# Gravity, Buoyancy and Levity

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## Gravity

How do things fall and how do they rise? This question leads us into the very heart of the scientific revolution. First, let us consider the nature of things falling. Since the work of Aristotle, the dominant idea for several centuries was,firstly,that bodies fell at a *constant* speed proportional to their weight, and secondly, thatthis speed was inversely proportional to the density of the medium through which they fell. Heavier things fall faster, denser media cause a slowdown. This constancy of speed, as well as the properties of the medium, came to be completely re-evaluated by the time the 17th century began, thanks to the pioneering contribution of Galileo Galilei.

A significant period of the study of motion of nearly six centuries was culminated with his discoveries – a scientific development that involved original minds such as Ibn Sina (Avicenna), Leonardo da Vinci, Albert of Saxony and Jean Buridan. Galileo progressed much further along the lines laid by his predecessors. He observed simple everyday phenomena like a falling sphere, an oscillating pendulum, or a ball rolling down an incline,and used them to obtaina new*law of falling bodies*[1]:

> … spaces traversed in natural motion are in the double proportion of the times … and consequently that the spaces traversed in equal times are as the odd numbers starting from 1.

In other words, the distance covered by a falling bodyis proportional to the square of the time, and hence there is no constant velocity: the body *accelerates* instead. "Accelerare" means to move quicker or hasten, in Latin.The importance of this law for the development of modern physics cannot be overstated, as entire fields of science were born from it. For example, Galileo's contemporary, Johannes Kepler, pondered falling bodies in a much larger context thus[2]:

> How is it possible that a sphere thrown vertically upward-while the earth rotates meanwhile-does return to the same place? the answer is that not only the earth but together with the earth, the magnetic invisible chains rotate by which the stone is attached to the underlying and neighboring parts of the earth and by which is retained to the earth by the shortest, that is, the vertical line.

These "magnetic invisible chains" postulated by Kepler were later picked up by Newton to extend Galileo's law of falling bodies to the entire cosmos, resulting in Newton's famous "Law of gravity". Contemporary scholarship clearly recognizes this transition[3]:

> Kepler was the genius who introduced physics into astronomy… Ironically, it was pious Kepler who forced the angels out of astronomy. Prior to Kepler, the planets were propelled in their orbs by spirits; after him, they were moved by physical forces. Kepler was the first to extend the reach of gravity beyond the Earth, making it a truly celestial force. He conceived the idea of gravitational "mass" long before Newton.

According to this law of gravity, not only does a ball fall toward the Earth, but *everything*is said to fall towards everything else. This gave birth to the field of modern astronomy, or more specifically, to astrophysics. The notion of acceleration was used in the definition of *force*, opening the door to modern mechanics. Moreover, the equations of gravity, when applied to electricity and magnetism (as the force between two charges instead of masses), gave rise to Coulomb's law and the field of electromagnetism.

Let us now return to the second part of the statement of Aristotle, regarding the medium.Aristotle considered the velocity to be inversely proportional to the density of the medium, so if the density goes to zero (for example, if the air is continuously diluted), the velocity ought to go to infinity. Since we do not observe anything falling at infinite speed, the existence of a "vacuum" was unphysical to Aristotle. Galileo, however, focused his attention on the idea of "free" fall (or *natural motion*), where the falling object has a minimum of drag resistance from the air while falling, and noticed that it was the same for most bodies and was not dependent on their weight, contrary to Aristotle. Hence, while pondering the question of what really constitutes a "free" fall, there was the need to seriously consider the possibility of evacuating a space of all substance i.e. the idea of a real physical void or *vacuum* gained traction. The pursuit of physical vacuum resulted in the measurement of atmospheric pressure by Galileo's student Torricelli, which opened up the field of meteorology for scientific measurement. Use of the vacuum through condensation of steam by Newcomen and Watt led to the development of the first steam engine, which gave birth to the Industrial Revolution. Evacuated glass tubes gave rise to the study of electricity, which led further into the modern electronic information age. In fact, making all modern devices such as computer chips, lasers and solar cells, would be impossible without the presence of the vacuum chamber.

