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A simple theory of earthquakes according to quantum mechanics

Abstract

Centuries have passed to understand the earthquake, which is a natural phenomenon. Many earthquake theories have been put forward as a result of hundreds of years of observations and theories. Some of these theories have been accepted, and some have not been accepted at all. Important ones of the currently accepted earthquake theories are given by Keiiti Aki and Paul G. Richards in a book published in 1979 and 2009, and cited in references. All these earthquake models contributed by these authors are based on the seismic wave propagation theory. It is based on the fact that seismic waves occur as a result of ruptures, fragmentations, dispersions and sliding of some layers on each other in the earth and the classical spread of these waves. Calculation of earthquake parameters is mostly made with the values obtained by statistical models of observed values. All calculations are based on classical physics laws. In this article, the theory we have given is proposed according to the laws of Quantum Mechanics. Therefore, the calculation of earthquake parameters does not depend on any statistical model. In this proposed new earthquake model, magnitude of the earthquake, its energy that may be released when the earthquake will occur, the depth of the earthquake from the earth surface, and in which regions it may occur on earth can be predicted in advance. This will enable people to take precautions in advance. It appears that quantum mechanics can also be applied to macroscopic physical phenomena.

Keywords: earthquake theory, underground faults, vibrations underground, earthquake intensity, earthquake time, earthquake depth

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Hasan Hüseyin Erbil
Department of Physics, Faculty of Sciences, Ege University(Retired)), Turkey

Correspondence: Hasan Hüseyin Erbil, Department of Physics, Faculty of Sciences, Ege University (Retired)), 35100 Bornova–İzmir, Turkey, Email hhuseyin.erbil@gmail.com

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Introduction

Since the formation of the world, it is known that earthquakes occur sequentially in regions that are seismically active and millions of people and shelters have been destroyed as a result. Earthquake is the phenomenon where the vibrations that occur suddenly due to the breaks in the earth's crust, thus they spread in waves and shake the surface and the environment they pass through. Earthquake is a natural event that shows the soil that people regarded as immobile and safely stepped on would also move, and that all the structures on it could be destroyed in a way that their lives could be damaged and even be lost. The branch of science that examines how the earthquake is occurred, how earthquake waves spread across the earth, measuring instruments and methods, evaluation of records, and other issues related to earthquakes is called seismology.

Regarding the internal structure of the world, there is a ground model supported by the data obtained as a result of geological and geophysical studies. According to this model, there is a lithosphere formed around 70-100 km thick on the outer part of the earth. The continents and oceans are located in this rock. The belt between the lithosphere and the core, which is 2.900 km thick, is called Mantle. The core under the mantle is considered to be composed of a nickel-iron mixture. The place is known to increase the temperature as the surface goes deeper from the surface. From the fact that the transverse earthquake waves cannot propagate in the core of the earth, it is concluded that the core should be a liquid medium. Although the mantle is generally solid, it contains local liquid environments as it descends from the surface.

Under the lithosphere, there is a soft Upper Mantle called the Asthenosphere. The forces formed here, due to the convection currents, break the stone crust and divide it into many Slabs. Convection currents formed in the upper mantle are connected to the high temperature caused by radioactivity. As the convection currents rise upwards, they cause stresses in the rock and then the formation of plates by breaking weak zones. There are still about 10 large plates and many small plates. Together with the continents standing on these plates, they float like a raft on the asthenosphere and move at a speed that people cannot feel relative to each other.

In places where convection currents increase, the plates move away from each other and form the mid-ocean ridges in the hot magma emerging from there. In the regions where the plates touch each other, there are frictions and jams, one of the rubbing plates sinks down to the Mantle and melts to form the loss zones. This sequential event caused by convection currents continues under the same frame. Here, the boundaries of these plates, where the plates that make up the earth's crust are rubbed against each other, compress each other, climb over each other or enter one another's below, due to the places of earthquakes in the world. The vast majority of earthquakes in the world occur on narrow belts at the plate boundaries where these plates force each other. Above, we have said that the slabs that make up the earth's crust are in motion due to the convection currents in the asthenosphere and therefore they push each other or sever from each other, and the zones where these events occur also form earthquake zones.

There is a frictional force between the two plates that push each other or go under the other, which prevents movement. In order for a plate to move, this friction force must be removed. A movement occurs when the friction force is exceeded between one sheet being pushed and another sheet. This movement takes place in a very short time unit and is shocking. Eventually, earthquake (shaking) waves can emerge to far distances, and these waves propagate by shaking the environments they pass through and decreasing their energy as they move away from the direction of the earthquake. Meanwhile, land fractures called fault can occur on the earth, sometimes visible, extending for kilometers. These fractures are sometimes not observed on earth, they may be hidden by surface layers. Sometimes, a fault that was formed from an old earthquake and reached to the surface, but covered in time, can play activate again.

The description of the occurrence of earthquakes in this way and under the name of "Elastic Back Tab Theory" was made by American Reid in 1911 and it has been proved by being tested in laboratories. According to this theory, at any point, when the energy that is gradually formed by the elastic deformation accumulation, reaches a critical value, it overcomes the frictional force along the fault plane and creates relative movements of rock blocks on both sides of the fault line. This event is a sudden displacement movement. These sudden displacements, on the other hand, occur when the unit deformation energy accumulated at one point is released, discharged, in other words, it turns into mechanical energy and as a result, the breaking and tearing motion of the ground layers.

In fact, it is impossible for rocks to break without prior accumulation of a unit. This unit creates the movement of displacement, convection currents formed in the upper crust in the earth crust seen, rocks can resist until a certain deformation and then break. As a result of these breaks earthquakes occur. After this event, some or all of the stresses and energy accumulated from the rocks for a long time have been removed. In the faults mostly formed during this earthquake event, elastic back tabs (beats) are formed on both sides of the fault and in the opposite direction.

