THE SIMPLE UNIVERSE

ALIREZA MALEKZADEH

ABSTRACT. This paper presents a unified theory for the universe which encompasses the dominant theories of physics. Our work is strictly based on the philosophy that the work of the universe is extremely simple in the fundamental level. We provide a minimal set of elements as the fundamental constituents of the universe, and demonstrate that all natural phenomena can be explained by a minimum number of laws governing these fundamental elements and their minimal set of properties.

1. Introduction

In this paper, we present a model for the universe and its fundamental elements. Our goal is to develop a unified theory which encompasses the major theories of physics, i.e., classical mechanics, electromagnetism, special relativity, general relativity, and quantum mechanics. Throughout our development, we abide by the *Principle of Simplicity* which states that the work of the universe and its elements is extremely simple in the fundamental level. In accordance with this principle, we start our work by assuming a minimal set of axioms from which we try to infer the laws of the universe as much as possible in order to explain the natural phenomena. We do not introduce a new axiom unless it becomes absolutely necessary for our development to proceed.

In section 2, we discuss matter, space, and time as the constituents of the universe. Section 3 presents the two fundamental forces, i.e., gravity and electricity. In section 4, we examine the absolute motion of an object. Section 5 introduces the concept of a force line through the space of an object, and presents a differential equation for the force line of an object in constant velocity motion. In section 6, we discuss the space horizon. Section 7 shows that Newton's third law is not valid in general. In section 8, we verify the Doppler effect for the force lines of an object in constant velocity motion. Section 9 studies the mutual forces exerted on two objects moving in parallel with a constant velocity. In section 10, we explain the magnetic phenomenon. Section 11 investigates the precession of the orbit of a planet, and provides an algorithm to compute such an orbit. Finally, in section 12, we suggest some ideas for further research.

Date: October 2011.

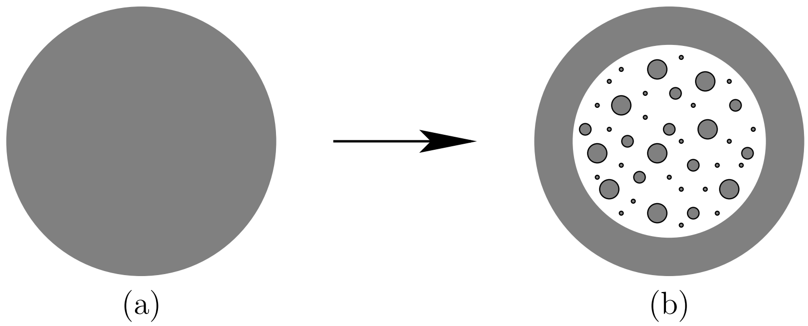

FIGURE 2.1. The universe: (a) before the big bang (b) after the big bang

2. Universe, Matter, Space, and Time

Before the beginning of time, the universe was entirely matter in three infinite dimensions, as shown in figure 2.1(a). Due to its infinite size, the universe has no center and no edge. There was no space before the beginning of time. As depicted in figure 2.1(b), the matter universe shattered apart in a *Big Bang*, creating an infinite three-dimensional space and an infinite number of matter fragments floating in that space. We call the created infinite space the *Background Space* of the universe. By shattering of the universe, a universal absolute time also started running across the background space. As it can be seen in figure 2.1(b), the background space (with its absolute time) is yet surrounded by infinite matter.

The matter fragments can have different sizes and masses; the size as well as the mass of a matter fragment may be any positive real number. In addition to its mass, each matter fragment also has an electric charge; the electric charge of a matter fragment can be any real number (positive, negative, or zero). Familiar examples of matter fragments are nuclei of atoms, electrons, and photons. The common matter fragments have extremely tiny masses and very small-magnitude electric charges (due to their extremely small sizes, they are called particles). However, a matter fragment may have any finitely great mass or electric charge magnitude. Furthermore, it is theoretically possible to break any matter fragment into a number of smaller matter fragments, or fuse a number of matter fragments together to make a larger matter fragment. The mass of a matter fragment (which does not break into smaller matter fragments, and does not fuse with other matter fragments) remains constant through time, but its electric charge can spontaneously vary over time.

Due to the finite size of any matter fragment and the infinite size of the background space, we treat a matter fragment as a point object in the background space. (Throughout this paper, unless stated otherwise, the word *object* indicates a point object.) An object such as p creates its own space through time as follows: It generates a layer of its space in the form of a sphere like s at any instant of time like t. At the time t, the center of s is p, and the radius of s is zero. The radius of s increases through time at a constant rate, but its center remains fixed in the background space regardless of any possible motion of p in the background space. We call this constant expansion rate of s the *Speed of Space*, and represent it by c.