It is therefore no exaggeration to say that the law of freely falling bodies opened the door to the modern age of science and technology, through the laws of gravity and vacuum.Looking back at both Aristotle's and Galileo's ideas, we can now question: who was right? Or, what do the phenomena themselves say? When an object starts falling in any medium (even dilute air), it initially accelerates and graduallyreaches what is called "terminal velocity". Thus, even though there is a period of acceleration initially, the *final* state is that of a steady velocity. Naturally, when comparing the fall of two objects, we can only compare it correctly when they *both* have enough space to reach their terminal velocity, so that no further change takes place and the phenomenon is, in a sense, complete. A fountain of water out of a hose accelerates downwards when falling, but the same water, when it falls as rain, hits us with a *constant* velocity. When we jump on a trampoline, we can use acceleration in our equations, but if we go skydiving, after the initial acceleration our velocity reaches its limit in a few seconds and then we fall at constant velocity. Hence, only if one "zooms in", as it were, on the initial behaviour, is the law of acceleration best observed. This is precisely what Galileo did: he "zoomed in" on the initial few seconds of an object falling by rolling it on different inclined planes, dragging out its fall so that he could measure it properly. And this measurement turned out to be the same for different objects. Aristotle had not developed this differentiated observation of the initial moments but had focused on the overall behaviour of everyday objects, and in that context, he was accurate, even according to current standards: terminal velocity is different for different objects.

What about the medium? Even using the best techniques, we do not have "absolute" vacuum; we can obtain very low pressures (up to a trillion times less than the atmospheric pressure), but never *zero*. By diluting the medium more and more, we can increase the distance an object has to fall before hitting terminal velocity, and therefore increase its final terminal velocity, but the overall behaviour is not changed. Creating a vacuum ishence another way of "zooming in" to the *initial* part of the phenomenon of fall. Even a high speed meteor which is expected to have been falling through the "vacuum of outer space" for a long time, reaches a speed of about 100 km/s[4], i.e. what it would have reached if it was free-falling for just about 3 hours. This is far less than the speed one expects for a days-long journey in an absolute vacuum.

The full description of the phenomenon of falling of even a simple spherical object is therefore quite complex: fall begins with acceleration, and then terminates in a velocity, with a gradual variation in the middle. Aristotle and Galileo approached it from two sides. Since Galileo approached it from what happens "initially" or "in a vacuum", he could disregard Aristotle and say that all objects fall at the same rate. Disregarding the value of Aristotle's contribution in this way is incorrect, as described by Rovelli[5]:

> The bad reputation of Aristotle's physics is undeserved, and leads to widespread ignorance… Aristotle never claimed that bodies fall at different speed "if we take away the air". He was interested in the speed of real bodies falling in our real world, where air or water is present.

There are two important points to be noted here. One: even a simple observation, in this case the initial behaviour of a falling object, when permeated with the right understanding, has immense potential for scientific progress. Two: if the observation of an object approaching the Earth has proved so fruitful, is it not equally important to focus on how an object stays stationary, or even *recedes* from the Earth? That is the question that will be examined further.

## Buoyancy

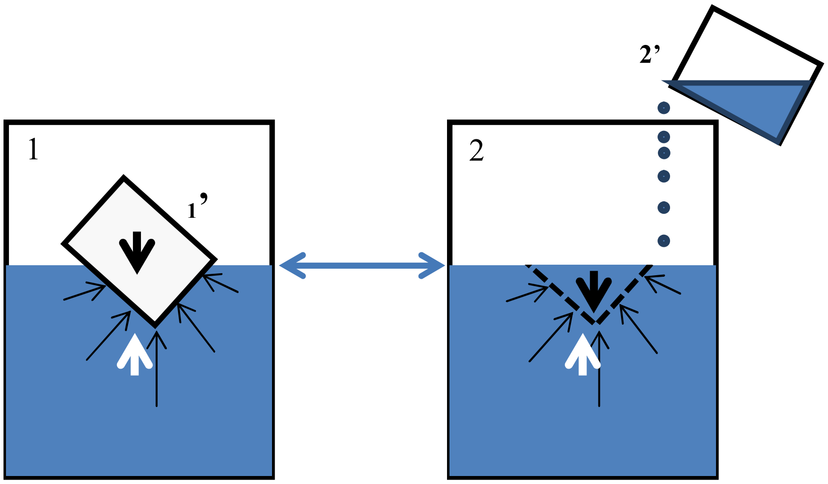
Let us consider our experience of objects *not* falling downwards, at least in the non-living world, and moving *up* e.g. the movement offlames, smoke andhot air, or *floating* e.g.a piece of wood floating on water, metal boats on the water, soap bubbles anddust particlesin the air. All these phenomena are usually explained using the concept of buoyancy, with the help of Archimedes' Principle: a body experiences an upward force equal to the weight of the fluid it displaces. It is important toaddress this concept of buoyancy, in order to see whether all these examples are indeed sufficiently illuminated by it.

