Momentum: Physics Education Journal
7 (2), 2023, 178-187
Available at: ejournal.unikama.ac.id/index.php/momentum
ISSN 2548-9127(print) | 2548-9135 (online)

Misconceptions on the understanding of flying objects in fluids

Edy Wibowo[a]*, Naily Ulya[a], Whibatsu Helvantriyudo[a], Muhammad Maliki Azyumardi[a], Fata Hafiduddin[a], Mamat Rokhmat[a], Ismudiati Puri Handayani[a], Abrar[a], Nurwulan Fitriyanti[a], Sutisna[b], Amira Saryati Ameruddin[c]

[a]Telkom University, Jl. Telekomunikasi. 1, Bandung, West Java, 40257, Indonesia
[b]Universitas Jember, Jl. Kalimantan Tegalboto No.37, Jember, East Java, 68121, Indonesia
[c]Persiaran Tun Dr. Ismail, Parit Raja, Johor, 86400, Malaysia
e-mail: edywibowo@telkomuniversity.ac.id
* Corresponding Author.

Received: 29 April 2022; Revised: 7 January 2023; Accepted: 10 January 2023

Abstract: The concepts of floating, flying, and sinking object have been studied since junior high school. However, we still often find students' misconceptions regarding the concept, especially of flying objects, even at the university level. This work aims to propose a clarification of the concept of a flying object in the fluid to be correctly described the condition for the flying object. We used eggs, water, and salt solutions to demonstrate sinking, rising, and floating objects in the fluids. The results showed that when the density of the object is the same as the density of the fluid, the position of the object is still at the bottom of the fluid since it was not flying in the middle of the depth of the fluid. But the object does not touch the bottom of the container so that the object's height is zero. This is because the object has not had a driving force (F_d = 0) that pushes the object upward towards the surface of the fluid to float. When the density of the fluid slightly exceeds the density of the object, the object immediately moves upward to the fluid surface - floating phenomenon is started. The greater the difference between the density of the fluid and the density of the object, the faster the object moves towards the surface. The object cannot stay at any position between the bottom and the surface of the fluid. A stable position is reached when the object reaches the surface of the fluid to float. This work is expected to increase students' understanding of flying objects in fluids.
Keywords: misconception; flying object; fluid density; object density

How to Cite: Wibowo, E., Ulya, N., Helvantriyudo, W., Azyumardi, M. M., Hafiduddin, F., Rokhmat, M., Handayani, I. P., Abrar, A., Fitriyanti, N., Sutisna, S., & Ameruddin, A. S. (2023). Misconceptions on the understanding of flying objects in fluids. *Momentum: Physics Education Journal*, *7*(2), 178–187. https://doi.org/10.21067/mpej.v7i2.6881

Introduction

Static fluid is one of the topics in fundamental physics. This topic has been studied even in junior high school. The concepts of density, Buoyancy force, sinking, floating, and flying are discussed (Abdullah, 2016; González-Espada & Jones, 2020; Halliday, Resnick, & Walker, 2010; Loverude, Kautz, & Heron, 2003; Noxaïc & Fadel, 2022; Olascoaga et al., 2020; Puspita, Sutopo, & Yuliati, 2019; Susanti, 2021). We can easily see the phenomena of sinking or floating objects in our daily life. Nevertheless, we often found a misunderstanding of physics concept even among physics students regarding this phenomenon, especially in the case of flying objects in fluids (Hewitt, 2020; Kim & Paik, 2021; Nikolić, 2022). This misunderstanding usually arises from either the teacher's mistaken illustrations in explanation or inaccuracy of the illustrations in the student reference books (Astuti, 2017; Aulia, Diana, & Yuberti, 2018; Ceuppens, Deprez, Dehaene, & De Cock, 2018; Efwida, S & Sopandi, 2016; Febrianti, Akhsan, & Muslim, 2019; Fongsamut, Tanasittikosol, & Phaksunchai, 2023; Gumilar, 2016; Jannah, Yuliati, & Parno., 2016; Krishnan, Puthenveettil, & Hopfinger, 2020; Marcom, Villar, & Kleinke, 2022; Neidorf, Arora, Erberber, Tsokodayi, & Mai, 2020; Onder-Celikkanli & Tan, 2022; Wilson, 2021).

Many physics students already understand that an object will float if its density is smaller than that of the fluid (ρo < ρf). In this condition, the object is illustrated as laying on the surface of the fluid. The amount of the part of the object that appears above the surface of the fluid depends on the difference in the density of the object and that of the fluid. The object will sink as long as the density of the object is greater than that of the fluid (ρo > ρf). In this situation, the object is illustrated to be resting at the bottom of the container. The object is flying in the fluid if the object's density is equal to that of the fluid (ρo = ρf). In this condition, the object is illustrated to have a certain fixed depth staying in a stable position in the middle of the fluid's depth.