3. Two Fundamental Forces: Gravity and Electricity

For the rest of this paper, for brevity, if it is not explicitly indicated, a space layer will have an age and a radius greater than zero. Each space layer of object p like s has a gravitational strength which pulls any encountered object toward its center (not necessarily toward p because p might have moved away from the center of s). In addition, s also has an electric strength which may pull or push any encountered object toward or away from its center (again, not necessarily toward or away from p). Both gravitational and electric strengths of s originate from their corresponding strengths of p. The gravitational strength of p is proportional to its mass, so it remains constant through time. The electric strength of p is proportional to its electric charge, so it has a non-deterministic nature, and can change over time. Either of these two strengths of p which is carried away by s spans over the surface of s; therefore, the gravitational or electric strength of any point on s is equal to its corresponding strength of p divided by the surface area of s.

Assume object p_1 has mass m_1 and electric charge q_1. Then, we have

$$G(m_1) = k_g m_1 \tag{3.1}$$

for the gravitational strength of p_1 and

$$E(q_1) = k_e q_1 \tag{3.2}$$

for its electric strength where k_g and k_e are the positive gravitational and electric constants respectively. Therefore, for a space layer of p_1 like s with radius r, the gravitational strength is

$$G(m_1, r) = \frac{G(m_1)}{4\pi r^2} = \frac{k_g m_1}{4\pi r^2}, \tag{3.3}$$

and the electric strength is

$$E(q_1, r) = \frac{E(q_1)}{4\pi r^2} = \frac{k_e q_1}{4\pi r^2}. \tag{3.4}$$

As the radius of s increases through time, its gravitational and electric strengths decrease in magnitude according to the above equations. Now, consider any object like p_2 with mass m_2 and electric charge q_2. If p_2 encounters s, it will experience a gravitational force with the magnitude of

$$F_g(m_1, r, m_2) = G(m_1, r)m_2 = \frac{k_g m_1 m_2}{4\pi r^2} \tag{3.5}$$

and an electric force with the magnitude of

$$F_e(q_1, r, q_2) = |E(q_1, r)q_2| = \frac{k_e|q_1 q_2|}{4\pi r^2}. \tag{3.6}$$

Both force vectors are along the radius of s which passes through p_2. The direction of the gravitational force vector is always toward the center of s. The direction of the electric force vector will be toward the center of s if q_1q_2 is negative, and away from the center of s if q_1q_2 is positive; if q_1q_2 is zero, there will be no electric force.

The gravitational and electric forces bind the matter fragments together in both large and small scales. In either case, we treat any collection of matter fragments bound together gravitationally or electrically as yet a point object in the infinite vastness of the background space. These two fundamental forces can modify the velocity of an object according to Newton's second law of motion; a change in the speed of an object in turn leads to a change in the kinetic energy of that object. In the large scale, any finite region of the background space is surrounded by infinite amount of matter while it contains a finite amount of matter; therefore, the objects contained in that region are gravitationally pulled outward and away from each other. This accounts for the accelerating expansion of the observable universe. In the small scale, because the electric charges of the matter fragments spontaneously vary over time, the motion of the electrons around the nuclei of the atoms is not deterministic.

In breaking and fusing reactions among matter fragments, tiny matter fragments with very small masses (which become separated from the rest of the matter fragments) can get carried away by the space layers. In this process, any such tiny matter fragment with mass m_1 may gain a speed up to the speed of space and so a maximum kinetic energy of

$$\frac{1}{2}m_1c^2.$$

If we denote the combined mass of all these tiny matter fragments by m, the maximum of their combined kinetic energy will be

$$E_{max} = \frac{1}{2}mc^2 \tag{3.7}$$

which resembles Einstein's equation.

FIGURE 4.1. The space of an object: (a) at rest (b) in motion

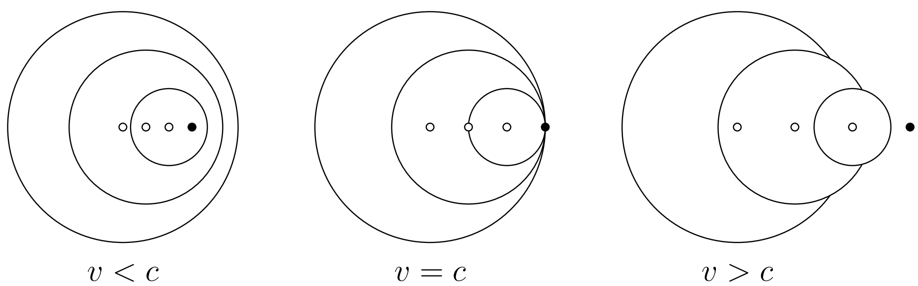

FIGURE 4.2. Three distinct topologies for the space of an object in motion with constant velocity v

4. Absolute Motion

We may now examine the absolute motion of an object like p in the background space through time: Suppose t_0 is an arbitrary instant of time in the lifetime of p, and let s be the space layer of p created at t_0. After an arbitrary time interval like t since t_0, s reaches the age of t, and expands to the radius of ct. p will be at *Absolute Rest* in the background space during the time interval t since t_0 if and only if at the moment of $t_0 + t$, p is at the center of all of its space layers with ages from zero to t (or equivalently, radii from zero to ct). See figure 4.1 (unless otherwise mentioned, throughout this paper, rest and motion are absolute).