Faults are often named according to their direction of movement. Faults that are mostly formed as a result of horizontal movement are called "strike slip fault." It can also be mentioned that the two separate blocks formed by the fault move left or right relative to each other, which are examples of right or left directional pulsed faults. Faults occurring with vertical movements are called "slope slip fault." Most of the faults can have both horizontal and vertical movements. Earthquakes can be of different types according to their causes. Although most of the earthquakes in the world occur in the form described above, there are also minor types of earthquakes that occur due to other natural causes. The earthquakes resulting from the movement of the plates described above are generally described as "tectonic" earthquakes and these earthquakes mostly occur at the boundaries of the plates. 90% of the earthquakes in the world fall into this group. The second type of earthquakes are "volcanic" earthquakes. These are formed as a result of eruption of volcanoes. In the depths of the earth, it is known that these types of earthquakes have come to light due to the explosions of the gases formed as a result of physical and chemical events during the emergence of the molten substance. Since they are related to volcanoes, they are local and do not cause significant damage. Another type of earthquakes is collapse earthquakes. These are formed by the collapse of the ceiling block of cavities underground (cave), galleries in coal mines, melting in salt and gypsum areas. The sensing areas are local and their energy is low and they do not cause much harm. Large landslides and meteorites falling from the sky are also known to cause small jolts. After the Deep Sea Earthquakes, whose focus is at the bottom of the sea, waves are formed in the seas leading up to the shores and sometimes causing great damage to the shores, which are called Tsunami.

Earthquake parameters: When an earthquake occurs, some concepts defined as earthquake parameters are mentioned in order to describe and understand this earthquake. The following will briefly explain these parameters.

Focus point (inner center)**:** The focus is on the earth where the earthquake's energy emerges. This point is also called the focal point or the inner center. In reality, energy is not a point where it appears, but it is an area, but it is considered a point in practical applications.

External center (outer center, epicenter): It is the point on the place closest to the focal point. It is also the point where the earthquake suffered most or felt strongest. In fact, this is an area rather than a point. The outer center area of the earthquake can be of various sizes depending on the severity of the earthquake. Sometimes the dimensions of the focal point of a large earthquake can also be determined by hundreds of kilometers, so it will be more accurate to define it as "epicenter area."

Focus depth: The shortest distance from the earth's point where the energy is released in the earthquake is called the focal depth of the earthquake. Earthquakes can be classified according to their depth of focus. This classification is valid for tectonic earthquakes. Earthquakes with a depth of 0-60 km of the ground are considered as shallow earthquakes. Earthquakes with a depth of 70-300 km of the ground are medium-depth earthquakes. Deep earthquakes are more than 300 km of the earth. Deep earthquakes are felt in very large areas, and their damage is minimal. Shallow earthquakes are felt in a narrow area and can cause great damage in this area.

Equal intensity curves: They are the points that connect the points that are shaken by the same intensity. According to the generally accepted situation, the area formed by the curves, that is, the area between the two curves, is limited in terms of severity being affected by earthquakes. For this reason, the intensity of the earthquake is written in the field, not on the intensity curves.

Earthquake intensity: It is defined as the measure of the impact of the earthquake of any depth at a point where it is felt on earth. In other words, the severity of the earthquake is a measure of its effects on structures, nature and people. This effect, the magnitude of the earthquake, the depth of focus and the distance of the structures against the earthquake can be different. Although intensity does not provide accurate information about the magnitude of the earthquake, it reflects the damage caused by the earthquake depending on the factors mentioned above. The intensity of the earthquake is evaluated according to the intensity charts prepared as a result of the observed effects of the earthquakes and based on the experience of many years. In other words, earthquake intensity tables evaluate the response of everything living and inanimate to the earthquake. These previously prepared rulers determine the effects of earthquakes in every degree of violence on people, structures and land. When an earthquake occurs, the effects occurring in that area are observed to determine the severity of this earthquake at any point. The intensity of the earthquake is considered to be the degree of severity, as long as these impressions fit the definition of the severity scale in the Intensity Chart. For example; if the effects caused by the earthquake include the findings defined in the violence scale of VIII intensity, that earthquake is defined as an earthquake with the intensity of VIII. In the Earthquake Intensity Charts, the intensities are shown in roman numerals. The main intensity rulers used today are the modified Mercalli Ruler (MM) and Medvedev-Sponheur-Karnik (MSK) intensity ruler. XII intensities are covered in both scales. According to these rulers, earthquakes with a intensity of V and less generally do not cause damage to the structures and are evaluated according to the way people feel the earthquake. The intensities between VI-XII are evaluated based on the damage caused by earthquakes in the structures and the findings are such as fracture, splitting, landslide caused by the land.

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Magnitude: It is defined as a measure of the energy released during the earthquake. Since there is no possibility to measure energy directly, Magnitude, an instrumental measure of earthquakes, was identified by a method found in the 1930s by Prof. C. Richter in United States. The magnitude of the earthquake is determined according to the ruler prepared by Richter. Since the formation of the world, it is known that earthquakes occur sequentially in regions that are seismically active and millions of people and shelters have been destroyed as a result. A logarithm of the maximum amplitude measured in micron (1 micron 1/1000 mm) of ground motion recorded with a special seismograph (2800 magnification, with a special period of 0.8 seconds and 80% damping) placed on a hard ground at a distance. He described it as the magnitude of the earthquake. When the earthquakes up to date are analyzed statistically, it is seen that the largest recorded magnitudes are 8.9. The magnitude of this earthquake reported by the observatories does not give an idea about the earthquake energy, because the earthquake can be shallow or deeply focused. Of the two earthquakes with the same magnitude, the shallower will do more damage, while the deeper will do less damage, so there will be a difference. However, the Richter scale (magnitude) is a very important factor in determining the properties of earthquakes.[1]

In short, it is not possible to predict when the earthquake will happen and how much energy will be generated in the earthquake theory already known. However, in the theory we give here, it may be possible to predict the time of the earthquake and the energy that will emerge.

New earthquake theory

We tried to give information about how earthquakes occurred in the introduction. It is impossible to know all of the reasons why earthquakes occur. We consider all of these reasons as a result of the movement of masses m. This mass represents not only faults, but all formations other than faults that caused the earthquake to occur. But in order to be short, we will accept the masses of these formations (all formations that cause earthquakes) as a fault. We briefly call these underground masses faults. Therefore, we consider mouvemens of the faults that exist underground or that will occur with different forces. We assume that these faults do harmonic motion, their energy increases during their movements, and they occasionally release some of this energy as waves to the earth surface. We call this event an earthquake.We consider that when the faults make harmonic motion, gain energy as a result of this movement, and some of the energy they give from time to time, as waves to the earth surface, and this event is called earthquake. Energy gain of faults occurs when their volume changes. When the volume of the fault changes, its mass changes. So examining the motion of the fault means examining the earthquake, that is, understanding the earthquake. Until today, the earthquake was investigated according to elasticity theory of continuous environments and statistics models.[1,2] In this study, we propose an earthquake model that is not based on these models and is dependent on the motion of the earth and quantum mechanics. We explain this model below.