Apparently, these understandings are not entirely correct. We have found when the object density is equal to that of the fluid, the object will not be flying yet. The position of the object is still at the bottom of the fluid, not flying in the middle of the depth of the fluid. However, when the object does not touch the bottom of the container, its height is zero. Then, if the fluid's density is slightly increased (ρf >ρo) the object will suddenly fly upward to the fluid surface. After reaching the surface, the the floating phenomenon starts, and the flying-object phenomenon stops. The amount of the object immersed in the fluid and the amount that appears on the surface depends on the difference in density between the object and the fluid. The object's velocity in flying to the fluid surface increases by the increase of the fluid density.

Demonstration of sinking, flying, and floating needs to be conducted to help students understand these phenomena. Students need to be allowed to prove themselves directly the suitability of the theories they have obtained in class with experimental facts (Efwida, S & Sopandi, 2016; Koster & de Regt, 2020; Lestari, Hariyono, Dwikoranto, Prahani, & Deta, 2022; Wilujeng & Hidayatullah, 2021). It has been demonstrated that an egg placed in a salt solution then left to stand for several days will change the state even without increasing the fluid's density. The egg that initially sank a few days later was floating. However, there is no measurement of changes in egg and salt solution density during the experimental process. As a result, the phenomenon of sinking to floating could be observed. Still, it had not been able to prove the fulfillment of sinking, flying, and floating conditions that theoretically had been accepted by students in the class (Featonby, 2019).

In this paper, we presented a clarification of the concept of flying objects in fluids through a simple experiment. We demonstrate the phenomenon of sinking, flying, rising, and floating in a fluid accompanied by measuring fluid density changes during the experiment. Unlike the experiment reported by Featonby (2019), here we reported an egg's behavior when it is inserted in the water, then the water density is gradually increased. We measured the egg's density and the change in fluid density. Therefore, we can observe and prove the whole phenomena regarding an object inserted into the fluids. Based on the results, the condition of flying objects in fluids can be correctly described.

Method

The method used in this study is experimental. The research was conducted at the engineering physics laboratory, Telkom University. We used eggs, water, and salt solutions to demonstrate sinking, rising, and floating objects in the fluids. We used three eggs with different densities. We measured the water, egg, and saltwater's mass and volume separately to determine their density (ρ). Measurement of mass (m) was carried out by using a balance, while the volume (V) of water and egg by using a beaker glass. The density of water and egg are calculated using the equation, $\rho V = m$. We obtained the density of the water (ρ_f) being 1000 kg/m^3, and the density of the eggs (ρ_o) being 1058.059 kg/m^3, 1069.912 kg/m^3, 1089.887 kg/m^3, respectively. After we had obtained the density of the eggs and water that we used, we put one of the eggs in the water and measured its position from the water's surface (depth) by using ruler. The water is in a measurable transparent container. In this condition, the egg sank to the bottom of the container. We added the salt powder to the container and then stirred it to make a homogenous salt solution. The concentration of the solution was measured by using a Salinometer. We continually increased the salt solution's concentration so that the rising and floating phenomena could be observed. The concentration of the solution was then converted to the density of the solution. The capture of the changes of an egg's position due to concentration variation of the salt solution is shown in Figure 1, while the measurement results are presented in Table 1.