In figure 4.2, we have depicted three distinct topologies for the space of an object in constant velocity motion. If an object encounters the space layers of its own (by increasing its speed past c or the reverse), that object will be subject to the gravitational and electric forces of its own space accordingly.

5. Force Line

Consider the snapshot of the space of object p at an instant of time. Let p_1 be an arbitrary point in this still space, and assume s_1 is the youngest space layer which passes through p_1. (When the speed of p is equal to or greater than c, its space layers can overlap each other, and so there may be more than one space layer passing through p_1.) Then, the dominant force vector (either gravitational or electric) at p_1 (corresponding to the youngest space layer passing through p_1) lies along the radius of s_1. Suppose we move an infinitesimal distance from p_1 inward along the radius of s_1, and reach at a point like p_2. Let s_2 be the youngest space layer which passes through p_2. Because p_2 is inside s_1, s_2 will be younger than s_1. Depending on the motion of p, s_1 and s_2 may not be concentric, and so the direction of the dominant force vector at p_2 may deviate from the direction of the dominant force vector at p_1. We repeat our inward radial movement from p_2 on s_2, and continue this process until we reach the space layer of age zero, i.e., p itself (depending on its motion, we may not reach p, but we can get infinitesimally close to it). We call the traced path from p_1 to p (excluding p) the *Force Line* of p passing through p_1. The dominant force vector at any point on the force line is tangent to the force line.

Figure 5.1 shows the typical force line of an object for three particular types of motion. Any force line of a stationary object is a straight line. The typical force line of an oscillating object resembles a wave. The so-called gravitational and electromagnetic waves are merely the force lines produced by the expanding space layers of some vibrating objects. It can be verified that the established laws of reflection and refraction for the electromagnetic waves are fully compatible with the previous statement about the nature of these waves: In accordance with Huygens' principle, the force lines of adjacent vibrating objects constructively add up in a particular direction to generate the reflected or refracted waves. A matter fragment with an electric charge of zero or a non-vibratory motion does not generate wavy electric force lines; in other words, that matter fragment does not emit electromagnetic radiation. This justifies the familiar concept of dark matter in cosmology. Note that we have specified oscillatory motion here for convenience; in general, wavy force lines may be created by any kind of back and forth motion, including a revolving one. We should also point out the fact that while the space layers are physical entities, the force lines are just mathematical constructs which represent the directions of the force vectors associated with a succession of space layers.

We further study the force line of an object in constant velocity motion. To simplify the arguments, for the rest of this paper, unless specified otherwise, the motion of any object is contained within the xy plane, and all related calculations are also performed in the xy plane accordingly.

Suppose object p is in motion with constant velocity v, and consider the coordinate system whose origin is p, and its positive y axis is in the direction of the motion of p. (We choose the motion of p to be along the y axis so that the force line can be expressed as y a function of x.) Then, as illustrated in figure 5.2(a), for the force line of p passing through the arbitrary point (x, y),

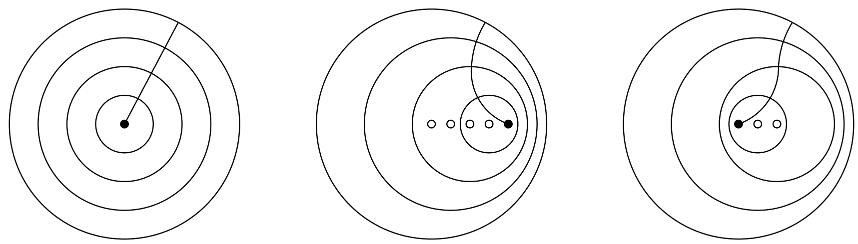

FIGURE 5.1. The typical force line of an object: (a) at rest (b) in constant velocity motion (c) in oscillatory motion

we have

$$(y+vt)^2 + x^2 = c^2t^2. \tag{5.1}$$

Moreover, in figure 5.2(a), the tangent to the force line at the point (x, y) passes through the center of the shown circle; therefore, we also have

$$y' = \frac{y+vt}{x}, \quad x \neq 0. \tag{5.2}$$

Note that we exclude the two trivial force lines of positive and negative y axes so that y is a function of x, and y' is always defined. Eliminating t between equations 5.1 and 5.2 yields the differential equation

$$\left(\frac{c^2}{v^2} - 1\right) x^2 y'^2 - 2\frac{c^2}{v^2} xyy' + \frac{c^2}{v^2} y^2 - x^2 = 0 \tag{5.3}$$

for the force line. Equation 5.3 may be expressed in polar coordinates as

$$\cos^2(\theta) r'^2 + \left(\cos^2(\theta) - \frac{c^2}{v^2}\right) r^2 = 0. \tag{5.4}$$

If v is equal to or greater than c, the space of p will have a horizon, and so its force lines cannot cover the entire xy plane. We discuss this topic in further detail in section 6.