First of all, how are we to test this process directly? Let us pick a medium: water. If a hand is gradually immersed in water, one of the primary impressions (assuming it is not too hot or cold) is the gentle pressure it exerts on the skin. This "pressing in" is quite different from the pressure experience we are normally accustomed to, where our skinencounters some *surface* of a particular shape. Almost all instances of touch, except for electric shocks, usually involve touching surfaces and sensing the *texture*: sharp, smooth, rough, curved, hard or soft. Even on immersing in sand, one can feel the graininess of the individual sand particle surfaces on the skin. However, when the hand is fully immersed in water, there is no distinct surface – a surface is only felt in the process of immersing. Instead, there is a compression from all directions acting on the hand: a *squeeze*. It is important to distinguish this from the pressure on the hand when carrying a heavy stone, which is more a *push* in one direction than a *squeeze* in all directions.

But, even though water squeezes the hand, water itself is not easily *squeezable* in the way a piece of wax is, and does not allow us to easily change its volume or shape from the inside. It is also called (mostly) incompressible, and shares this quality with many solids. One cannot easily compress a piece of iron, or a volume of water, by hand, for totally different reasons. A hard solid does not allow the penetration of the surface. Water allows penetration *into* it, but *inside* a body of water, there is no surface to penetrate. If a volume of water is squeezed in a closed syringe, it yields very little, almost like a solid. Since water is not easily squeezable, when a hand is inserted into a bucket full to the brim with water, the water spills out. It had to, because its volume cannot be reduced, but only moved around. This is what is called *displacement* of the water. If the bucket was exactly full before inserting the hand, the water that overflows has the same volume as the hand. So the immersion displaces the same volume of water as the hand itself.

Next, let us focus on the pressure felt on the hand in water. This unique “squeezing” pressure has an interesting net result: the hand feels lighter. On the other hand (literally), when in air, the hand feels heavier. Those who swim would have the clear experience of feeling much heavier on climbing out of a pool, and lighter when entering it. So, somehow, the combined activity of the “squeeze” results in a loss of weight. Interestingly, the squeeze increases as we go deeper into the water – this is where we can see that the water is a tiny bit squeezable, else there would be no variation with depth. A ping pong ball zips up when released from the bottom of a pool much faster than when it is released close to the surface of the water. Hence, even if the “squeeze” does not have a unique direction, since the squeeze below is more than that above, this creates a direction to the net effect: upwards.This is similar to what happens when a slippery bar of soap shoots out of our hand in the bath when we try to hold on to it: the combined grasp of our fingers has an imbalance, and the net effect is to launch the soap into an inaccessible corner. This “net result” of the squeezing is the *buoyant force*.

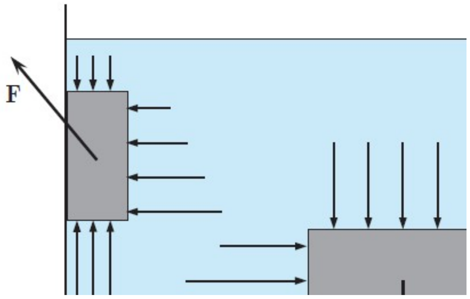
Now let us combine the two facts – displacement and buoyant force – witha simple experiment. Take two large beakers of water, 1 and 2, and two small beakers, 1’ and 2’, all with measuring scales for volume. To begin with, let the large beakers have the exact same amount of water (but not up to the brim). Now let beaker 1’ float in the larger beaker 1. Observe the change in level of water in beaker 1. Gently pour some water into beaker 2 using the small beaker 2’, until beaker 1 and 2 reach the same level. This volume of water added to beaker 2 would be the same volume that beaker 1’ has displaced in beaker 1.