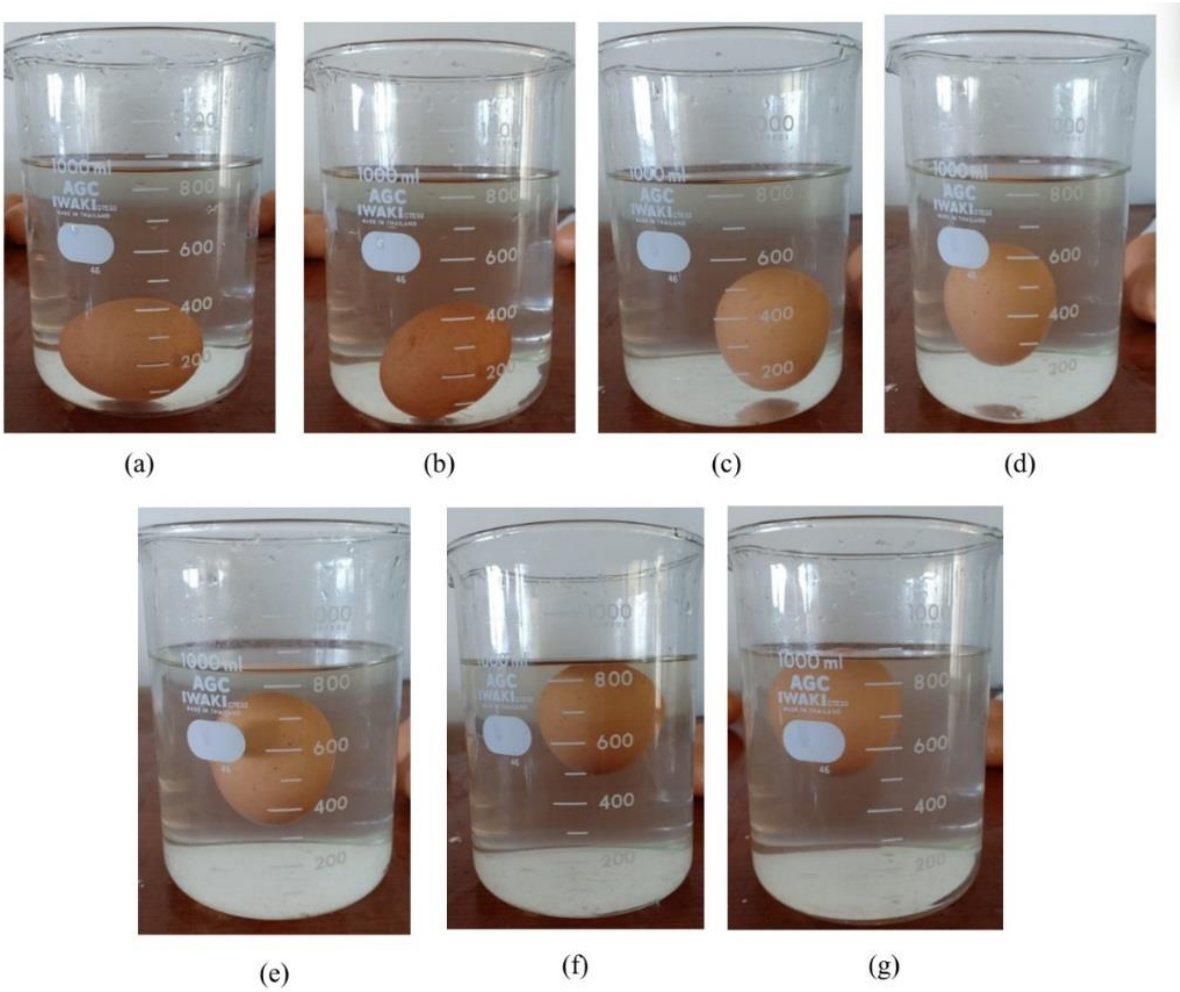

Figure 1. The changes in an egg's position due to the concentration variation of the salt solution. The egg was sinking when $\rho_f < \rho_o$ (a), but when the fluid density was slightly increased so that $\rho_f > \rho_o$, the egg suddenly flew upward to the fluid surface (from b to g)

Table 1. The measurement results of fluid density around the transition state

Experiment	ρ_o (kg/m^3)	ρ_f (kg/m^3)	ρ_f- ρ_o (kg/m^3)	Egg's condition
1	1069.912	1069.439	-0.472	sinking
		1069.669	-0.243	sinking
		1069.784	-0.128	sinking
		1069.899	**-0.013**	**sinking**
		1070.014	**0.102**	**rising**
		1070.244	0.332	rising
		1070.474	0.562	rising
		1070.589	0.677	rising
2	1058.059	1055.646	-2.413	sinking
		1056.221	-1.839	sinking
		1056.221	-1.839	sinking
		1057.600	**-0.459**	**sinking**
		1058.290	**0.230**	**rising**
		1058.634	0.575	rising

Experiment	ρ_o (kg/m^3)	ρ_f (kg/m^3)	ρ_f- ρ_o (kg/m^3)	Egg's condition
		1058.749	0.690	rising
		1058.864	0.805	rising
3	1089.888	1082.772	-7.115	sinking
		1084.497	-5.391	sinking
		1085.761	-4.127	sinking
		1088.864	**-1.023**	**sinking**
		1091.968	**2.080**	**rising**
		1096.106	6.218	rising
		1097.830	7.942	rising
		1099.554	9.666	rising

Results and Discussion

Figure 1 shows the changes in an egg's position due to the salt solution's concentration variation. We can see that an egg that is initially sinking then floating when the fluid density is increased. We measured the density of the fluid every time salt is added, and then we observe whether there is a change in the position of the eggs in the fluid. We can see that this simple work can demonstrate the phenomenon of sinking to floating clearly. The rising phenomena as the transition phase from sinking to floating can also be observed.

From Table 1. The measurement results of fluid density around the transition state, we can see evidence that if the object's density is greater than that of the fluid, the object will sink. However, when the fluid density is slightly higher than that of the object, the egg will immediately rise to the fluid's surface. In the first experiment (we used an egg with a density of 1069,912 kg/m^3), the eggs continued to sink even though the fluid density was only 0.013 kg/m^3, which was less than the density of the eggs. However, when the fluid density is increased so that it becomes 0.102 kg/m^3 more significant than the eggs' density, the eggs will rise to the fluid's surface. Similar results were shown in the second and third experiments when we used eggs with densities of 1058.059 kg/m^3 and 1089.887 kg/m^3, respectively. A sinking egg suddenly rose when the fluid density exceeded the egg, even though the differences are tiny. This experiment confirms the validity of the theory of sinking, flying, and floating objects that students have obtained in class.