We assume the earth to be an ellipsoid. However, as seen in Figure 1, the sphere is practically accepted. There should be N spaces called faults inside this ellipsoid. Let the masses of these voids be $\mathrm{m} = \mathrm{m_i} = -\mathrm{m_0}, (i = 1, 2, \ldots N)$ and the total mass of the ellipsoid M as shown in Figure 1. The center of mass of this ellipsoid is the Q point and the axis of rotation of the ellipsoid is the QZ axis. The ellipsoid rotates about the QZ axis with angular velocity $\vec{\omega} = \omega \vec{K}$. We assume the effect of the earth's rotation around the sun is negligible. So the QXYZ system can be taken as an inertial system. As seen in Figure 1, consider the OXYZ system (relative system) that rotates around the fixed QXYZ system. This system is also an inertial system. Let the angle between the QZ axis and the QZ axis be α . Angular velocity in QZ axis is $\vec{\omega} = \omega_0 \vec{K}$ and angular velocity in OZ axis $\vec{\omega} = \omega_0 \vec{K}$. Since the angular velocities will be equal in the two coordinate systems, the angular velocity of the QZ axis is as $\omega = \omega_0 \vec{K}.\vec{K} = \omega_0 \cos(\alpha)$.

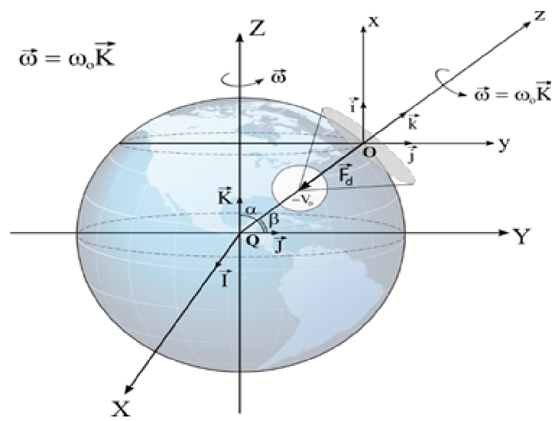

Figure 1 Depiction of the earthquake event on the earth globe.

We call the earthquake to feel the motion of the faults in the ellipsoid on the earth. So to understand the earthquake, it is necessary to examine the motion of these faults. Suppose that $\vec{R}$ is the position vector of origin O of relative system to origin Q of the QXYZ system. (Figure 1). Denote $\vec{R}$ and $\vec{R}$ the velocity and acceleration of O relative to Q, respectively. Consider the motion of the mass m (fault) located at the point V_0 (focus of fault) with the position vector $F\vec{d}$ on the axis of OXYZ. When the beginning of the relative coordinate system is taken in the center of mass, the reduced mass is taken instead of mass. Here the QXYZ relative system is not in the center of mass. For this reason, the mass m can be taken directly instead of the reduced mass. If the total force affecting the mass m in the relative system is $\vec{F}$, according to Newton's second law, the motion equation of this mass is as follows:

$$m\frac{d^2\vec{r}}{dt^2}\vec{F} - 2m\left(\vec{\omega}\times\vec{V}\right) - m[\vec{\omega}\times\left(\vec{\omega}\times\vec{r}\right)] - \mathrm{m}\ddot{\vec{\mathrm{R}}},(t\, is\, time) \quad (1)$$

In (1), $\vec{\mathrm{v}}$ is the linear velocity and we are using the following terminology: $2m\left(\vec{\omega}\times\vec{V}\right)=$ coriolis force, $\mathrm{m}[\vec{\omega}\times\left(\vec{\omega}\times\vec{r}\right)]$ =centripetal force, $-\mathrm{m}[\vec{\omega}\times\left(\vec{\omega}\times\vec{r}\right)]$=centrifugal force. $\vec{F}$ is the resultant of all forces acting on the fault. $\ddot{\vec{\mathrm{R}}}=\vec{\omega}\times\left(\vec{\omega}\times\vec{R}\right)$ and $\vec{\omega} = \omega_0\vec{K} = -\omega_0 \sin\left(\alpha\right)\vec{i} + \omega_0 \cos\left(\alpha\right)\vec{k}$. The angle α is the longitude and $\beta=\pi/2-\alpha$ is the latitude of the Opoint. So, $\vec{\omega}=\omega_0\left[-\cos\left(\beta\right)\vec{i} + \cos\left(\alpha\right)\vec{k}\right]$. If $\omega=\omega_0$ is taken for $\alpha = \pi / 2 \, and \;\; \beta = 0, \vec{\omega} = \vec{\omega}\left(\alpha,\beta\right) = \omega_0\left[-\cos\left(\beta\right)\vec{i} + \cos\left(\alpha\right)\vec{k}\right]$. If ω_0 is calculated, $\omega_0 = 7.29212\times10^{-5} \;\; rad / s$. So,

$$\omega\left(\alpha,\beta\right) = \omega_0 w\left(\alpha,\beta\right);[w\left(\alpha,\beta\right) - \sqrt{\cos^2\left(\alpha + \cos^2\left(\beta\right)\right.}] \quad (2)$$

Equation (1) represents both the translational and rotational motion of the mass m (fault). If the $\vec{F}$ force acting on the mass m and the angular velocity $\vec{\omega}$ are known, its motion can be examined by solving the differential equation (1) which the second order differential equation is according on time. And comments can be made; desired physical sizes can be calculated. But the solution to this equation is very difficult. Because it is very difficult to find the mass m and the force $\vec{F}$ acting on it, it is almost impossible. This problem is quantum

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mechanically easier to solve. Therefore, we will consider and solve this problem as a quantum mechanics problem.