Each force line of p has an absolute minimum point as depicted in figure 5.2(b). At the absolute minimum point of a force line, y' is zero. According to equation 5.2, y' will be zero if the equation

$$y + vt = 0 \tag{5.5}$$

holds. Replacing t in equation 5.1 with its value from equation 5.5 results in the two half-line equations

$$y = \frac{v}{c} x, \quad x < 0 \tag{5.6}$$

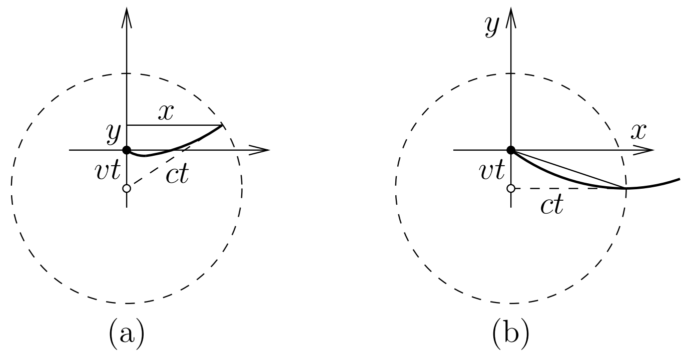

FIGURE 5.2. Determining the force line's equation for an object in motion with constant velocity v

and

$$y = -\frac{v}{c}x, \quad x > 0 \tag{5.7}$$

which represent the locus of the absolute minimum points of all force lines. Therefore, every force line emanates from behind p in the nagative y region of the plane between these two half-lines.

For an object like p in constant velocity motion, a simple algorithm can be developed to compute its force line which passes through a particular point like p_1 in its space. In compliance with the definition of the force line, the algorithm works by iterative inward radial movement from p_1 toward p. In section 11, we present a similar algorithm in detail to calculate the orbit of a planet around a moving star.

6. Space Horizon

Assume object p is in motion with constant velocity v, and consider a three-dimensional Cartesian coordinate system whose origin is p, and its positive x axis is in the direction of the motion of p.

For v equal to c, all space layers of p are contained in the negative x region of the space, and each of them is tangent to the horizon plane $x = 0$ at the origin.

When v is greater than c, p is outside any of its space layers. As shown in figure 6.1, consider the space layer of age t and a tangent line to it from p. Then, we have

$$\sin(A) = \sin(\pi - A) = \frac{ct}{vt} = \frac{c}{v}. \tag{6.1}$$

A is constant; therefore, a tangent line from p to any of its space layers makes the same angle with the x axis. This means that all space layers of p are contained in an infinite cone with the origin as its apex and the negative x axis

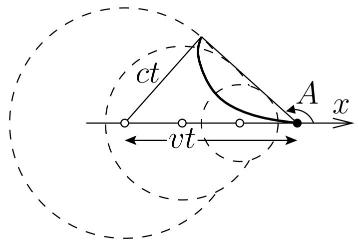

FIGURE 6.1. The conic space of an object in motion with constant velocity v greater than c

as its axis of rotational symmetry. We call this space a *Conic Space* and the aperture of the horizon cone, i.e., the angle

$$2 \arcsin\left(\frac{c}{v}\right)$$

the *Horizon Angle* of that space.

In figure 6.1, we have also depicted a typical force line of p through its conic space. As you can see, the tangent to the shown force line at its endpoint on the horizon is along the radius of the space layer of age t and thus perpendicular to the shown horizon line; in fact, it is normal to the horizon cone. This indicates that every force line vertically hits the horizon.

7. Action and Reaction

As far as the interactions between space layers and objects are concerned, Newton's third law does not hold in general when objects are in motion. In figure 7.1(a), the law of action and reaction is valid for the two stationary objects A and B. But in figure 7.1(b), the mutual forces exerted on the two moving objects A and B are not equal in magnitude, nor are they opposite in direction. In figure 7.1(b), at an instant of time, due to their motions, A and B encounter space layers of different radii, and thus experience forces of different magnitudes.