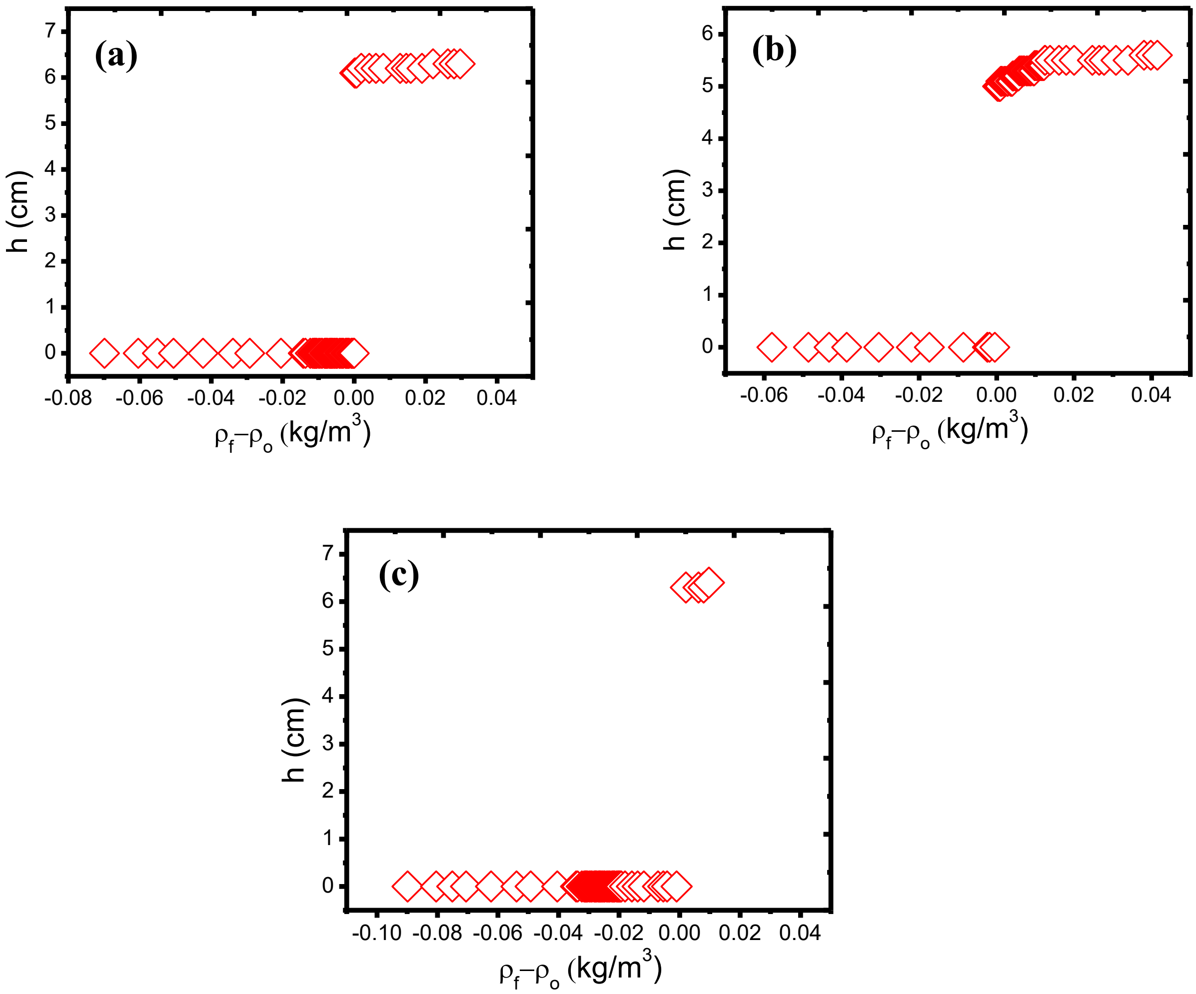

Figure 2. The stable positions of an egg in a salt solution with different concentrations; *h* is the height of the egg, which is measured from the bottom of the container to the bottom part of the egg when it is floating on the fluid surface. Three variations of egg density are used. (a) ρ_o = 1069.912 kg/m^3, (b) ρ_o = 1058.059 kg/m^3, and (c) ρ_o = 1089.887 kg/m^3

Figure 2 shows plot of the entire measurement results of fluid density and the egg position. We plot the stable positions of the egg in the fluid due to the addition of salt concentration (from sinking to floating). Figure 2a shows that an egg (ρ_o = 1069.91 kg/m^3) immersed in water (ρ_o = 1000 kg/m^3) will sink to the bottom of the container, so the height of the egg is zero (h = 0 cm). When the concentration of the solution was gradually increased so that the fluid's density reached an equal value to the egg's density (1069.91 kg/m^3), the egg did not start to fly yet, but it did not touch the container bottom anymore. The height of the egg from the bottom of the container was zero. Then, the egg suddenly rises to the fluid's surface when the fluid density was slightly increased ($\rho_f > \rho_o$). After reaching the fluid's surface, the egg's upward motion stopped, and it floated there. When the fluid density was further increased ($\rho_f >> \rho_o$), the egg's movement velocity also increased, and the part of the egg that appeared on the surface of the fluid also increased. Similar trends were also observed when we used an egg with a different density, as shown in Figure 2b and Figure 2c. Figure 2b showed the experimental data plot when we used an egg with a density of 1058.059 kg/m^3, while Figure 2c for an egg with a density of 1089.887 kg/m^3. Based on these experimental results, the sinking, flying, and floating objects' requirements could be easily described using 1st Newton's Law as follows (Abdullah, 2016; Halliday et al., 2006; Hewitt, 2020). We used F_{bmax} for the maximum Buoyancy force-it happen when the full body of object submerged in the fluid, F_b for the Buoyancy force ($F_b < F_{bmax}$), W_o for the object's weight, N for a normal force, and F_d for the driving forces. The illustration of sinking, flying, and floating objects in fluids is presented in Figure 3.

