Gravitational Fields

Gravity is the fundamental attractive force that exists between objects because they have mass. A more common name for the force of gravity is **weight**.

Unlike a push or a pull, gravity is able to act at a distance. For example, any object that is anywhere near the earth will be attracted by Earth's gravity. Because of this, we say that Earth is surrounded by a **gravitational field**.

Gravitational Field – the region surrounding a mass in which any other mass will experience a force of attraction due to gravity.

The strength of a gravitational field is defined as the amount of gravitational force the field exerts on an object per kilogram of the object's mass. Mathematically, this can be determined using:

$$F_g = mg$$

$$\boxed{g = \frac{F_g}{m}}$$

Thus, the value of g can be described as the strength of the gravitational field. In the past, we have referred to g as the acceleration due to gravity, but it can also be referred to as the **gravitational field strength**.

The units of g depend on what it is describing. When g is being used to represent the acceleration due to gravity, the units are m/s^2. However, when g is being used to represent the gravitational field strength, the units are N/kg.

The gravitational field strength is fairly constant at the surface of the earth. For that reason, we will always use a value of $g = 9.8\ N/kg$ when discussing problems on Earth. The value of g is known as the **gravitational field constant**.

Although we will use $g = 9.8\ N/kg$, the actual value varies slightly depending on your latitude and altitude.

At sea level at the equator, for example, $g = 9.7805\ N/kg$. As you travel north or south from the equator, the value of g increases. At sea level at the North Pole, $g = 9.8322\ N/kg$.

For the same altitude, as latitude increase the gravitational field increases.

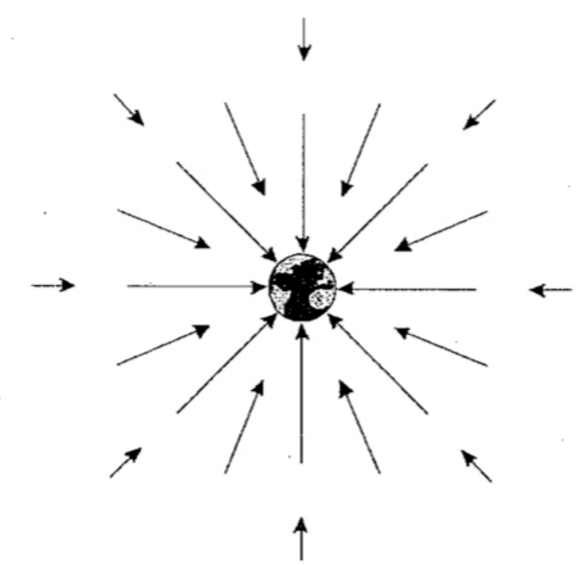
In Toronto (altitude $162\ m$, latitude $44°$) the value of g is $9.8049\ N/kg$, while on Mount Everest (altitude $8848\ m$, latitude $28°$) the value of g is $9.7647\ N/kg$, and at the Dead Sea (altitude $-397\ m$, latitude $32°$) the value of g is $9.7962\ N/kg$. All three locations have fairly similar latitudes, but different altitudes.

For the same latitude, as altitude increases the gravitational field decreases.

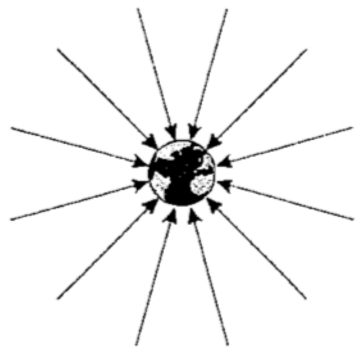
Picturing Earth's Gravitational Field

We know that the gravitational field near Earth's surface is about $9.8\ m/s^2$ and that it gets weaker as you move farther away from Earth. One way to show this would be to put number values for g around a picture of Earth.

We can also represent the gravitational field as a collection of vectors surrounding Earth and pointing in the direction of the gravitational field (towards the center of Earth). In this case, the longer the vector, the stronger the gravitational field.