Motion of a mass m; in classical mechanics, by solving the differential equation obtained by force $\vec{F}$ according to Newton's second law; in quantum mechanics, the Schrödinger equation obtained with the U(r) potential is determined by solving it. There is $\vec{F} = -grad\,U(r)$ equation between U(r) potential and $\vec{F}$ force. So in order to examine the motion or state of mass m at point $-V_0$ it is necessary to find the potential U(r) in which this mass m is located. We assume the earth to be an ellipsoid with center of mass at Q rotating about the QZ axis with angular velocity $\vec{\omega} = \omega_0 \vec{K}$ (Figure 1). We also use the fact that the effect of the earth's rotation around the sun is negligible, so that the QXYZ system can be taken as an inertial system. ω is the same on both systems, and if the angular velocity of the earth's sphere around its axis is ω. If the origin of the coordinate is taken in the mass center system according to the two-body problem, it is necessary to take a reduced mass instead of the mass m. Here, as mentioned above, mass can be taken remaining mass of the earth sphere (M-m_0). According to the general gravitation law, the potential directly instead of reduced mass. If the mass of a fault in the earth sphere is taken as $m = -m_0$, the of the mass m is

$$V_m(r) = -G_0 \frac{(-m_0)(M - m_0)}{r} = G_0 \frac{m_0(M - m_0)}{r} = \frac{cc}{r}, [cc = G_0 m_0 (M - m_0)].$$ G_0

general gravitational constant, and M is the total mass of the earth sphere. This $V_m(r)$ potential is repulsive, that is, an obstacle potential and prevents the movement of mass $m - m_0$. Here we accept that the fault makes harmonic motion. So the potential we get should be the harmonic oscillator potential. As shown in Figure 1, the position vector of the fault relative to point O is $\vec{Fd}$. Suppose an observer at point O follows the motion of the $\vec{Fd}$ position vector. An observer at point O examines the motion of vector $\vec{Fd}$ is equivalent to that an observer at point Q examines the movement of the observer at point O, that is, the movement of point O relative to point Q. Therefore, as shown in Figure 1, consider the position vector $\vec{R}$ of the point O relative to point Q. α and β are the longitude and latitude of the point O, respectively. The vector $\vec{R}$ moves in the OXY plane (parallel circles plane) (Figure 1).

Calculation of the energy

Consider a particle of mass or reduced m captured in spherical symmetric quadratic potential well, as follows: $V(r) = -V_0 + a\,r^2$. The effective potential for this central potential is $U(r) = V(r) + b/r^2$. Here, the potential $a\,r^2$ is isotropic harmonic oscillator potential; the term b/r^2 is the centrifugal potential and comes from the rotation of the particle (not coordinat system) (Figure 2).

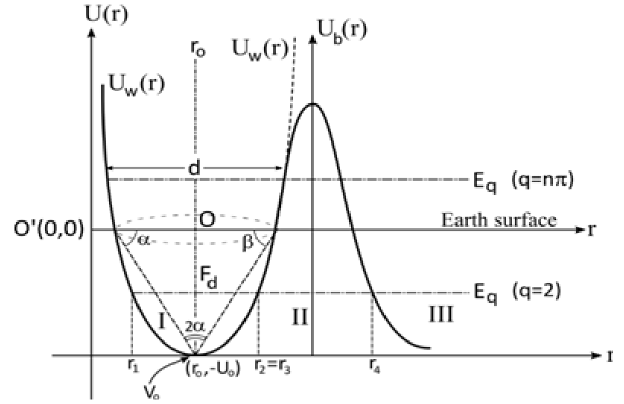

Figure 2 Graph of potential energy function at points O and $-V_0$. in Figure 1.

If the potential is given as $V(r) = V_0(r) - V_0, (V_0(r) > 0)$, the effective potential is $U(r) = V_0(r) - V_0 + \frac{b}{r^2} < 0$ in the bound states. Here, $-V_0$ is the depth of the potential well (Fd point). Let us find the maximum and minimum values of this effective potential $U(r)$. Let the roots of the equation $U'(r) = 0$, r_{ml} and r_{m2} be. $r_0 = (r_{ml} + r_{ml})/2$ is the point where the potential receives the smallest values $U(r_{ml})$ and $U(r_{m2})$, and the largest value $U(r_0)$. Let $U_0 = U(r_0) - V_0$. Thus $U(r) = V_0(r) - U_0 + \frac{b}{r^2} < 0$ can be written. By solving this $U(r)$ potential directly, energy values and wave functions can be found. However, if this potential is divided into two parts with an obstacle and a potential well, there may be some convenience. The obstacle in the potential well comes from rotational energy and the potential energy $(-V_0)$. Apart from the rotational potential, for example the gravitational potential, it is necessary to add them to this potential. Therefore, the $U(r)$ effective potential can be written as the sum of three parts as follows:

$$U(r) = V_0(r) - U_0 + \frac{b}{r_2} + \frac{cc}{r} = U_w(r) + U_b(r); [U_w(r) = V_0(r); U_b(r) = -U_0 + \frac{b}{r^2} + \frac{cc}{r} \quad (4)$$

Here, the $U_w(r)$ potential is the vibration part of the $U(r)$ potential, and the $U_b(r)$ potential is total of the rotational and the other obstacle potential parts of the potential $U(r)$. U_0 is the depth of the potential well. If the coordinate start is taken at the point $(r_0, -U_0)$, in this new coordinate system, $U_b(r) = \frac{b}{r^2} + \frac{cc}{r}$ and $U_W(r) = V_0(r)$. Thus the effective potential is written as follows:

$$U(r) = V_0(r) + \frac{b}{r^2} + \frac{cc}{r} = U_w(r) + U_b(r); [U_w(r) = V_0(r); U_b(r) = \frac{b}{r^2} + \frac{cc}{r}] \quad (5)$$

The graph of this potential is shown in Figure 2. (Shape of the U(r) function $(r_0, -U_0)$ in the coordinate system). Here, if the roots of the equation $U(r) = EU$ are r_1 and r_2, $r_0 = (r_1 + r_2)/2$. In this way, three domains I, II, III are obtained. Thus, by solving the equation (5), Eenergy values are found.[3,4] If the fault with mass m is assumed to make three-dimensional harmonic motion, the potential of this motion is $V_0(r) = \frac{1}{2} m\omega^2 r^2 = ar^2$. Thus, the following values are obtained from (5):

$$U_w(r) = ar^2; U_b(r) = \frac{b}{r^2} + \frac{cc}{r}; U_0 = 2\sqrt{ab} - V_0; a = -\frac{1}{2} m\omega^2; b = \frac{\hbar^2}{2} m \quad (6)$$