8. Doppler Effect

In figure 8.1(a), object p oscillates with period T along the y axis (to avoid cluttering the picture, x and y axes have not been drawn). In each oscillation, p generates one complete wave cycle in each of the two force lines to the right and left of it. At the end of that oscillation, the front of each of the two wave cycles is on the space layer of age T while p is back at the center of that space layer (the origin). Therefore, both wave cycles have a length of cT.

Now, as depicted in figure 8.1(b), assume p also has a second velocity component along the positive x axis with constant magnitude v less than c. Again in each oscillation, p creates a full wave cycle in each of the two force lines ahead

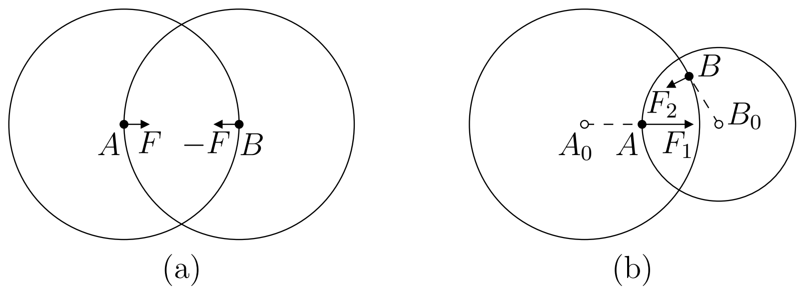

FIGURE 7.1. The attractive interactions between two objects: (a) at rest (b) in motion

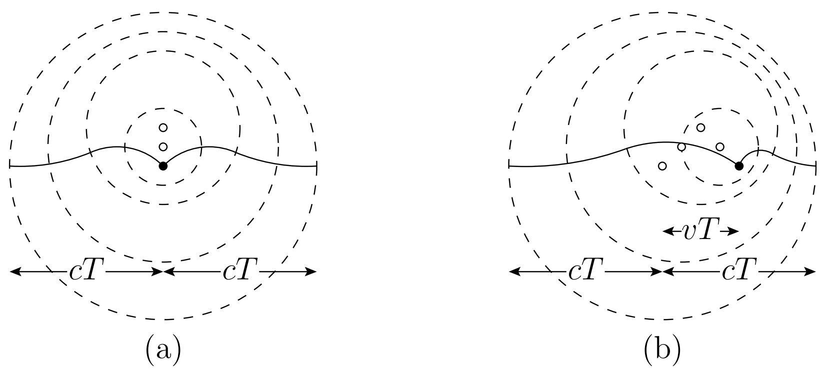

FIGURE 8.1. Wave in the force lines of an object: (a) oscillating vertically with period T (b) oscillating vertically with period T and moving horizontally with constant velocity v less than c

of and behind it. During that oscillation, p also moves a distance of vT along the positive x axis while the space layer which has the fronts of the two wave cycles expands to a radius of cT. Therefore, as illustrated in figure 8.1(b), the length of the wave cycle ahead of p is

$$\lambda_1 = cT - vT = (c - v)T, \tag{8.1}$$

and that of the wave cycle behind p is

$$\lambda_2 = cT + vT = (c + v)T \tag{8.2}$$

(note that both endpoints of each of the two wave cycles are on the x axis).

9. Parallel-Moving Objects

Consider two like charges q_1 and q_2 which are both stationary; assume q_1 is at the origin, and q_2 is on the positive y axis at the distance r from q_1 (unless otherwise noted, throughout this paper, the word *charge* refers to an object with an electric charge). As demonstrated in figure 9.1(a), the space layer of

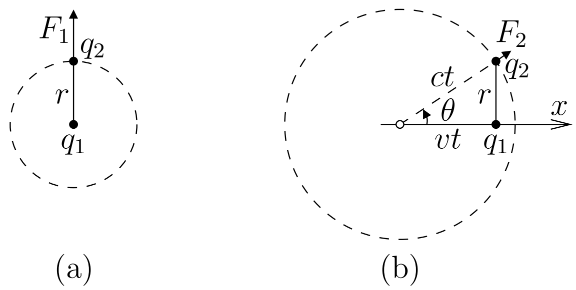

FIGURE 9.1. Computing the repulsive interaction between two like charges: (a) at rest (b) moving in parallel with constant velocity v less than c

q_1 with radius r is centered at the origin, and passes through q_2. Therefore, q_2 experiences an electric force along the positive y axis with the magnitude of

$$F_1 = \frac{k_e q_1 q_2}{4\pi r^2}. \tag{9.1}$$

Now, suppose q_1 and q_2 are still a vertical distance r apart, but both moving parallel to the positive x axis (q_1 is actually on the x axis) with constant speed v less than c. As depicted in figure 9.1(b), the space layer of q_1 which encounters q_2 has a center on the x axis behind q_1 and a radius greater than r. The direction of the electric force exerted on q_2 is determined from

$$\theta = \arccos\left(\frac{v}{c}\right). \tag{9.2}$$

We have

$$c^2t^2 = \frac{r^2}{\sin^2(\theta)} = \frac{r^2}{1-\cos^2(\theta)} = \frac{r^2}{1-\frac{v^2}{c^2}} \tag{9.3}$$

for the square of the radius of the shown space layer. Therefore, the magnitude of the electric force exerted on q_2 is

$$F_2 = \left(1-\frac{v^2}{c^2}\right)\frac{k_e q_1 q_2}{4\pi r^2} = \left(1-\frac{v^2}{c^2}\right)F_1. \tag{9.4}$$