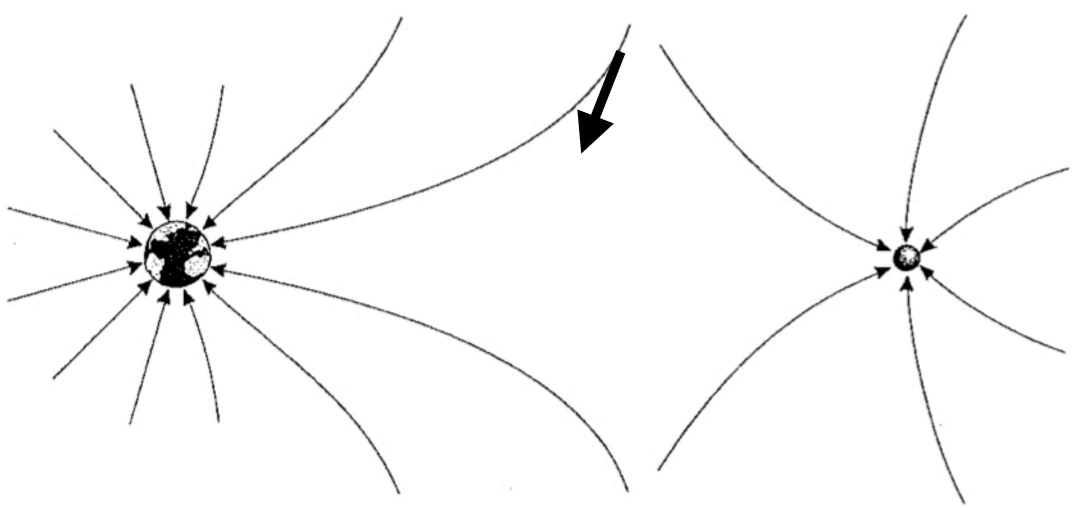
A third way to visualize the gravitational field (as well as other types of fields), and the method that we prefer, is to use a **field line diagram**.



The direction of the field lines shows the direction of the field at various points. In the case of Earth's gravitational field, the field lines all point towards the center of the Earth.

The spacing of the field lines suggests the relative strength of the field. Where the field lines are closer together, the field is stronger. Where the field lines are farther apart, the field is weaker.

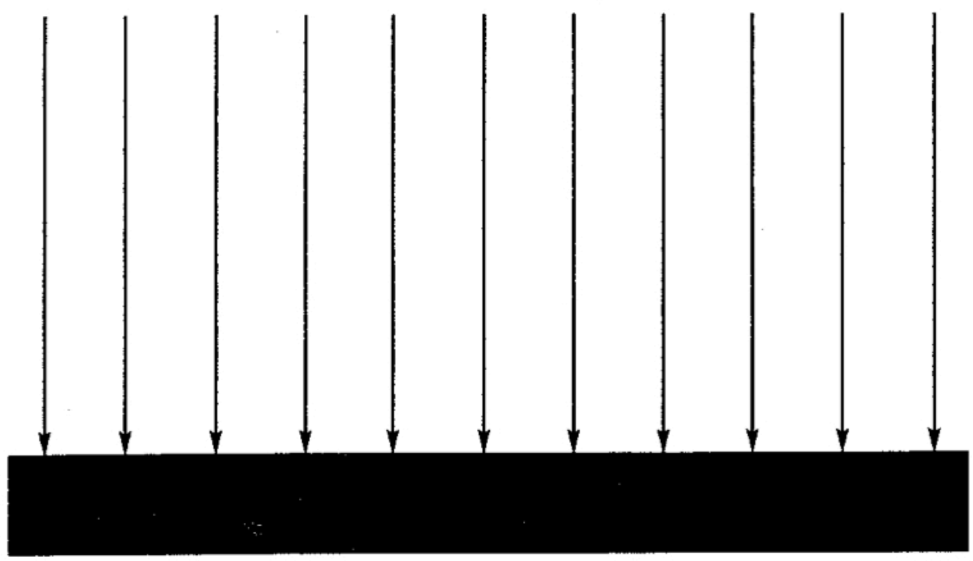
For Earth's gravitational field, the field lines are straight. This makes it very easy to see their direction at any point. The direction is not as obvious when there are curved field lines. In any case where the field lines are curved, the direction of the field is understood to be tangent to the field lines at any given point.



Gravitational Field at Earth's Surface

At Earth's surface, we consider the gravitational field to be constant at $9.8\ N/kg\ [down]$. Over a small distance, the surface of Earth can be considered flat. Thus, the field lines will be perpendicular to the surface of Earth. In addition, a constant field is indicated by spacing the field lines equally. Thus, a diagram of the gravitational field at Earth's surface could be represented as shown below.

Gravitational Field at the Surface of the Earth



Gravitational Fields Worksheet

1. A vehicle is being designed to explore the moon's surface and is being tested on Earth, where it weighs roughly six times more than it will on the moon. In one test, the acceleration of the vehicle is measured. To achieve the same acceleration on the moon, will the net force acting on the vehicle need to be greater than, less than, or the same as that required on Earth?

2. The gravitational field constant on the surface of Pluto is $0.31\ N/kg$. What would the gravitational force be on a person of mass $50\ kg$ on Pluto? $(15.5\ N)$

3. A space traveler whose mass is $115\ kg$ leaves Earth. What are his weight and mass
   a) on Earth? $(1127\ N)$
   b) in interplanetary space where there are no nearby planetary objects? (0)

4. Describe two methods by which the gravitational field intensity can be measured here at the surface of the earth.

5. What are two factors that affect the gravitational field intensity at the surface of the earth? How does each factor affect the value of the gravitational field intensity?

6. Distinguish between the terms: gravitational field, and gravitational field intensity.

7. State two facts about the gravitational field that are given by a diagram of gravitational field lines.