The $U_b(r)$ potential is an obstacle in the $U_w(r)$ potential well. The following energies are obtained by solving the $U_w(r) = E_q$ equation:

$$Eq = \pm \frac{q}{2} \sqrt{am_h}; [m_h = \frac{\hbar^2}{2} m] \quad (7)$$

For the isotropic harmonic oscillator, $a = \frac{1}{2} m\omega^2$ is. If these values are replaced in (7), the following energies are obtained as follows:

$$E_{q1} = \frac{q}{4} \hbar\omega(\alpha, \beta); E_{q2} = -\frac{q}{4} \hbar\omega(\alpha, \beta)$$

�$$E_q = E_{q1} - E_{q2} = \frac{2q}{4} \hbar\omega(\alpha, \beta); E_q = \frac{�E_q}{2} = \frac{q}{4} \hbar\omega(\alpha, \beta)$$

$$E_q(q, \alpha, \beta) = \frac{q}{4} \hbar\omega(\alpha, \beta); [q = 2 \text{ and } n\pi, (n = 1, 2, 3, ..)] \quad (8)$$

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We have for q=2 the minimum (ground) state energy occurs; for $q = n\pi, (n = 1,2,3,...)$, for the exited state energies occur. We have: symmetric states for odd integer values of n; antisymmetric states for even integer values of n. E_{q2} shows the energy of the particle that it is bound, and E_{q1} shows the energy of the state after out of getting of the bound state. An earthquake event occurs when the fault becomes excited states while vibrating with E_q constant energy at ground state. When it gets excited state, it gains kinetic energy. Since $\omega(\alpha,\beta)$ is constant at point O(α,β) the excitation of the fault occurs by changing its mass. It cannot remain steady while stimulated and tries to become at its ground state. This kinetic energy being in zone (I) passes through the zone (II) to zone (III) by tunneling. Region (III) becomes the region where earthquake is felt on the earth. It appears that the energy given by (8) does not depend on the mass of m. So whether the mass m is big or small, it doesn't matter. Therefore, it is not necessary to calculate this mass precisely, ie to know it exactly.

Finding wave functions

The radial normalized wave functions can be written as follows:[2,3]

$$Q(r) = m_1 \int \sqrt{|U_w(r)|}dr \; ; \; [m_1 = \sqrt{\frac{2m}{\hbar^2}} = \frac{\sqrt{2m}}{\hbar}]$$

For the state of E_q, the independent of time and time dependent normalized wave functions are as follows, respectively:

$$F^s(r) = A\cos[K\, r e^{\pm iQ(r)} \text{ and } F^a(r) = B\sin[K\, r]e^{e\pm iQ(r)}$$

$$F^s(r,t) = A\cos[K\, r]e^{\pm iQ(r)} e^{-\frac{i}{\hbar}E_q t} \text{ and}$$

$$F^a(r,t) = B\sin[K\, r]e^{\pm i\, Q(r)} e^{-\frac{i}{\hbar}E_q\, t} \tag{9}$$

$$A = B = \sqrt{2K/q} = \sqrt{2/d}, K = \sqrt{\frac{2m}{\hbar^2}}E_q = m_1\sqrt{E_q}, [m_1 = \sqrt{\frac{2m}{\hbar^2}}]$$

The independent of time and time dependent total normalized wave functions are as follows, respectively:

$$\psi^s(r,\theta,\phi) = R(r)|jm> = \frac{F^s(r)}{r}\, |jm> \text{ and}$$

$$\psi^a(r,\theta,\phi) = R(r)|jm> = \frac{F^a(r)}{r}\, |jm>$$

$$\psi^s(r,\theta,\phi) = R(r)|jm> = \frac{F^s(r)}{r}\, |jm> e^{-\frac{i}{\hbar}E_q t};$$

$$\psi^a(r,\theta,\phi) = R(r)|jm> = \frac{F^a(r)}{r}\, |jm> e^{-\frac{i}{\hbar}E_q t}.$$

Let us consider a general solution of the type time-depending functions:

$$\Psi(r,t) = \frac{1}{\sqrt{2}}\{\psi_s(r)e^{-iE_S t/\hbar} + \psi_a(r)e^{-iE_a t/\hbar}\}$$

(a: antisymmetric; s: symmetric). Here, both states, symmetric and antisymmetric, are equally probable. Let us calculate the probability density of presence as follows:

$$\rho = \Psi^*(r,t)\Psi(r,t) = \frac{1}{2}\{\psi_s^2 + \psi_s^2 + 2\psi_a\psi_s\cos[(E_a - E_s)t/\hbar]\} \tag{10}$$

When the cosine is equal to 1, we have $\rho = \frac{1}{2}(\psi_a + \psi_s)^2$, and this corresponds to a state where the probability of finding the particle in domain I is zero. When the cosine is equal to -1, we have $\rho = \frac{1}{2}(\psi_a + \psi_s)^2$, and this corresponds to a state where the probability of finding the particle in domain II is zero. The expression (10) must be interpreted by saying that it is a state where particle oscillates from the left bowl (domain I) to the right bowl (domain II). The frequency of this oscillation is $f = (E_a - E_s)/h$. To perform such an oscillation corresponding to the energy variation $(E_a - E_s)$, the particle must receive energy from the outside, for example by placing it in an electromagnetic field having the frequency f. Such an oscillation is not possible classically because the energy supplied $(E_a - E_s)$ is insufficient for the particle to cross over the hump of the potential U_b. Here, the energy of the fault changes from the movements of the fault (with shrinkage, growth and similar events of fault), that is, it gains kinetic energy.