10. MAGNETIC EFFECT

In the arguments presented in this section, for brevity, let us call a space layer with positive electric strength a positive space layer and one with negative electric strength a negative space layer.

Figure 10.1(a) shows two space layers of a stationary positive charge like q_1, and figure 10.1(b) shows two space layers of a negative charge like q_2 which moves along the positive x axis with a speed less than c. Assume both charges are of the same magnitude. Furthermore, suppose the inner space layers have the same radius r and the same minimum distance x from their corresponding outer space layers. Then, as illustrated in figure 10.1, the radius of the outer space layer of q_1 is $r + x$ while that of q_2 is $d + r + x$ (which is greater). In figure 10.1(c), we have superimposed the space layers of the two charges so that their inner space layers fully overlay each other; this also makes the outer space layer of q_2 a surrounding tangent to the outer space layer of q_1. Now, in figure 10.1(c), consider a charge like q positioned on the inner space layers ahead of q_1 and q_2 on the x axis (q_1 and q_2 are also on the x axis). If q remains stationary there, the net electric force exerted on it will be zero. But if q moves from the inner space layers toward the outer space layers along the positive x axis, throughout its trip outward, the radius of the positive space layers will increase more slowly than that of the negative space layers, and consequently, the magnitude of the positive electric strength will fall off more slowly than that of the negative electric strength. Therefore, if q is positive, it will feel a repulsive electric force away from the center of each encountered positive space layer; conversely, if q is negative, it will feel an attractive electric force toward the center of each encountered positive space layer. We call this phenomenon the *Magnetic Effect*. The faster q_2 moves, the more squeezed its negative space layers are (encountered by q), and thus the faster the magnitude of the negative electric strength falls off; this will result in a stronger net electric force exerted on q. Also, the faster q moves, the shorter the time is for q to travel the same distance x to experience the same amount of net electric force; therefore, q will undergo a greater amount of net electric force per unit of time. In figure 10.1(c), the direction of the motion of q is the one in which the magnitude of the negative electric strength falls off at maximum rate, causing q to feel the strongest net electric force.

A similar argument can be used when the direction of the motion of q is reversed, or when q is behind q_1 and q_2 on the x axis, or when the positive charge q_1 moves and the negative charge q_2 is at rest. Note that for the simplicity of the presentation, in figure 10.1, q_2 and q move on the same line; they could move on two parallel lines, similar to the case of two parallel current-carrying wires. Finally, imagine that we have a stack of the configuration of figure 10.1(c) along the z axis (perpendicular to the page), and q is again positioned on the inner space layers. If q moves along the z axis, all encountered positive and negative space layers will be of the same radius r, and so the net electric force exerted on q will remain zero; this is like the situation when a charge moves along the axis of a current-carrying coil.

We should now emphasize that there is no such thing as a magnetic field to cause a force in a perpendicular direction. We may have an illusion of the so-called magnetic field lines by looking at the lines of iron filings formed on a

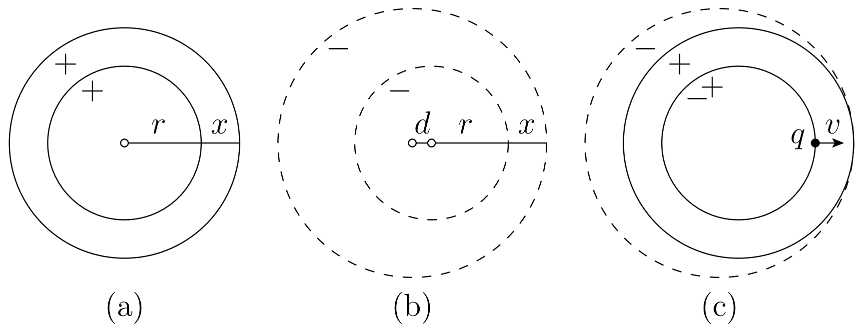

FIGURE 10.1. Illustration of the magnetic effect

sheet of paper placed over a magnet bar. In fact, each iron filing simply acts like a very small magnet bar in an equilibrium of forces exerted upon it by its neighboring iron filings and the main magnet bar; this results in the formation of the chains of iron filings. The magnetic effect, as described before, is the sole nature of the forces which cause each iron filing to become a small magnet bar, and stand in a state of equilibrium.

