Wind and sand

Borhan Albiss & Khalaf Abdel Azez

Department of Physical Sciences - Jordan University of Science and Technology

In the name of God

I am Dr Khalaf Abdel Azez from (JUST) Department of Physical Sciences. I will present this topic about wind and sand, which I prepared with of my colleague Dr. Borhan Al-Biss.

The goal of this study is to relate physics principles to natural phenomena while simultaneously incorporating the context of global and environmental issues.

This blossom module aims at informing high school students of physics applications far beyond pure theoretical physics principles which are related to school taught mechanics.

Students will apply their knowledge about Newton's laws, and the basics of fluid dynamics in order to understand some natural phenomena such as erosion, desertification, and sand dunes.

This module has been designed. It is a wooden box with the side walls made of glass, a hair drier with different speeds. The amount of sand within the box can be controlled by a wooden shaft.

If we use both hands to hold a handful of sand then let the sand fell freely through our fingers. Have you ever thought how deserts form?

To answer these questions we must be equipped with the basic laws and principles of physics

Segment 1: Introduction

Our image of the Mediterranean climate is always related to the sea breezes, which remind us with the beautiful summer days. But this is only imaginary. In reality, the climate of the Mediterranean is not of such beauty.

During the transition time, speedy, dry, and dusty wind blows through the grand desert in Egypt, Jordan, and proceeds to the east till the Kingdom of Saudi Arabia, causing sand storms that make the climate dark and the weather becomes annoying. The stormy wind might continue for days causing diseases for human, plants and animals.

If we caught an apple with one hand and a handful of sand with the other, and let the apple fell freely. This should remind us with Newton's theory, and his three laws of physics.

Newton's first law: The object sustains its state of motion (whether motionless or in uniform motion) unless an external force affects it and changes its state of motion.

$F_{ext} = 0$

Newton's second law: an object under the influence of a net force experiences acceleration that is directly proportional to the net force acting upon it, and inversely proportional to its mass.

$F_{ext} = ma$

Newton's third law: For every action there is an equal and opposite reaction.

$F_{12} = F_{21}$

Pressure: pressure is the force applied over an area. Air pressure can be thought of as the weight of the air above a certain level.

I wil leave you for a while and come back

Segment 2: Wind dynamics

I believe that you know, now what do we call this type of wind. We call it "Khamasin", the name is derived from the Arabic word "khamsin", meaning fifty. It was believed then that this wind would blow for periods that would extend to

fifty days a year. To be aware of the source of this wind (and wind in general) the student must know some basic laws and principles of physics.

When we try to control things around us, for instance; picking a book, throwing a ball, or shutting a door, we apply force upon these objects causing them to move. Wind then, is air at motion that is pushed by various forces. Stormy, destructive wind is the result of the complicated interaction of various forces. The gentle summer breezes are the result of the complicated interaction of various forces as well!

Now look, sand is falling! It falls out of my hand. But its speed is going to be less than that of an apple. That's due to friction with the air. These laws help us understand the motion of sand. What are the forces affecting it? And how are they related to the motion of sand and wind?

There are many forces moving air. Air weight is a force that pushes downwards towards the centre of earth. There is also Coriolis force, the pressure gradient force, and the force of friction. All of these forces play their roles in the motion of wind.

1. Coriolis force
2. Pressure gradient force (PGF):
3. Friction Force

Newton's laws of motion are defined according to definite stationary frames of reference. Earth is in continuous motion, and its motion must be taken into consideration. The force that results of this motion is named the Coriolis force. This force is directly proportional to the speed of wind. If the speed of wind is zero, for instance, then there is no relative motion, thus the Coriolis force is zero as well.

Coriolis force increases directly with the increase of the speed of wind. Coriolis force controls the direction of the wind only, but it never causes wind to blow. Coriolis force is dependent of the position at which it is measured; its value is zero at the equator, and reaches its maximum at the poles.

Pressure gradient force (PGF):

When pressure changes rapidly within a small distance, the pressure gradient force becomes large. As a result the force acting upon the wind increases.