Based on Figure 3, we can see that the egg is sinking when $\rho_f < \rho_o$; in this situation, the egg is resting on the container's bottom surface ($F_{bmax} < W_o$). The egg is flying when $\rho_f = \rho_o$; in this work, the egg does not touch the container's bottom surface, but it is not yet rising to the surface of the fluid ($F_{bmax} = W_o$). Therefore, the egg's height is zero. The egg will be increasing when ρ_f is slightly higher than ρ_o; in this condition, the egg will suddenly move upward from the bottom of the container at $t = t_i$ to the final position at the fluid's surface $t = t_f$ for floating. A floating object is clearly observed when the fluid density is significantly higher than that of the object ($\rho_f >> \rho_o$) - the part of the egg that emerges on the surface of the fluid will increase by increasing fluid density. Then the phenomena of sinking, float and float can be mathematically expressed as follows:

1. For a sinking object, the object rests on the surface of the container bottom, therefore

$$\sum F = 0 \tag{1}$$

$$F_{bmax} + N - W_o = 0 \tag{2}$$

$$F_{bmax} = W_o - N \tag{3}$$

The consequence of Eq. 3 is $F_{bmax} < W_o$, and then we can write the following expression

$$\rho_f g V_o < \rho_o V_o g \tag{4}$$

$$\rho_f < \rho_o \tag{5}$$

Based on Eq. 5, we confirmed that the object would sink if its density is higher than that of the fluid ($\rho_o > \rho_f$).

2. Based on Eq. 2, if the object does not touch the surface of the container bottom, but it still rests at bottom (object's height is zero) so that $N = 0$, then Eq. 2 can be written

$$F_{bmax} - W_o = 0 \tag{6}$$

$$F_{bmax} = W_o \tag{7}$$

$$\rho_f g V_o = \rho_o V_o g \tag{8}$$

$$\rho_f = \rho_o \tag{9}$$

Based on Eq. 9, the flying object occurs when $\rho_o = \rho_f$; in this experiment, we showed an egg's position remains at the bottom of the container. The egg did not rise due to the absence of driving force ($F_{bmax} - W_o = 0$).

3. For a rising object (ρ_f is slightly higher than ρ_o), we showed that the egg suddenly moves upward from the bottom of the container at $t = t_i$ to the final position at the surface of the fluid at $t = t_f$ due to the emergence of a driving force ($F_{bmax} - W_o > 0$), which pushes the object upward to the fluid surface for it to be floating. Therefore, we can state that the flying phenomenon is a transition from sinking to floating.

$$F_{bmax} > W_o \tag{10}$$

$$F_{bmax} = W_o + F_d \tag{11}$$

$$F_d = F_{bmax} - W_o \tag{12}$$

$$F_d = Vg(\rho_f - \rho_o) \tag{13}$$

Based on equation 13, the driving force will appear if $\rho_f - \rho_o > 0$. So that when the density of the fluid is slightly greater than that of the egg, the egg will rise to the surface for floating when it is placed on the base of the fluid. Hence, the requirement for the floating object is expressed by $\rho_f > \rho_o$.