Calculation of the transmission coefficient through the zone (II) to zone (III)

The particle is unbound state in this region (II). From the solution of the $[U_b(r) = E_q]$ equation, r_3 *and* r_4 values depending on E_q are obtained. The solution to this equation (at the point r_0) gives the following values r_3 *and* r_4 $r_3 = r_0 - d_2/2$ and $r_4 = r_0 + d_2/2$. From here, the width of the obstacle d_2 is found: $d_2 = r_4 - r_3$. The energy E_q is found by the equation (8). In the region II, $E_q < U_b(r)$, (unbound state), thus the particle (here kinetic energy of the fault) cannot remain stable in zone (II), it can pass from region I to region III by tunneling from region (II). Here the probability of passing coefficient is calculated. The tunneling probability coefficient (or transmission coefficient) is given by the following formula:[3–5]

$$T = \frac{2}{\cosh[2\, K\, d] + \cos(2\, P)}$$

Here, the width of the potential barrier d, $K = m_1\sqrt{|E|}$, $m_1 = \sqrt{\frac{2\, m}{\hbar^2}}$, E energy, $Q(r) = m_1\int\sqrt{|U(r)|}\, dr$, $U(r)$ barrier potential and $P = Q(r_4) - Q(r_3)$. Here, according to our quantities, these quantities are as follows:

$$P = \sqrt{\frac{2\, m}{\hbar^2}}\int_{r_3}^{r_4}\sqrt{|U_b(r)|}\, dr = Q_b(r_4) - Q_b(r_3); [Q_b(r) = m_1\int\sqrt{|U_b(r)|}\, dr]; \; d = d_2$$

$$K = m_1\sqrt{|E_q|}; \; m_1 = \sqrt{2\, m}/\hbar$$

If $Q_b(r)$ is pair, $P = 0$. If $Q_b(r)$ is odd, $P = \text{Real}[Q_b(r_4) - Q_b(r_3)] = 0$. If $P = 0$, the following coefficient transmission is obtained as follows:

$$T = \frac{2}{1 + \cosh[2\, K(E)\, d_2(E)]}, \text{ and If } d_2 = 0, \text{ then } T = 1 \tag{11}$$

In zone (I), the energy provides the quantization condition $K(E_q)d_1(E_q) = q$. Energy in the (II) region is not quantified, but since the energy in the (I) region will pass through the (II) region, $K(E_q)d_2(E_q) = q$ equation is also provided in the (II) region. Thus, the coefficient of transmission obtained in the region (II) from (11) as follows:

$$T(q) = \frac{2}{1 + \cosh(2q)}; [q = 2\, and\, n\pi, (n = 1,2,3,...)] \tag{12}$$

We have for q=2the minimum (ground) state energy occurs; for $q = n\pi, (n = 1,2,3,..)$, for the exited state energies occur.

Calculation of the energy released in the earthquake

In the ground state q = 2. An earthquake occurs when the fault is excited states. $q = n\pi, (n = 1,2,..)$. The difference between the excited

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states and the ground state energy gives kinetic energy. So kinetic energy (Ke) is as follows:

$$E_q = \frac{q}{4}\hbar\omega(\alpha,\beta); E_2 = \frac{2}{4}\hbar\omega(\alpha,\beta); Ke = E_q - E_2 = \left(\frac{q}{4}-\frac{2}{4}\right)\hbar\omega(\alpha,\beta) = \frac{(q-2)}{4}\hbar\omega(\alpha,\beta)$$

$$Ke = E_k(q,\alpha,\beta) = \frac{(q-2)}{4}\hbar\omega(\alpha,\beta) - \frac{(q-2)}{4}\hbar\omega_0 w(\alpha,\beta)\,\mathrm{J}\,;[q = 2 \, and \, n\pi, (n = 1,2,3,..)] \quad (13)$$

If $q = 2$, $E_k = 0$, then an earthquake does not occur in ground state.. When $q > 2$ an earthquake occurs at excited states.

Calculation of earthquake intensity and magnitude

We define the earthquake intensity as follows:

$$\text{Intensity} = \frac{\text{Kinetic energy}}{\hbar\omega_0} = \frac{E_k(q,\alpha,\beta)}{\hbar\omega_0} = \frac{\frac{(q-2)}{4}\hbar\,\omega(\alpha,\beta)}{\hbar\,\omega_0} = \frac{(q-2)}{4}w(\alpha,\beta)$$

$$\text{Ins}(q,\alpha,\beta) = \frac{(q-2)}{4}w(\alpha,\beta);[q = 2 \; and \; n\pi, (n = 1,2,3,..)] \quad (14)$$

For $q = 2$, $E_k = 0$ then an earthquake does not occur. Therefore (14) should also be $q \geq 2$. Today, the Richter scale is used as intensity in the world. So it is more convenient to use Rm (Richter magnitude) as below to compare it to this familiar scale. It can be taken according to the Richter scale [Int(q,α,β) = I, II, III, IV, V, VI, VII, VIII, IX, X, XI, XII]. Thus, earthquake intensity as Richter magnitude is obtained as follows:

$$\text{Rm}(q,\alpha,\beta) = \text{Inq}(q)w(\alpha,\beta); \text{Inq}(q) = \frac{(q-2)}{4};[q = 2 \; and \; n\pi, (n = 1,2,3,..)] \quad (15)$$

If the seismic intensity found by seismographs is Rm (sis), the value of q is found by the solution of the equation Rm(q,α,β)=Rm(sis). So q is obtained by solving the equation $\text{Inq}(q) = \frac{\text{Rm(sis)}}{w(\alpha,\beta)}$.

Calculation of the focus depth (Earthquake focus depth)

In $U_0 = U(r_0) - V_0$, $-V_0$ gives the depth (as energy) of the earthquake relative to the surface of the earth. When calculating energy, the start of the coordinate was taken as $-U_0 = -2\sqrt{a\,b} + V_0 = 0$. From here, $V_0 = 2\sqrt{a\,b}$ is found. If $a = \frac{1}{2}m\omega^2$ and $b = \frac{\hbar^2}{2\,m}$ values are replaced, V_0 is obtained as $V_0 - \hbar\omega(\alpha,\beta)$. This V_0 is energy dimension. The depth is usually measured by length or dimensionless. Therefore, it is necessary to calculate this in length or dimensionless. If $1/\lambda$ is the number of waves (λ is wavelength), it is $\lambda/\omega = 1$ and can be written $\lambda = \omega(\alpha,\beta)$. Thus, the following formula is obtained as the depth of the earthquake:

$$\text{Focus depth} = Fd(\alpha,\beta) = \omega(\alpha,\beta) = \omega_0 w(\alpha,\beta) \quad (16)$$