What about the squeeze? We know that the immersed portionof beaker 1’ (weight down: thick black arrow) is getting squeezed, resulting in a net force upwards (white arrow). So, in beaker 2 as well, on the same volume, the exact same squeezing force must be acting on the extra volume of water, to keep it in place (white arrow). Also, the squeezing force in beaker 2 must match the weight of the extra water, since the water has settled into a steady horizontal level. Therefore, the squeezing force on beaker 1’ should be equal to the weight of this extra volume of water (black arrow point down). Hence this is Archimedes’ principle: weight lost (or the upward squeezing force) is equal to the weight of the water displaced.

It is important to note that it is because the compression from below is slightly higher than the compression above that the buoyant force is upwards. If in some way the compression force from below or the side is removed, then we would expect the object to get pushed down or to the side. This is shown in the following instances (where F is the buoyant force[6]):

*Checking the validity of Archimedes' law*



In the two cases shown here, Archimedes' principle, as stated by Archimedes, is violated! This is because Archimedes' principle does not account for the primary phenomenon directly: that any buoyant force is the *net result* of all the compressions on the immersed body. By attending to the secondary situation ("weight of the water displaced") the primary phenomenon gets masked.Rectifying this gives us the core phenomenon of buoyancy.

**Behind Buoyancy**

Now that we have a reasonable grasp on the idea of buoyancy, it is worth digging into the real cause of it. The squeeze of a medium, or how much it compresses us, depends on its relative incompressibility. And what, exactly,*is*incompressibility? There is something within the object that *resists* the push or squeeze that is exerted from outside. When we can no longer compress something, whether it is a stone, a sealed volume of water, or a rigidlysealed volume of air, the "squeeze" gets balanced by an "anti-squeeze", *in all directions*. The multi-directionality of this type of force is once again quite unique: it is the exact opposite of a compression. It is the pressure – one could say – of *swelling.* This is the same experience as that of filling air in a rubber tube or a balloon as we hold on to it.

In case of a solid, this incompressibility is easily perceived – in fact, this is the first characteristic that comes to mind when speaking of something "solid". Compressing a solid in all directions is met with a resistance directed outward, but only as a response. The solid does not automatically "swell" in our hand. We could call this a *passive* pressure, which is only perceived when there is a push or a squeeze from the outside. In a liquid, the incompressibility is harder to notice directly, but it nevertheless still exists, as mentioned earlier. Slapping the surface of the water hard with the palm, or with the whole body as is the case with inexperienced divers, also shows that there is sufficient resistance in a body of water to push back against outside pressure. But, unlike a solid, a liquid *does* "swell" actively: when a body of liquid is sealed off in a container with some air in it, the liquid evaporates into the surrounding air and creates a swelling pressure called *vapour pressure*.

In a gas, however, we experience this active "swelling"directly as its natural property and it spreads out as much as it can i.e. it is *always* swelling. Unlike solids and liquids, a gas can easily be compressed, butit naturally decompresses as soon as the compression is removed.We get a sense of the incompressibility of gas only in extreme cases when the gas is pressed together so much that it acts almost like a solid e.g. explosions or tornadoes where a shockwave can be “solid” enough to knock down buildings and cause damage. This is also seen in the case ofa long-term erosion of land features. On the whole, though, gases are mostly compressible and can be penetrated easily.We can summarize the behaviour this way:

Solid: Mostly Incompressible, Impenetrable

Liquids: Mostly Incompressible, Penetrable

Gas: Mostly Compressible, Penetrable

In terms of the variation of the swelling pressure, the behaviour is thus:

Solids: Passive pressure

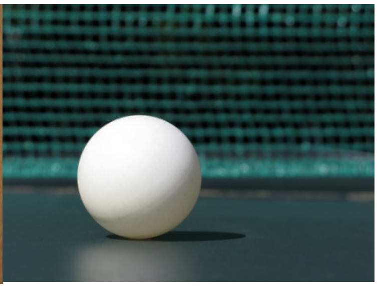
Liquids: Mostly passive pressure, some active pressure (vapour)

