oscillation continues due to the competition between the inertia and surface tension forces. The linear dependency of V_0 with A_r0 points to the fact that the force-deformation relationship may be assumed to be linear while modelling the droplet oscillations associated with small initial deformations, similar to that in Rayleigh’s analysis [11] as discussed above. We found that all these droplets fall along the axis of symmetry, i.e. they do not exhibit path instability, but undergo shape oscillations. As discussed in the introduction, in case of a rising air bubble in a liquid, vortex shedding is known to promote path instability (wobbling motion) when the bubble undergoes asymmetrical shape oscillation (see e.g. [4, 5]). As a hypothesis, shape oscillations may only be expected in case of falling liquid drop when the inertia of the drop is comparable to the hydrodynamic forces exerted by the surrounding air. A known mechanism to achieve path oscillations is vortex shedding, which may provide sufficient forcing amplitude and frequency in the lateral directions to overcome the inertia. Thus, to investigate the role of vortex shedding and inertia in the dynamics of a nonspherical droplet, we vary Ga and the results are presented in Figs. 8-10. It

**FIG. 4.** Evolutions of shapes of the drop for (a) A_r0 = 1.19 and (b) 1.95. The rest of the parameters are the same as those of Fig. 3.

**FIG. 5.** The temporal variations of the diameters of the drop along the radial and vertical directions, (a – b) for different initial prolate shaped droplets. Circles: A_r0 = 0.857; filled triangles: A_r0 = 0.729, pluses: A_r0 = 0.614 and squares: A_r0 = 0.512. The rest of the parameters are Ga = 10, EO = 10^{-3}, µ_r = 55 and ρ_r = 998. The magenta dotted line shows the aspect ratio of a perfect sphere (A_r = 1).

**FIG. 6.** Evolutions of shapes of the drop for (a) A_r0 = 0.729 and (b) 0.512. The rest of the parameters are the same as those of Fig. 5.

**FIG. 7.** The variations of the oscillation velocity, V_0 = 2(a_max – a_min)/T_P, of the drop with A_r0. The rest of the parameters are the same as those used to generate Figs. 3 and 5.
should be noted that the present definition of $Ga$ based on the outer fluid density is suitable for this purpose because it gives a measure of inertia or the aerodynamic forces due to the outer fluid (i.e. air).

B. Effect of inertia

FIG. 8. The temporal variations of the diameters of the drop along the radial and vertical directions, $(a - b)$ for different values of $Ga$. The initial aspect ratio is $A_{r0} = 1.33$ for all values of $Ga$. The rest of the parameters are $Eo = 10^{-3}$, $\mu_r = 55$ and $\rho_r = 998$. The magenta dotted line shows the aspect ratio of a perfect sphere ($A_r = 1$). The filled red squares and blue circles represent the time instants for which the shapes of the drop are plotted in Fig. 9 for different values of $Ga$. They correspond to the time instants at which the drop undergo prolate and oblate shapes.

In Fig. 8, the variations of aspect ratio of the droplet for different values of $Ga$ at later times ($8.9 \leq t \leq 15.3$) are plotted for $A_{r0} = 1.33$. At the early times (not shown) the droplet undergoes an oblate-prolate-oblative periodic deformation exhibiting the same behaviour (i.e. the same amplitude and time period of oscillations) for all the values of $Ga$ considered. At later times, however, both the amplitude and time period of oscillations increase with an increase in $Ga$ as shown in Fig. 8. This behaviour is due to a rise in aerodynamic inertia (inertial force due to the surrounding fluid) and the appearance of vortex shedding in the wake region of the droplet (see discussion of Fig. 11).

Close inspection of Fig. 8 also reveals that for high $Ga$ ($Ga = 100$), at later times (see $t > 13$), the droplet remains only in the prolate shape during the oscillation. The shapes of the droplet at the troughs (shown by filled red squares in Fig. 8) and peaks (shown by filled blue circles in Fig. 8) of the oscillations during $12 < t < 14$ are shown in Fig. 9. It can be seen that for low $Ga$ ($Ga \leq 50$) the droplet undergoes an oblate-prolate-oblate deformation, whose amplitude of oscillations increases with increase in $Ga$. For $Ga = 100$, an elongated prolate and ‘onion-type’ shapes are seen at $t = 12.7$ and $t = 13.8$, respectively. The variations of an average velocity of oscillation, $V_0$ of the droplet-air interface are shown in Fig.
It can be seen that at later times, the droplet migrates slightly away from the axis of the domain. We see some lateral path migration in Fig. 12(a) and (b); however, they are very small (less than $R_{eq}$). As the lateral migration is very small, this might be attributed to the asymmetrical shape deformation of the droplet, and not to path instability. An animation for $Ga = 100$ (see supplementary movie) showing the dynamics of the droplet also reveals that the droplet continues to elongate in the axial direction at later times, and it does not show any characteristic of path instability.

In summary, a falling nonspherical droplet in air undergoes shape oscillations even for a small degree of non-sphericity. As discussed in Figs. 8-11, this behaviour can be attributed to the inertial force due to the surrounding fluid (aerodynamic inertia). In a liquid-liquid system, in the absence of inertia (i.e. in creeping flow regime), Koh & Leal [9, 10] observed decaying shape oscillation even for an initial aspect ratio much higher than that of the present study. Thus, one can conclude that in the inertial regime the droplet dynamics is different from that observed in the creeping flow (negligible inertia) regime. If we compare our study with that of Koh & Leal [9, 10], there are two main effects, namely, inertia and density ratio between the fluids. To isolate the effect of inertia, we conduct simulations by varying the density ratio from 998 to 10, while keeping a finite inertia ($Ga = 10$). Out of curiosity, we also investigate the effect of varying the viscosity ratio in the inertial regime. These results are discussed in Figs. 13 - 15.