Pressure gradient force is always directed from high pressure towards low pressure.

PGF = change in pressure/ distance

When pressure changes rapidly within a small distance, the pressure gradient force becomes large, hence, speedy wind results from large pressure gradient force. It follows that the relation between the pressure gradient force and wind speed is a positive linear relationship. Air moves under the influence of such pressure. When a rapid pressure change takes place over a small area the pressure gradient force becomes large.

(figure)

Force of friction:

Force opposes wind. Hence it decelerates wind. As a result, it limits Coriolis force. Friction reaches a maximum at the atmospheric boundary layer, the air layer nearest to the ground. Frictional force is dependent upon the roughness of the surface, and the speed of the wind. Hence, frictional force is small over still water, or ice ponds. Trees in forests strongly oppose wind, so the frictional force of forests is large. While the wind may be blusterous over an ice pond, it will be calmer in the woods. Friction near the surface not only slows the wind, it also mixes the air.

The following diagram illustrates the path of the wind when only the pressure gradient and Coriolis forces are taken into consideration. Then it shows its path when friction is taken into consideration. Notice that friction causes wind to cross over isobars (lines representing equal pressure) whereas with no friction air would be always parallel to isobars. The diagram to the right illustrates the path of wind under the influence of the combination of these forces.

(diagram)

Activity:

What happens when one region of air is warmer than another?

Is the Coriolis force a real force?

Do you know any other force similar to the Coriolis force?

Do you know how wind storms are created?

What are the main forces involved in storms motion?

How can we predict the path of wind?

Segment 3:

Wind erosion:

We are talking about erosion here, which is an important issue. Erosion means that soil loses its fertility because its contents are fragmentized and wearied away, then the land becomes poor and its ability to produce crops decrease.

Erosion is a natural process in which soil and rocks are wearied away of earth's surface in a certain region, and moved to another region. Erosion reforms earth's surface and changes its land marks; it lowers down mountains by cutting them into pieces, and buries valleys, and makes rivers appear or disappear.

How does erosion occur?

Various environmental factors chip mountains and soil into tiny fragments that can be freed from the face of earth. The formation of frost is one of the causes of this process. When water in the cracks of rocks freezes it expands to a larger size, so it becomes capable of fragmentizing rocks into pieces. Some of the other causes of erosion are: Chemical factors, living organisms, motion of air, ice, or

water, and heat emitted by sun. The eroded material are released, and then transferred to other regions.

Disadvantages of erosion:

Erosion deprives agricultural land of the fertile surface soil. That's why it is considered one of the dangers threatening the sources of nutrition. Erosion can drain fertilizers from agricultural land, and transfer chemicals causing pollution in lakes and rivers.

Controlling erosion:

The major variables are: 1- amount of sand 2- speed of wind 3-mass of sand particles 4- Inclination of land in addition to 5- extent of plant cover.

Notice that the faster the wind moves the more energy it contains, therefore it becomes more powerful in moving sand particles. Larger sand particles require more energy to be moved. Erosion rate decreases with the increase of plant cover. The more the direction of wind parallelizes the incline of land, the more the erosion rate increases.

Plant roots as well as plant left over's keep the soil together, hence, farmers protect soil of being eroded by keeping ex-plantation such as grass in the fields.

Although erosion is a natural process people can cause its increase. As an example erosion rates might increase when land is cleaned and ploughed, because some trees and plants protect the soil from the effects of wind and rain.

Wind has a harmful effect on land crops and humans as well. Erosion caused by wind is considered one of the most natural factors causing the wearing away of earth surface (rocks, soil, sand).

The movement of sand grains can be categorized into three different kinds:

Saltation: when under strong winds, sand particles are pushed towards each other causing them to collide. As a result, some particles are projected in the air. These particles are accelerated by wind. Eventually, they collide with other sand particles, continuing the cycle.

Suspension: this is the result of the collision of large sand particles and the projection of small particles which remain suspended in air, and are carried to high altitudes

Creep: slow wind is not capable of carrying sand particles, due to their mass, so it rolls sand particles horizontally.