Gas: Mostly active pressure, some passive pressure (shock wave)

This passive pressure, which accompanies incompressibility, is precisely the “squeeze” that generates buoyancy.In case of liquids, the liquid as a whole is incompressible, but in case of a rigid solid, all parts of the solid are predominantly incompressible. In case of a gas, it is only a strong gust that can show this incompressible nature. Thus, all the three states have the capacity to resist compression, but to different degrees. A simple comparison will illustrate this further: consider a ping pong ball in three different configurations:

Above a Hair Dryer

In water



On a table

In the case of air, it requires a strong gust generated by a hair dryer to balance the weight and keep the ball afloat. In water and on a table, the ball stays stationary simply through contact. This opens the door to an important idea: *even a ball on a table is floating,* but on a solid instead of on a liquid. This means that swelling pressure, in both its active and passive forms, has a net effect that is the opposite of gravity, and can therefore by called by its right name: *levity*.

Gravity draws objects together towards the center of the earth, and taken as a whole it can be called a compression. Levity, or swelling pressure,opposes objects coming together counteracting the effect of gravity. When a ball is sitting on a table, gravity is active since the ball has a finite weight, and at the same time, levity is also active because the ball does not fall *through* the table. There has been a long standing question in physics: why don’t we fall through the floor? Even as recently as 1976[7], the answer to this question is pursued through the path of convoluted developments in quantum physics involving exclusion principles and electromagnetic behavior. The primary reason for the rigidity of matter according to this approach is the Pauli Exclusion Principle (we need not go into what it is at the moment). And what is the reason for this principle?

> *No theoretical proof of the Pauli's Exclusion Principle can be given as yet and for the present it must be regarded as something empirical added to and regulating the vector atom model.*[8]

In other words, there is no understanding of this phenomenon available, and it does not "fit in" anywhere. Besides, how does a "principle" cancel out an attraction by repelling? Weren't we thought that only a *force* (and not a "principle") can oppose and cancel a force?

On the other hand, with a clearer observation of the behaviour of our physical surroundings, it can be seen that the action of levity is visible in solids, liquids and gases. In solids, levity occurs in all directions only as a passive reaction to externally applied forces and pressures: the so-called rigidity of matter. In liquids, there is active levity present in terms of vapour pressure, while the passive levity is observed in the relative incompressibility of the liquid, just as with solids. With gases, active levity is far more effective as the gas spreads everywhere, while passive levity is present to some degree in shockwaves.

## Levity

Is it possible to see any phenomena in nature where the activity of levity is more unhindered? After all, we see objects falling all the time, or rising due to buoyancy, but is there anything that is *rising* or *swelling all the time*? Now that we know that levity is an expression of swelling pressure, this has to be the primary signature of this phenomenon.On the other hand, levity must also be far more active than it is in a gas. Solids are virtually impenetrable, and they also do not penetrate anything else, since they retain their shape. Liquids penetrate the container, and also seep to occupy every corner in the downward direction. Gases, with far more active levity, penetrate other gases and even liquids. If we combine an increase in penetrative power, with the propensity to induce swelling, what do we have? *Heat*.

Heat penetrates all known substances, including solids, and induces an expansion or a swelling wherever it acts. This thermal expansion is multidirectional, in the same way that a squeeze or compression was multidirectional. Even in terms of gravity, heat is *related* to substances which fall, like solids, liquids and gases, but is not by itself *susceptible* to gravity. It cannot be weighed, and therefore, treating heat or fire as an independent "state of matter" like solids, liquids and gases is virtually unheard of in modern science. But the notion that an element has to have "weight" is by no means a pre-requisite. Instead, a progression in the properties of observable phenomena itself points to the validity of treating it as an independent element.

Heat has two sides: not only does it penetrate substances with weight through direct contact and generate swelling or levity in them, but it also *radiates* without the need of a heavy substance as a carrier. Conduction and infrared radiation are the names given to these two forms. Radiation is where the properties of levity are expressed in their purity: there is a propagation of the effect outwardly in all directions at a high speed, which passes through even a highly evacuated region. There is no direct relationship to weight: radiation is "weight-free" and always directed *away* from a point, unlike gravity which is directed *towards* a point – the center of the earth. Even if heat radiation cannot generate swelling pressure directly, when this radiation falls on a substance with weight, it can exert what is called *radiation* *pressure*: a very slight outward pressure which one can measure with fine instruments (such as a Nichols radiometer).