11. Orbital Precession

Figure 11.1(a) depicts the elliptical orbit of a planet around a star in accordance with the Newtonian theory of gravity where the star is at rest, and the planet has the distance x from the star and the velocity v at its perihelion. Figure 11.1(b) illustrates the orbit of the planet around the same star where the star moves along the positive x axis with a speed less than c, and the planet initially has the same distance x from the star and the same orbital velocity v relative to the moving star. (In figure 11.1(b), at any instant of time, the planet also has another velocity component which is exactly equal to the velocity of the star, so the planet would be at rest relative to the moving star if its orbital velocity were eliminated.) At the beginning of the orbit of figure 11.1(b), the planet is on a space layer with a larger radius compared to the orbit of figure 11.1(a); therefore, the planet is pulled by a weaker gravitational force, and drifts more outward. Then, roughly speaking, in the upper part of the orbit of figure 11.1(b), the angle between the orbital velocity and acceleration vectors of the planet is smaller compared to the orbit of figure 11.1(a); this also results in less curving of the orbit around the star. Conversely, in the lower section of the orbit of figure 11.1(b), the angle between the orbital velocity and acceleration vectors of the planet is larger compared to the orbit of figure 11.1(a); this curves the orbit more inward. The overall effect of these differences is the precession of the orbit of the planet around the moving star. For a more elongated elliptical orbit, the planet journeys through more space

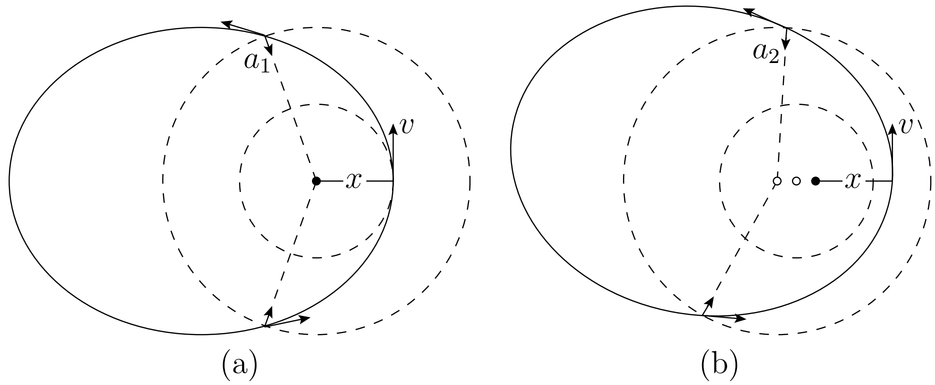

FIGURE 11.1. Demonstration of the orbital precession

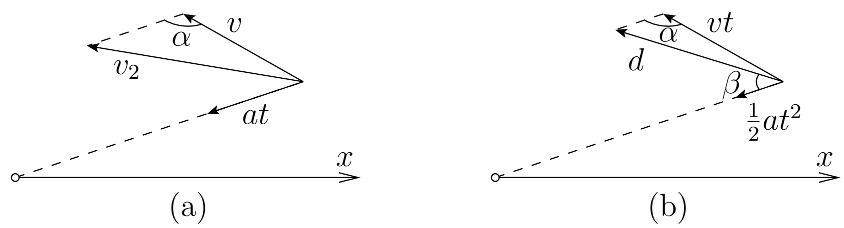

FIGURE 11.2. (a) Computing the new velocity of the planet on its orbit (b) Computing the new position of the planet on its orbit

layers; as the planet encounters more space layers, its orbit around the moving star may undergo more precession.

We can devise a simple iterative algorithm to actually compute the orbit of the planet around a star which moves with a constant velocity less than c: Assume we have the initial position, velocity, and acceleration of the planet on its orbit. Then, we need to calculate the new position, velocity, and acceleration of the planet after an infinitesimal time period. After this, we simply treat the new position, velocity, and acceleration of the planet as the initial ones, and repeat the process. (We may run the algorithm for any period of time as needed.)

The computations are in compliance with classical mechanics. Suppose the planet has the initial orbital velocity v and acceleration a. Figure 11.2(a) shows how to calculate the new velocity v_2 of the planet after the infinitesimal time period t by using the law of cosines. From figure 11.2(b), again by using the cosine formula, we determine the displacement vector and so the new position of the planet after the same time interval t.