Agricultural remains should be left in the fields to keep the soil fixed. Dry roots of the remains of the plants in the field limit the erosion of soil. As can be seen in the photo, sand have hyped behind and around dry plants.

According to the photo taken in the Rum valley, the speed of wind can erode light sand particles, to leave rocks and stones exposed.

It is possible to decrease the speed of wind by:

- Building windbreaks and fences.
- Maintaining plant cover and keeping plant remains.
- Making blocks of constructions and supporting them with proper services
- Contouring land.

Now we will observe the process of erosion using a simple inexpensive sandbox, in addition to a hair drier to blow air. Then we will apply what we have previously learned about forces to explain our observations.

Now we will demonstrate wind erosion using the sand box model. In this model we will use sand grains of different sizes as shown. The walls of the box should be made of glass so that we can see and record what's happening inside from various sides. Several variables were controlled to visualize the effect of wind speed and direction on the erosion rate and sand motion. In addition, it is also possible to change the slope of the sand level to see its effect on the rate of erosion and sand motion. In conclusion, humans represent the biggest main parameter (whether positive or negative) affecting erosion.

The following diagram demonstrates the kinds of sand motion described earlier.

(diagram)

Activity:

What is the force causing erosion?

Where does the eroded soil go?

How can we decrease the rate of erosion?

What are human activities that might increase the rate of erosion?

Segment 4: Desertification:

The phenomenon of desertification is one of the important problems in the region. It has effective disadvantages on our lives. This problem became apparent in the last two decades. Its effect on all social, economic, and environmental aspects cannot be missed. It threatens large areas and huge numbers of populations with famine and homelessness.

Back to the reasons of desertification; we find that they can be categorized into factors related to climate and factors related to humans:

1. Factors related to climate such as the lack of rain, sand storms, years of dryness, soil erosion due to running water, global warming, pollution, and the decrease in the ozone layer.
2. Factors related to humans are exploitation of fertile land by cultivation, excessive shepherding, cutting down woods and trees, wood fires, unwise use of water resource, and bad irrigation methods.

The photos of the Jordanian desert show the effect of desert plantation, and how it limits the movement of sand and the problem of desertification as well.

To present desertification we will use an enhanced model of the sand box. We will plant some plants in the sand, then we will repeat the steps of the previous experiment using the same amount of sand. What change do you expect to

happen to the rate of erosion if the speed of the wind is much larger than that of the previous experiment? Will the plants affect the rate of erosion? How will the plants affect the rate of erosion?

We see that humans, at the end, are the most effective factor, whether positive or negative, on desertification. We must assert that cooperative methods of fighting desertification must start from base to top.

There are certain issues that I wonder about and I'd like to ask you about:

1. The loss or low income of some croplands either artificially irrigated or those irrigated by rain water.
2. The decrease of plant cover in some shepherd regions, and the lack of food for flocks.
3. Disappearance of woods due to the use of wood as a source of energy.
4. The lack of drowned water and surface water in addition to the increase of the evaporation process
5. The creep of sand that might cover agricultural land.
6. Causing unsustainable economic and political conditions in regions affected by desertification, and the increase of conflicts on resources and water, in addition to the increase of migration rates to other regions.
7. The loss of biological variety especially in regions that are considered to be the home place for the main crops in the world such as wheat and corn.

Compare that with what you have observed in the previous experiment when there was no plant cover.

(photos)

Segment 5: Sand dunes

Sand dunes form due to the factors of erosion. It is the interaction of desert rocks with the heat and the continuous blowing of wind which results in the fragmentation of rocks into sand grains of various sizes and shapes.

The stages of forming sand dunes resemble the stages of erosion which we have studied earlier. Wind moves the sand randomly until their movement becomes saltation and creep and a stable state of the sand movement is reached.

Sand dunes are classified according to their shapes as: Transverse, longitudinal, linear, parabolic, star, crescent, reversing and dome dunes.

Here are some photos of the desert in the Rum valley, where the dunes are observed to have the shape of waves. They have hyped above those dry roots, while some of them are shaped as pyramids.