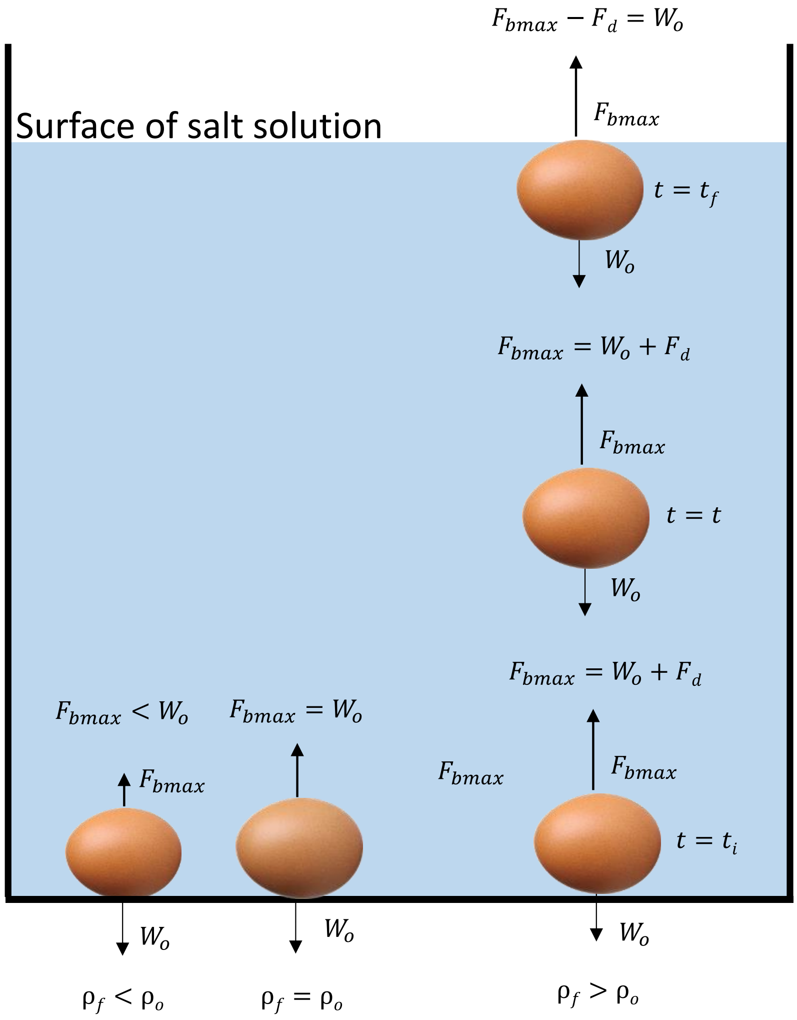

Figure 3. The illustration of sinking, flying, rising, and floating objects in a fluid

4. After the egg reaches the fluid's surface and settles there, the first Newton's law can be applied. In this condition, all parts of the egg are no longer immersed in the fluid so that the eggs get an upward force that is less than the maximum Buoyancy force (when all parts of the egg are immersed in the fluid). The object is resting on the surface of the fluid, while the amount of the part of the object that appears above the surface of the fluid depends on the difference in the density of the object and that of the fluid. In this condition, therefore

$$\sum F = 0 \quad (14)$$
$$F_b - W_o = 0 \quad (15)$$
$$F_b = W_o \quad (16)$$
$$F_b < F_{bmax} \quad (17)$$

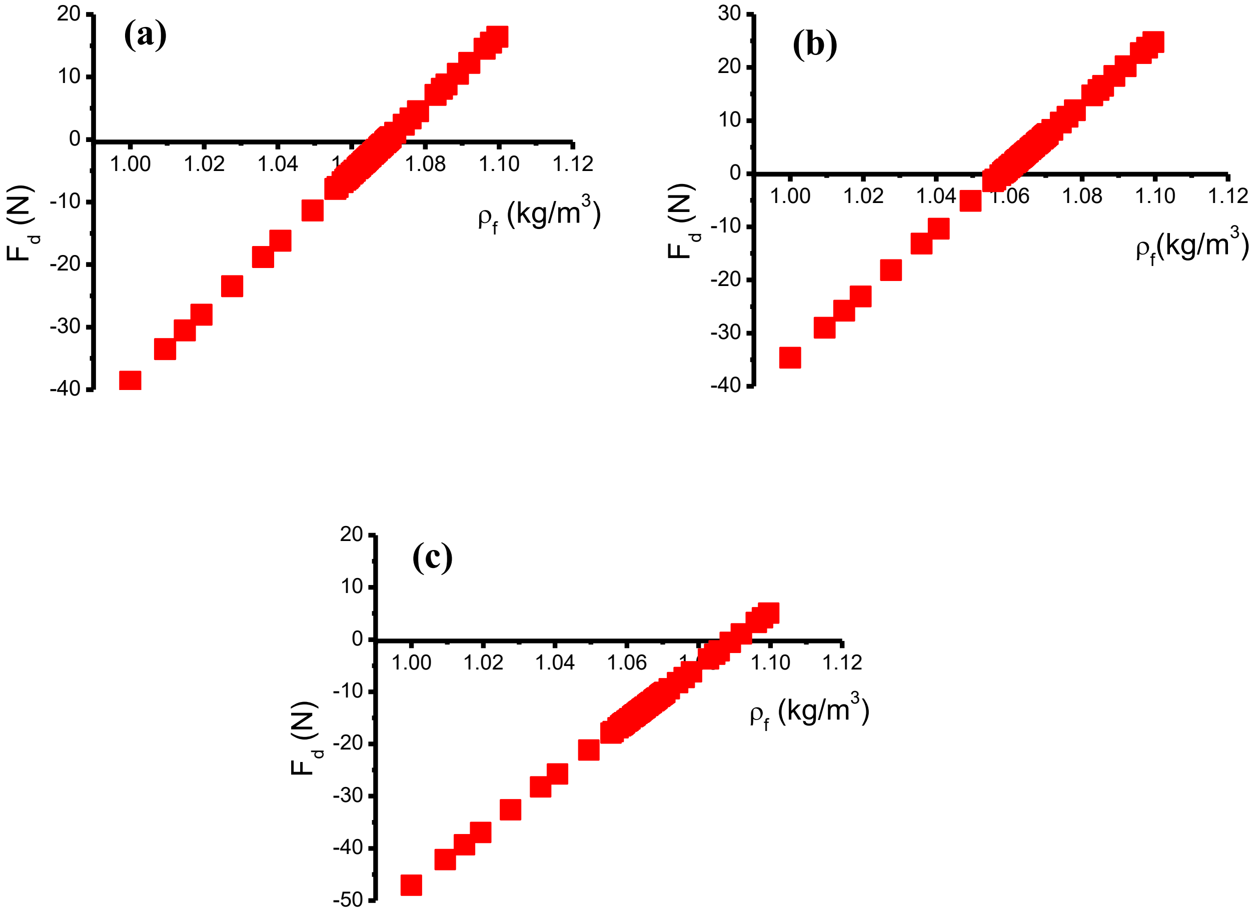

Figure 4. The stable positions of an egg in a salt solution with different concentrations. Three variations of egg density is used. (a) ρ_o = 1069.912 kg/m³, (b) ρ_o = 1058.059 kg/m³, and (c) ρ_o = 1089.887 kg/m³