(16) focal depth is dimensionless. This depth can also be calculated as the length dimension as follows: The equatorial radius of the earth is $R_0 = 6378$ km. At point O, the radius of the earth is $R = R_0 cos\,(\beta)$. The focus depth is proportional to the radius of the earth. Utilizing this proportional situation, the depth of focus is found as follows:

$$\text{Focus depth} = Fd\,km(\alpha,\beta) = \frac{Fd(\alpha,\beta)10^5}{6378\;\cos(\beta)}\,km \quad (17)$$

Focal depth in length dimension can also be calculated as follows:

$$V_0 = \hbar\omega(\alpha,\beta) = \hbar 2\pi f = \hbar 2\pi c/\lambda \rightarrow \lambda = \omega(\alpha,\beta) = \frac{2\pi c}{\omega(\alpha,\beta)} \rightarrow \omega(\alpha,\beta) = \sqrt{2\pi c}\,.$$

Here c is the speed of light in space and its value is $c = 2.99792458 \times 10^8$ m/s $= 2.99792458 \times 10^5$ km/s. If the value of cis replaced, the depth value of the earthquake will be obtained in length as follows:

$$\text{Focus depth} = Fd\,km(\alpha,\beta) = \frac{1372.46}{Fd(\alpha,\beta)}\,km \quad (18)$$

The formulas (17) and (18) give slightly different results. The reason for this is that the earth is not a full sphere, so the radius is not the same everywhere. As seen in Figure 1, a cone with a height h=Fd is formed at the center O point (epicenter). An earthquake with an epicenter of point O, all observers inside the bottom circle of this cone will feel the earthquake. An earthquake is felt in the area within a circle with $2\pi r$ r around. When Fd is large, the bottom circle of the cone is also large. So it is felt in a very wide area. From Figure 2, r is obtained as follows: At the point O, $r = d/2$. From here,

$$r(\alpha,\beta) = Fd(\alpha,\beta)wd(\alpha,\beta); [wd(\alpha,\beta) = \cos(\alpha)\cos(\beta) = \sin(\alpha)\sin(\beta) \quad (19)$$

It is seen from (19) that; in the equator $\alpha=\pi/2, \beta=0$, $wd(\alpha,\beta) = 0$, $r = 0$, and in the poles too $\alpha = 0$, $\beta = \pi/2$, $wd(\alpha,\beta) = 0$, $r = 0$. So there is no earthquake in the equator and poles. Indeed, when earthquakes in the past are investigated, it is seen that there are no earthquakes at the equator and poles.[5,6]

Calculation of the half-life and the average life of the earthquake

The earthquake event can be compared to a radioactive atomic nucleus. If a nucleus is radioactive, the half-life of the particle (here fault, that is energy) coming out of the atomic nucleus is given according to the formula $t_{1/2} = \frac{0.693}{f\,T(q)}$. Here f is the frequency of the particle emitted by the atomic nucleus to find itself in front of the potential barrier, and T is the probability of passing the barrier. P article is not emitted here, energy is emitted, that is, earthquake energy is released instead of particle. Therefore, the particle emission half-life can be taken as the earthquake half-life. Thus, the half-life of the earthquake would be as follows:

$$t_{1/2} = \frac{0.693}{fT(q)} = \frac{0.693}{\omega/(2\pi)T(q)} = \frac{0.693 \times 2\pi}{\omega(\alpha,\beta)T(q)}s = \frac{0.693 \times 2\pi}{\omega_0 w(\alpha,\beta)T(q)}s = \frac{59711.7}{w(\alpha,\beta)T(q)}s$$

This half-life can also be achieved with the help of kinetic energy as follows:

$$K_e = E_k(q,\alpha,\beta) = \frac{(q-2)}{4}\hbar\omega(\alpha,\beta) \rightarrow \omega(\alpha,\beta) = \frac{4Ke}{\hbar(q-2)}$$

$$t_{1/2} = \frac{0.693}{fT(q)} = \frac{0.693 \times 2 \times \pi}{\omega(\alpha,\beta)T(q)} = \frac{7.1651 \times (q-2)}{Ke \times (q)}s = \frac{59711.7}{T(q)w(\alpha,\beta)}s$$

$$T(q) = \frac{2}{1+\cosh[2\,q]}; t_{1/2}(q,Ke) = \frac{7.1651 \times (q-2)}{Ke \times T(q)}s, [s \text{ second}, q = n\pi, (n = 1,2,3,...)] \quad (20)$$

Here, Ke should be taken as MeV and T(q) is the transmission coefficient given by (12). $t_{1/2} = 0$ for $q = 2$.

There will never be an earthquake.

The decay constant is given as $\lambda_c = fT(q)$. Thus the average life τ is found as follows:

$$\tau(q) = \frac{1}{\lambda_c} = \frac{1}{fT(q)} = \frac{2\pi}{\omega(\alpha,\beta)T(q)} = \frac{2\pi}{\omega_0 T(q)w(\alpha,\beta)} = \frac{86164}{T(q)w(\alpha,\beta)}s \quad (21)$$

This quantity shows how long the earthquake will last. As seen from (21), the average life is second.

Estimation of the time of the earthquake

No earthquake occurs when the fault remains in the ground states. The half-life indicates when an earthquake will occur after an earthquake occurs somewhere. Earthquake occurs in excited energy states, that is, if there is greater kinetic energy than the ground state energy, an earthquake occurs. There is a possibility of an earthquake in all of the excited states, but it cannot always pass the obstacle because energy is quantum. An earthquake occurs when the energy barrier passes. In other words, when an earthquake occurs, it passes the barrier. This time is equal to the half-life of the earthquake. Kinetic energy (13) , earthquake intensity (14) , Richter magnitude (15) and half-life (20) are given respectively. All of them depend on the number q, and in all they must be the same number q . How to find q in Richter magnitude expression is given. Accordingly, the half-life should be as follows:

$$\mathrm{T}(q)=\frac{2}{1+\cosh[2\,q]};\ \mathrm{t}_{1/2}(q,Ke)=\frac{7.1651\times(q-2)}{Ke\times T(q)}s,\ [s\ \text{second},\ q=n\pi,(n=1,2,3,...)] \quad (20)$$

$$\mathrm{Rm}(q,\alpha,\beta)=\mathrm{Inq}(q)\,w(\alpha,\beta);\ \mathrm{Inq}(q)=\frac{(q-2)}{4};[q=2\ \ and\ \ n\pi,\ \ n=1,2,3,..)] \quad (15)$$