We will use the model of the sand box to form some types of popular sand dunes. Here we have prepared some wood pieces to represent obstacles such as trees, as a result transverse dunes will shape like waves and they will be perpendicular to the direction of wind.

Those beautiful photos show us that these huge dunes can be of altitudes up to 150m approximately, and of a width of almost 200m. These dunes are isolated between two sequences of rocks which work as a trap of sand. We also observe the role of the thorny trees that stopped the movement of the creeping sand.

Sand dunes cover vast regions of the world. They are a great threat for the north of Africa because they are common around cities, villages, roads, farms, water resources and grazing land.

Most Arab countries face serious problems caused by the creep of sand dunes which are considered to be the final stages of desertification. The movement of sand dunes threatens agricultural and natural grazing lands, as well as economic and social constructions in the Arab world.

Here, we should mention some old cities that were buried under sand; for example the city of “Guaba” the capital of “Hessa” at the period of the prophet Mohammed peace upon him. “Iram” also was buried under sand due to the extraordinary sand storm that was their punishment.

In conclusion, this is a photo of the “Rum” valley, which demonstrate how could Jordanians live aptly with their environment and settle in their place, which aided

stability. As a result our goal of decreasing migration of population towards cities is scored.

Habitants of dry deserts exert huge efforts to stop the creep of sand dunes by planting palm trees in them or any other plants capable of holding the dune together. This takes place in the deserts of Mauretania and the Kingdom of Saudi Arabia.

These efforts are cooperative groups efforts, rather than individual efforts. They begin at the base and then go up to the top. Institutes and governments should support the habitants to settle down, because migration to cities confronts us with social, political, and environmental problems.

There are certain issues that we wonder about:

What is your role in preserving the environment, and what is your role in the social life to help habitants settle down in their regions. Further, what is your role in aiding the remarkable variety of life especially in the “Rum” valley, Petra, and Azraq oasis?

(photos)

Demonstrate for the students how do sand dunes form, and how to limit the phenomenon of desertification …

(photos)

It is difficult to understand natural phenomena just by looking at them. That’s why it is important to take into consideration the physical factors and the variables that control them. Can we understand, predict, and totally control the phenomena of desertification and erosion? How can we employ physics, math, and computer simulations to understand these phenomena? And to aid us in solving these problems.

Teacher‘s guide

Dear teachers, in this topic which is very important topic, I would like to give you some hints that you can use to implement this module and experiment to ensure the student's benefits.

To be able to apply this experiment you need the following things:

- A rectangular glass box (120cm× 88cm× 20cm)
- Hair dryer with three speeds to use as wind source
- Sand from the desert or from K.G. playgrounds (any substitute)
- Small plants with wide leaves
- Pieces of wood with different shapes
- Data show and a computer with PowerPoint software

In the first segment we talked about wind, and the Newton's laws . So if the students are aware of these basic physics concepts they will certainly be able to achieve the goals. It is better to divide the class into groups and ask them the questions and discuses with them the terms erosion, desertification and sand dunes.

Your role here is essential since you can motive the students to and once you managed to transfer the student knowledge for the theoretical side to the applications then you have achieved a great job.

Here we talked about wind and sand, there is a very special technique that students may not be able to accomplish easily, so you need to be patient and let them try more than once and give them time to repeat the trails again and again. By the way dividing the class into small groups makes the groups more efficient and that all the students will be having a role rather than keeping some just watching what is happening without having a role themselves.

In our experiment we used sand m but you can use any other substance that has small particles similar to sand. Also you can use gravels to represent rocks and may be use natural plants to help student apply the experiment correctly.

There are many variables in this box, we have sand and we will try to make the students think about the sand curving , since this curving has a major role in sand movement and is accumulation a specific location.

In sand dunes , the star dunes e need a very complicated technique which need three hair dryers , these will work simultaneously but at different directions so we can see the sand moving in all three directions resulting in formation of star dunes .

By this we enclose our module, hope I have managed to give you some special information that can be useful for you and your students

Thank you.