Based on Eq. 13, we can see that if the value of ρ_f - ρ_o = 0, then F_d = 0. Therefore, no force will drive the object to move to the fluid surface. The linear relationship between the fluid density and the driving force is plotted in Figure 4. Based on Figure 4, we see the driving force (F_d) needed for the object to rise from the bottom to the surface of the fluid. This force will exist if the density of the fluid is greater than that of the object. The object will rise if the value of F_d is greater than zero. This condition can be fulfilled if the fluid density is greater than the density of the object. Again, we can see that if the object's density is the same as the density of the fluid, the object will still be in a resting condition. Therefore, the phenomenon of a flying object (the object position in the middle of the fluid's depth) has not yet occurred. The flying object will occur if $F_d > 0$.

From this work, we can see that the sinking, flying, rising, and floating object phenomena occur due to the interaction between the object's weight and the Buoyancy force on the object. This work confirmed that if the maximum Buoyancy force is smaller than the object's weight ($F_{bmax} < W_o$), the object will sink, as shown in Figure 4 for $\rho_f < \rho_o$. If the maximum Buoyancy force is equal to the object's weight ($F_{bmax} = W_o$), it is flying. It will not be rising yet (Figure 4 for $\rho_f = \rho_o$), so the object's height is still zero. However, if the fluid density is slightly increased, the object will suddenly rise to the surface of the fluid (Figure 4 for $\rho_f > \rho_o$). The object experiences acceleration due to the presence of a maximum Buoyancy force that is greater than the object's weight (Hewitt, 2020; McKee & Czarnecki, 2019). Therefore, we considered that $F_{bmax} = W_o$ was the threshold for a rising object to occur. In the phenomenon of a rising object in a fluid, the maximum Buoyance force must be greater than the object's weight. The maximum Buoyancy force will be the driving force to release the object from a resting state, and the leftover will drive the object to move upward to the fluid surface for it to be floating. This work may help students clearly understand the phenomena of sinking, flying, rising, and floating objects in the fluid.

Conclusion

We have shown that when the density of the object was equal to the density of the fluid, the flying phenomenon would not occur yet. In this work, the flying object started when the density of the fluid was slightly higher than that of the object. We obtained that $\rho_o = \rho_f$ was the threshold for when the object would exactly start to rise. When the fluid's density slightly exceeded that of the object, the object immediately flew to the fluid surface. Besides, we found that there was no stable position of the object in the fluid during its flight from the bottom to the surface of the fluid. The object could not rest in any position between the bottom and the surface of the fluid even though ρ_f is slightly higher than ρ_o. The stable position was achieved when the object reached the surface of the fluid for it to be floating. This work is expected to broaden students' understanding of the concept of flying objects in fluids. When the density of the object is the same as the density of the fluid, the position of the object does not have to be in the middle of the fluid.

Acknowledgment

We would like to thank the support of the Material Research Laboratory, Engineering Physics at Telkom University. All procedures conducted in this work followed the ethical standards of publication. Informed consent was obtained from all individual participants included in this work. The authors declare that they have no conflicts of interest.

References

Abdullah, M. (2016). *Fisika Dasar 1*. Bandung: Institut Teknologi Bandung.

Astuti, L. S. (2017). Penguasaan Konsep IPA Ditinjau dari Konsep Diri dan Minat Belajar Siswa. *Formatif: Jurnal Ilmiah Pendidikan MIPA*, *7*(1), 40–48. doi: 10.30998/formatif.v7i1.1293

Aulia, S., Diana, N., & Yuberti, Y. (2018). Analisis Miskonsepsi Siswa Smp Pada Materi Fisika Analysis of Misconception of Junior High School Students in Physical Materials. *Indonesian Journal of Science and Mathematics Education*, *01*(2), 155–161.

Ceuppens, S., Deprez, J., Dehaene, W., & De Cock, M. (2018). Tackling misconceptions in geometrical optics. *Physics Education*, *53*(4), aac604. doi: 10.1088/1361-6552/aac604

Efwida, S & Sopandi, W. (2016). Peningkatan Penguasaan Konsep Siswa Melalui Pembelajaran Ipa Terpadu Berbasis Masalah Berbantuan Mind Map. *EDUSAINS*, *8*(1), 27–35.