Even though heat can penetrate a solid or liquid easily through contact by conduction, by radiation it cannot penetrate far: only the surface region of a solid or liquid is usually heated up. There is another element which, like heat radiation, cannot penetrate through contact but only through radiation: *visible light*. In light, we are in a domain which is even moreemancipated from gravity than heat is. Light is invisible to our perception without the presence of gases, liquids or solids – so there is still *some* relation with gravity-bound elements – but light cannot penetrate them through contact in the way heat does. Keeping a brick in the fire heats up the entire brick, but a flashlight in contact with a brick does not "light up" the whole brick from inside. The only way the effect penetrates inside is if *transparency* to radiation is present. In general, gases are all mostly transparent, liquids less so, and solids the least. Visible light does not make solids, liquids and gases expand, but like heat radiation, it exerts a very fine radiation pressure on these states.

Hence, levity is expressed in the best way with visible light radiation, and in fact, even the word "light" and "levity" arise from the same proto-Indo-European root word "legwh-". Unlike gravity, whose effect was projected out into the cosmos only since the 17th century, light has been seen as one of the active constituents of the cosmosfrom antiquity, and expressed through the arrangements of the Sun, Moon, stars and planets in the sky. This tradition continued, with some minor modifications, into the modern era. For example, modern scientists conjecture, just like Kepler and his predecessors, that the outward "swelling" pressure exerted by light was the reason for a comet's tail to point away from the Sun. But even though this action of levity was perceived as such, the effect of levity in more "earthly" substances has not been recognized.

## Conclusion

What has been attempted in this essay is to pay as much attention to how things rise, float, or swell as is normally done to how things fall. Regarding falling bodies, the difference between Aristotle's and Galileo's approaches was highlighted to show how the two views complemented one another to form a greater whole. Galileo and his followers, including Newton and Einstein, paid particular attention to the question of "free fall". Gravity and vacuum action formed the basis of scientific discovery.But still, there were other aspects of falling objects that did not command the same attention: what happens when an object hits the solid ground, what is the real origin of the buoyant force, and whether there is an antagonist to the compressive "squeeze" that we observe within liquids and gases. It was found through the study of incompressibility and swelling pressure that levity is present everywhere in both its activeand passive forms. Levity and swelling pressure hence replace gravity and vacuum as a new point of departure for investigation. Using the nature of levity as a guideline, it was possible to transition from the traditional "states of matter" to higher states of heat and light.

It must be noted that the polarity of gravity and levity, in a more linear form as push and pull, is present in the case of positive and negative electric charge, or north and south poles of a magnet. Opposite charges attract, as do opposite magnetic poles, while like repels like. This has prompted several scientists to explain the incompressibility of matter as being due to "electromagnetic repulsion". However, this attempt is bound to fail, as the phenomena do not support an imposition of electromagnetism in such everyday uncharged and un-magnetized situations like a bubble of air in water. This is why the explanations have reached a dead end with the "exclusion principles" introduced by fiat. Another attempt has been made to imagine "rigid" matter as being made of atoms, like little miniature balls with springy forces between them. This attempt is also doomed from the start, since conceptually we are simply miniaturizing a problem in order to "explain" it. Whether the ball is visibly big or miniscule, the question of incompressibility still remains.

Instead of being deviated into electromagnetism, we studiedlevity directly to show that it has been as ever-present in our surroundings as gravity. It has not been noticed as such on its own footing, leading "levity" or "anti-gravity" to occupy the domain of fringe research, "crackpot" science, or even science fiction. Some independent researchers like Dewey Larson[9] and Miles Mathis[10] have tackled the concept of levity in their individual ways, and have labelled it "outward scalar motion" and "photon charge field" respectively.

When studied using the methods of phenomenology, levity becomes an equal companion of gravity in the constitution of our perceptible world.In the past couple of centuries, science has been very active in projecting the workings of gravity on to the cosmos. Perhaps it is time to unravel the opposite: to observe and understand the workings of the light-filled cosmos in our own humble surroundings.

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