Now, in order to calculate the new acceleration of the planet after the time period t, assume the planet is initially on the space layer s_1 of the star with radius r_1. After determining the distance d and the angle β from figure 11.2(b), we can compute the distance r from the new position of the planet to the center of s_1 as illustrated in figure 11.3(a). From figure 11.3(a), we can also calculate the angle θ between the radius r and the x axis (we know the initial angle between the radius r_1 and the x axis). If the star were at rest, the new acceleration vector would be along the radius r, and the magnitude of the new acceleration could be determined from r. But because the star is in motion, we have to go one step further to compute the radius r_2 of the space layer s_2 corresponding to the new position of the planet. Suppose the star is moving along the positive x axis with constant speed V (less than c). After calculating r and θ from figure 11.3(a), we have

$$(11.1) \qquad {r_2}^2 = r^2 + D^2 - 2rD\cos(\theta)$$

in figure 11.3(b). Furthermore, in figure 11.3, we have

$$(11.2) \qquad r_2 - r_1 = ct_2 - ct_1 = c\frac{D}{V}$$

from which we derive

$$(11.3) \qquad D = \frac{V}{c}(r_2 - r_1).$$

Replacing D in equation 11.1 by its value from equation 11.3 results in a quadratic equation in r_2. It can be proved that for V less than c, the quadratic equation in r_2 has either only one real root equal to zero or two real roots, one positive and one negative. In the former case, the planet hits the star, and the algorithm is terminated. In the latter case, the positive root is the right value for r_2. We continue to determine the angle between the radius r_2 and the x axis from figure 11.3(b). The new acceleration vector can then be computed, and we are done with one iteration of the algorithm.

Note that in figure 11.3, r is greater than r_1; therefore, r_2 is also greater than r_1, and the center of s_2 is behind the center of s_1 on the x axis. If r is less than r_1, r_2 will also be less than r_1, and the center of s_2 will be ahead of the center of s_1 on the x axis. If r is equal to r_1, s_2 will be the same as s_1, and so the new acceleration will be calculated from r and θ. In figure 11.3, for convenience, we have used the angle between the radius r and the negative x axis. However, in the actual implementation of the algorithm, we may measure any such angle relative to the positive x axis; by doing so, we derive the same formulae for the new acceleration regardless of whether r is greater or less than r_1.

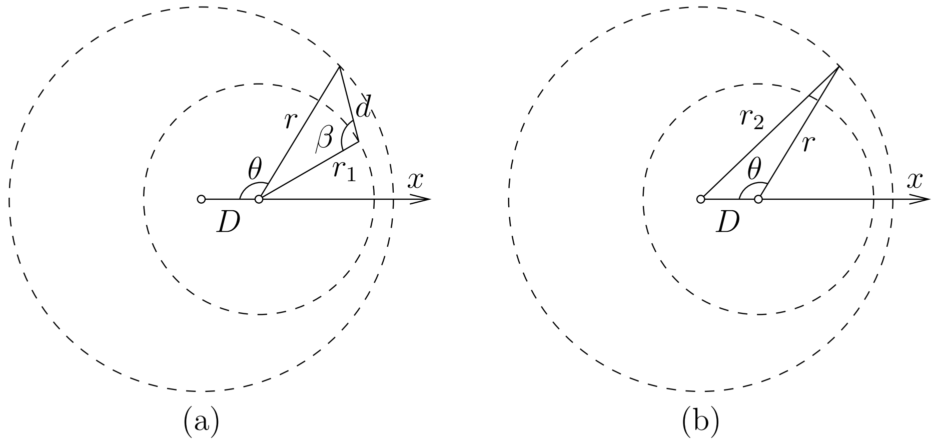

FIGURE 11.3. Computing the new acceleration of the planet on its orbit

12. Further Works

In this paper, we elaborated the space, force lines, and some effects for a particular type of motion, i.e., constant velocity. The interested reader may study these topics for other types of motion such as constant acceleration and regular oscillation (to be defined properly). One may also try to solve the differential equations 5.3 and 5.4.

For a real-world verification, you can employ the algorithm described in section 11 to compute the orbit of the planet Mercury around the Sun, and measure its precession. Since the motion of the Sun is not contained in the plane of the orbit of Mercury, you have to either extend the algorithm to the three-dimensional space, or reduce the problem into a two-dimensional one by applying some appropriate transformations. (Due to the vastness of the interstellar distances, you may assume the Sun has a constant velocity.)

References

[1] Carroll, S. M. *Spacetime and Geometry: An Introduction to General Relativity.* Benjamin Cummings, 2003.

[2] Goldstein, H., Poole, C. P., and Safko, J. L. *Classical Mechanics, 3rd ed.* Addison-Wesley, 2001.

[3] Griffiths, D. J. *Introduction to Electrodynamics, 3rd ed.* Benjamin Cummings, 1998.

[4] Griffiths, D. J. *Introduction to Quantum Mechanics, 2nd ed.* Benjamin Cummings, 2004.

[5] Taylor, E. F. and Wheeler, J. A. *Spacetime Physics: Introduction to Special Relativity, 2nd ed.* W. H. Freeman and Company, 1992.