Featonby, D. (2019). Floating eggs?—the answer. *Physics Education*, *54*(4), 047001. doi: 10.1088/1361-6552/aac857

Febrianti, J., Akhsan, H., & Muslim, M. (2019). Analisis Miskonsepsi Suhu Dan Kalor Pada Siswa Sma Negeri 3 Tanjung Raja. *Jurnal Inovasi Dan Pembelajaran Fisika*, *6*(1), 90–102. doi: 10.36706/jipf.v6i1.7819

Fongsamut, K., Tanasittikosol, M., & Phaksunchai, M. (2023). Effectiveness of the simulation-based learning (SBL) assisted with scaffolding approach to address students' misconceptions about projectile motion. *Physics Education*, *58*(2), 025002. doi: 10.1088/1361-6552/aca57d

González-Espada, W. J., & Jones, B. S. (2020). Betting on Better Buoyancy? Be Careful What You Wish For. *The Physics Teacher*, *58*(6), 413–415. doi: 10.1119/10.0001861

Gumilar, S. (2016). Analisis Miskonsepsi Konsep Gaya Menggunakan Certainty of Respon Index (CRI). *Gravity: Jurnal Ilmiah Penelitian Dan Pembelajaran Fisika*, *2*(1), 59–71.

Halliday, D., Resnick, R., & Walker, J. (2010). *Fundamentals of Physics*. John Wiley & Sons.

Hewitt, P. (2020). Buoyancies. *The Physics Teacher*, *58*(4), 228–228. doi: 10.1119/1.5145463

Jannah, A. N., Yuliati, L., & Parno. (2016). Melalui Pembelajaran Inquiry Lesson Dengan Strategi Lbq. *Jurnal Pendidikan : Teori, Penelitian Dan Pengembangan*, *1*(2), 409–420.

Kim, S., & Paik, S.-H. (2021). Archimedes' Balance Approach Applied to Buoyant Force. *The Physics Teacher*, *59*(2), 125–127. doi: 10.1119/10.0003469

Koster, E., & de Regt, H. W. (2020). Science and Values in Undergraduate Education. *Science and Education*, *29*(1), 123–143. doi: 10.1007/s11191-019-00093-7

Krishnan, S., Puthenveettil, B. A., & Hopfinger, E. J. (2020). Hole expansion from a bubble at a liquid surface. *Physics of Fluids*, *32*(3). doi: 10.1063/1.5139569

Lestari, N. A., Hariyono, E., Dwikoranto, D., Prahani, B. K., & Deta, U. A. (2022). Project-based inquiry-science: An innovative learning for thinking, teaching and assessing science-physics. *Momentum: Physics Education Journal*, *6*(1), 86–92. doi: 10.21067/mpej.v6i1.6254

Loverude, M. E., Kautz, C. H., & Heron, P. R. L. (2003). Helping students develop an understanding of Archimedes' principle. Part I: Research on student understanding. *Am. J. Phys.*, *71*, 1178.

Marcom, G. S., Villar, R. P., & Kleinke, M. U. (2022). Common errors in mechanical physics among high school graduates in Brazil. *Physics Education*, *57*(1), 015008. doi: 10.1088/1361-6552/ac24e9

McKee, K., & Czarnecki, A. (2019). Acceleration due to buoyancy and mass renormalization. *American Journal of Physics*, *87*(3), 165–170. doi: 10.1119/1.5089205

Neidorf, T., Arora, A., Erberber, E., Tsokodayi, Y., & Mai, T. (2020). *Student Misconceptions and Errors in Physics and Mathematics: Exploring Data from TIMSS and TIMSS Advanced*.

Nikolić, H. (2022). Submarine paradox softened. *American Journal of Physics*, *90*(11), 841–847. doi: 10.1119/5.0084185

Noxaïc, A. Le, & Fadel, K. (2022). How to Use the Archimedes Paradox for Educational Purposes. *The Physics Teacher*, *60*(2), 137–139. doi: 10.1119/10.0009424

Olascoaga, M. J., Beron-Vera, F. J., Miron, P., Triñanes, J., Putman, N. F., Lumpkin, R., & Goni, G. J. (2020). Observation and quantification of inertial effects on the drift of floating objects at the ocean surface. *Physics of Fluids*, *32*(2), 1–25. doi: 10.1063/1.5139045

Onder-Celikkanli, N., & Tan, M. (2022). Determining Turkish high school students' misconceptions about electric charge imbalance by using a four-tier misconception test. *Physics Education*, *57*(5). doi: 10.1088/1361-6552/ac68c1

Puspita, W. I., Sutopo, S., & Yuliati, L. (2019). Identifikasi penguasaan konsep fluida statis pada siswa. *Momentum: Physics Education Journal*, *3*(1), 53–57. doi: 10.21067/mpej.v3i1.3346

Susanti, M. M. I. (2021). The Analysis of Mastering of Concepts and Misconceptions in Elementary Teacher Education Students. *JPI (Jurnal Pendidikan Indonesia)*, *10*(1), 163. doi: 10.23887/jpi-undiksha.v10i1.26740

Wilson, M. T. (2021). Misconceptions Arising From the Infinite Solenoid Magnetic Field Formula. *The Physics Teacher*, *59*(3), 213–215. doi: 10.1119/10.0003670

Wilujeng, I., & Hidayatullah, Z. (2021). Alternative learning model in physics learning: Effect of the conceptual change model with cognitive conflict on critical thinking skill. *Momentum: Physics Education Journal*, *5*(2), 111–120. doi: 10.21067/mpej.v5i2.5260