### C. Effect of viscosity and density ratios

In Fig. 13(a) and (b), the temporal variations of $(a-b)$ are shown for different viscosity and density ratios, respectively. In Fig. 13(a), we observe that (for $t < 6$) the droplet undergoes a symmetrical periodic oblate-prolate oscillation (not shown). At later times (for $t \geq 6$), decreasing the viscosity ratio increases the tendency of the droplet to deform to a prolate shape. To understand this behaviour, we plot the iso-surface of $z$ vorticity and the evolutions of droplet shapes in Fig. 14(a) and (b), respectively. For $\mu_r = 100$, shedding of $z$-vorticity is clearly seen in the left column of Fig. 14(a). On the other hand, the $z$-vorticity is aligned along the vertical direction for $\mu_r = 10$. Although the wake of the drop for $\mu_r = 100$ is oscillatory, it doesn’t develop asymmetry as seen in the $\mu_r = 10$ case. This may be explained by considering the fact that the viscous time scale (dimensionless) for the former drop, $T_{\mu_1} = Ga_{\mu_1}/\mu_r = 99.8$, is two orders of magnitude greater than that of the oscillation time period. Whereas, the viscous time scale for the $\mu_r = 10$ case, $T_{\mu_2} \approx 998$ is about three orders of magnitude greater than the oscillation time period. This makes the $\mu_r = 10$ drop more amenable to deformation against the viscous forces.

In contrast to an almost equal time period of oscil-
FIG. 13. Effect of (a) viscosity ratio for $\mu_r = 998$ (b) density ratio for $\rho_r = 55$ on the temporal variations of the diameters of the drop along the radial and vertical directions, (a − b). The initial aspect ratio is $A_{r_0} = 1.33$. The magenta dotted lines show the aspect ratio of a perfect sphere ($A_r = 1$). The rest of the parameters are $Eo = 10^{-3}$ and $Ga = 10$.

In Fig. 8, the period varies significantly with $\mu_r$ and $\rho_r$, as shown in Fig. 13. As discussed in the aforementioned text, the drop viscosity does not affect the dynamics below a certain range, wherein the drop may be modelled as being inviscid. This explains an almost equal time period observed for different values of $Ga$ in Fig. 8. A variation in $\mu_r$ points to a change in drop viscosity which affects the stress distribution inside the drop. As it becomes easier for shear stresses to deform the drop with a reduction in the viscosity ratio, the drop favours a vertically elongated shape (see Fig. 14(b)), which considerably affects the time period of oscillation as shown in Fig. 13(a). Similarly, a reduction in density ratio ($\rho_r$) decreases the drop density which in turn reduces the inertia of the drop. As predicted by Rayleigh’s linear theory [11], the time period is expected to increase with inertia which is evident from Fig. 13(b).

The evolution of shapes of the droplet plotted for $\mu_r = 100$ (left column of Fig. 14(b)) reveals that the droplet undergoes asymmetrical oblate-prolate-oblature deformation, but maintains its azimuthal symmetry. This behaviour is different from that observed in case of a rising bubble, where vortex shedding promotes asymmetrical deformation and path instability [6]. For $\mu_r = 10$, the droplet becomes asymmetrical and develops a ‘mushroom-like’ shape at a later time (see $t = 12$ in the right column of Fig. 14(b)) for the aforementioned reasons.

The effect of density ratio on the aspect ratio of the droplet is investigated in Fig. 13(b). It can be seen in Fig. 13(b) that for $\rho_r > 100$ for this set of parameters the droplet exhibits periodic oscillations of almost constant amplitude (also see Fig. 15(a), which presents the evolution of shapes for $\rho_r = 998$). Fig. 13(b) also reveals that the time period of these oscillations decreases with a decrease in the value of density ratio. We observe that for low values of $\rho_r$ (see the result for $\rho_r = 10$ in Fig. 13(b)), the oscillations die down and an initially oblate droplet becomes spherical at $t \geq 4$ for this set of parameters. The evolution of droplet shapes for $\rho_r = 10$ shown in Fig. 15. Evolutions of shapes of the droplet for (a) $\rho_r = 998$ and (b) $\rho_r = 10$. The rest of the parameters are the same as those used to generate Fig. 13(b).
in Fig. 15(b) also reveals that the droplet remains spherical at later times. This behaviour is consistent with the finding of Koh & Leal [9, 10].

IV. CONCLUDING REMARKS

The hydrodynamics of an initially nonspherical (oblate or prolate shaped) liquid droplet falling in air is investigated via three-dimensional numerical simulations in the inertial regime. Several researchers have shown that a bubble undergoes wobbling motion for high $Ga$ and low $Eo$ [4, 5]. Vortex shedding plays an important role in this wobbling motion of an air bubble rising in a liquid. We found that a liquid droplet falling in air does not show path instability even when its initial shape is nonspherical. Although the vortex shedding occurs for high $Ga$, it does not cause the drop to oscillate in the lateral directions. The main difference between the dynamics of bubbles and drops lies in the distribution of the inertial force. A falling drop has a high inertia which prevents it from changing its momentum in the lateral directions, easily, under the influence of the aerodynamic forces. In contrast to this, a bubble with a significantly less inertia moves easily in the lateral directions when its wake becomes oscillatory (due to vortex shedding [19]). The shape oscillations are observed even for a slightly nonspherical droplet (low initial aspect ratio). This behaviour is different from that observed in liquid-liquid systems ($\rho_r \approx 1$) in the creeping flow regime revealing the effect of inertia on the dynamics of a droplet in air. A parametric study is also conducted by varying the density and viscosity ratios of the dispersed and continuous phases. This further confirms that the shape oscillations observed in the present study is due to inertia and the associated vortex shedding in the wake region of the droplets.