If the seismic intensity found by seismographs is $\mathrm{Rm}(\mathrm{sis})$, the value of q is found by the solution of the equation $\mathrm{Rm}(q,\alpha,\beta)-\mathrm{Rm}(\mathrm{sis})$. So q is obtained by solving the equation $\mathrm{Inq}(q)=\frac{\mathrm{Rm}(\mathrm{sis})}{w(\alpha,\beta)}$. From here $q=\frac{2[2\mathrm{Rm}(\mathrm{sis})+w(\alpha,\beta)]}{w(\alpha,\beta)}$. Thus, the probability of an earthquake with the same intensity somewhere is obtained as follows:

$$\mathrm{t}_{1/2}(q,\alpha,\beta)=\frac{59711.7}{T(q)\,w(\alpha,\beta)}s;q=\frac{2[2\mathrm{Rm}(\mathrm{sis})+w(\alpha,\beta)]}{w(\alpha,\beta)};w(\alpha,\beta)=\sqrt{\cos^2(\alpha)+\cos^2(\beta)]} \quad (22)$$

Here Rm(sis) is the intensity to be measured by the seismograph. If the expected intensity Rm(sis) is taken, the time and depth of the earthquake can be estimated before the earthquake occurs. In general, time is measured even in minutes, hours, days, months and years. When using, these seconds can be converted to desired units. This conversion is done as in Table 1.

Calculation of the Rm, Fd and t1/2 of some Earthquake and Comparison

Some earthquake data calculated by formulas (15), (16) and (22) given by earthquake observation agencies[6] are shown in Table 2.

As can be seen from the Table 2, the data given by the agencies and our calculation do not exactly match. We think our accounts are more accurate. Because our calculations are calculated directly from the theory. The values given by the agencies are calculated with the formulas obtained with some statistical models. Considering the location of earthquakes, the data are expected to be close to each other. However, their data is very different. It is seen that our accounts are more compatible.

Table 1 Half-life conversion table

Times	t1/2 years	t1/2 days	t1/2 hours	t1/2 minutes	t1/2 seconds
Td	3.14723x10^7 s	86164 s	3600 s	60 s	1 s
$\frac{t1/2(q,\alpha,\beta)}{Td}$	$\frac{0.00189728\ y}{T(q)w(\alpha,\beta)}$	$\frac{0.69001\ \text{d}}{T(q)w(\alpha,\beta)}$	$\frac{16.5866\ h}{T(q)w(\alpha,\beta)}$	$\frac{995.195\ \text{m}}{T(q)w(\alpha,\beta)}$	$\frac{59711.7\ \text{s}}{T(q)w(\alpha,\beta)}$

Table 2 Some earthquake data calculated by formulas (15) and (16) and given by earthquake observation agencies

Date	Latitude	Longitude	Depth Calculated (Measured)	Magnitude Calculated (Measured)	Half-life (Year)	Country Province
17.06.2020	37.5228	38.6763	8.11532 (4.02)	4.1 (4.1)	1.46787×10^{11}	Turkey Şanlıurfa
16.06.2020	39.3508	40.6721	7.89852 (7.02)	4.3 (4.3)	1.48357×10^{12}	Turkey Bingöl
15.06.2020	39.3678	40.7435	7.89339 (7.01)	5.6 (5.6)	2.25508×10^{16}	Turkey Bingöl
14.06.2020	39.3668	40.7488	7.89314 (9.28)	4.7 (4.7)	2.91692×10^{13}	Turkey Bingöl
14.06.2020	39.3621	40.7390	7.89398 (7.32)	4.6 (4.6)	1.38780×10^{13}	Turkey Bingöl
14.06.2020	39.3650	40.7140	7.89527 (8.00)	5.7 (5.7)	4.67393×10^{16}	Turkey Bingöl
26.06.2020	38.7676	27.8018	8.59850 (9.29)	5.5 (5.5)	3.52681×10^{14}	Turkey Manisa
25.06.2020	38.4720	44.0285	7.75138 (7.48)	5.4 (5.4)	1.08803×10^{16}	Turkey Van
05.06.2020	38.2576	38.7455	8.07061 (6.98)	5.0 (5.0)	1.16225×10^{14}	Turkey Malatya
03.06.2020	33.2213	25.0406	8.99240 (8.26)	5.1 (5.1)	4.91026×10^{12}	Turkey Mediterra.
28.06.2020	36.6563	28.2336	8.68895 (63.72)	5.2 (5.2)	3.15794×10^{13}	Turkey Muğla
17.08.1999	40.7000	29.9100	8.39749 (15.9)	7.4 (7.4)	4.76346×10^{20}	Turkey İzmit
11.12.1999	40.7900	31.2100	8.32940 (11.0)	7.2 (7.2)	1.80148×10^{20}	Turkey Bolu

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Conclusion

In previous studies, a simple procedure for the general solution of the radial Schrödinger equation has been found for spherical symmetric potentials without making any approximation. In this article, using this method, a new earthquake model was proposed. In this proposed new earthquake model; magnitude of the earthquake, its energy that may be released, the depth of the earthquake from the earth, and in which regions the probability of an earthquake may occur on earth can be predicted in advance. It is very important to know in advance the probability of an earthquake because they can take measures and precautions to minimize damage from this earthquake. This will enable people to take precautions in advance. Half-lives and average lives of expected earthquakes in places where earthquakes are likely to occur on the earth can be calculated. It is thought that the time of occurrence of consecutive earthquakes in the same places can also be calculated. However, these accounts continue. If it can be calculated, it can be published separately. Earthquake parameters actually used were calculated here. If other parameters are desired or required, they can be calculated in similar ways. Isotropic harmonic oscillator potential is taken here. By taking the non-isotropic (deformed) oscillator potential, similar calculations can be made and this model can be expanded as needed. In addition, it seems that the laws of quantum mechanics, which are valid in the microscopic universe, may also be valid in the macroscopic universe.

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Conflicts of interests

Author declares that there is no conflicts on interests.

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