Kite_Flying_-_Fun__Art_and_Science

[MUSIC PLAYING]

ARSHAD SALEEM BHATTI: [SPEAKING FOREIGN LANGUAGE] and a very good day. Welcome to another module of BLOSSOMS. I am Arshad Saleem Bhatti, a professor of physics working at the Concepts Institute of Information Technology.

Today's module is about kite flying. Kite flying has been wonderful sport. Particularly, it has fascinated me in my childhood. When I used to see a kite flying in the sky, I always used to wonder how it is possible to fly an object in the sky.

Kite flying since then has become a sport. It is a skill, an art, and it's a recreation activity not only for children, but for elders, as well. The history of kite flying goes back as long as 3,000 years, where it is believed that the kite was invited in China simply for the reason because silk was fabricated in China.

There are signs of kite flying in Far East countries like Malaysia and Indonesia. Since then, kite flying has become a recreational sport which has introduced kites of different shapes-- for example, box and diamond kite, square kite, and winged box kites. As you can see on your screen, a number of different shapes of kites are available.

Another dimension to kite flying has been given by these stunt kites where these kites have got more than one cord who maneuver the kites. You can see with this one, we can do synchronous kite flying where a number of kites flying, doing maneuvering with the kites in the skies. They can do it because they have much better control over kite flying.

I would like to share one historic event with you. When Benjamin Franklin, in Philadelphia in 1752, used the kite flying experience to prove his hypothesis of thunder electricity, he flew the kite on a very cloudy day into the cloud, and transferred the charge from clouds down to Earth to prove his hypothesis. This was the practical use of kite flying.

The flight of a kite is very much similar to flight of an airplane. The number of forces being exerted on a flight of a plane is almost the same as on the kite. You probably have seen the launch of a kite or the flight of a kite, and a plane taking off and then flying in air. You can very easily determine what are the forces which are being exerted on the plane, and also on the kite, if these are similar or dissimilar.

We can take a break here. You can discuss these forces with your teacher. And we come back, and then we will discuss more about the types of forces which are involved, the reasons for these forces which are acting on a kite and on a plane, which are similar. The only difference is the magnitude of these forces. Let's have a break and discuss these forces.

Welcome back. I'm sure you have rightly identified a number of forces acting on the two objects-- that is plane and the kite. Let's discuss the case of plane first.

Now the plane takes off, and gets to the maximum altitude. When it comes to the maximum altitude it can achieve, there are four forces which are involved. It's the weight, which is acting downward due to gravity. Then there's a force acting upward known as lift.

There's a force acting backward known as the drag. And then there's a force in the forward direction, which is known as thrust, produced by the engines. But these forces are acting on airplane when it is flying.

These similar forces are acting on the kite, as well. One thing which I have not mentioned, and you have noticed, is the angle of the launch. It is very important to start the flying.

The angle of launch is also known as the attack angle. That is the angle which the plane or the kite makes with blowing air so that it can feel the lift and the drag both. This is very important, and we will go through these later in this lecture.

Now flying of a kite can teach us some basic principles of aerodynamics. Now let's define aerodynamics. Aerodynamics is a sub-branch of fluid dynamics, and it deals with the dynamics of air when it interacts with solid objects.

Let's discuss the force exerted by one object on the other. In case both objects are solid, interaction takes place only at the point of contact of two objects. However, the situation is different if one object is solid and the other is liquid or gas-- air, for example, on the solid object is moving with certain velocity in the medium, or medium has a certain velocity. In this case, interaction will take place on all surfaces exposed to the medium.

The medium will exert force on the surface, and this pressure depends on the velocity of either medium. If it is moving or off the object if it is moving through the medium. We know that the fluid exerts a force on the object, which is submersed into that one. Let's think about an airplane wing or a kite when it is flying.

Air applies or exerts pressure on its strings. Can you determine the magnitudes of these pressures on the upper or the lower surfaces of a wing, how these air patterns would be? I would like you to discuss with your teacher. And we come back, and we will see how these patterns are the pressures on the wing, and how the difference of the pressure can result in a net force in the upward direction.

Welcome back. I'm sure you have discussed the air flow patterns around a wing with your teacher. And you might have guessed the right answer to the flow patterns being formed by air when a plane is flying in the air.

As you can see on your screen, we have two surfaces-- the upper surface and the lower surface. And the plane wing is designed in such a way that the lower surface feels the high pressure as compared to the upper surface, and the difference between the two pressures actually gives us the lift in the upward direction. And the shape of the frontal area of the wing actually results in the drag, which is in the opposite direction.

The sum of these two forces, which results in the aerodynamic force of the wing. Let's define these terms properly now. Lift is the force exerted by the fluid as a result of the difference in pressure-- the upper and lower pressures.

Drag force-- that resists the object motion in the fluid. Weight of the object acting at the center of gravity downward. Aerodynamics force is the resultant force of the lift and the drag force. And it is always is in the upward direction, and it is perpendicular to the plane of the object.

The drag force is given by a formula-- 1/2 of CD multiplied by the rho A and v squared, where the CD is the drag coefficient which depends on the shape of the object. And for radius shapes, it is determined experimentally in a wind tunnel where we know the Reynolds number, which gives us the type of the fluid motion. Either it's laminar or a turbulent flow.

Rho is the density of the medium. A is the frontal area which object is offering to the wind motion. And v is the velocity of either the wind or the fluid, or v is the velocity of the object moving in any medium. We can use this formula to determine the drag force.

On your screen, you can see the drag coefficient given for different shapes. It does depend on how much area being offered. The larger area being offered to the wind, the drag coefficient is high. The smaller is the area where the drag coefficient is small.

Before taking the break, I would like you to discuss with your teacher if you have ever experienced the drag force being exerted by air on you. If you wanted to move on a windy day, what happens if you move in the direction of the wind? And what happens if you move in the direction opposite to the wind blowing direction?

What happens if you run on a day where there's a light breeze going on? You can still feel the effect of drag. And we will discuss once we are back after the break.

Welcome back. As you have discussed, on a windy day, if we move in the direction of the wind, wind can help us move faster. But if we move in the opposite direction to the wind, we have to work really hard to move against the wind. And this is actually the drag force which is being exerted by air on our body.

If we are of a larger size, then this drag force will be larger, and we have to do a lot of effort to move in the direction opposite to the wind. Any of you who have flown, they might have seen on the airplanes, and sometimes the data is given about the head wind and the tail wind with which velocity it is moving. The head wind always opposes or offers a resistance to the plane's motion in the forward direction, while the tail wind actually helps the plane move in its original direction.

Now we have seen the forces being exerted on a kite or on any flying object, like airplane. Let's come back to the point of discussion. Can we measure the aerodynamic force which is the resultant of lift and drag due to the velocity of wind?

How we can measure the force? Very simple. I can measure the force using a spring. And you have done this in your high school. You can use spring to measure the weight.

I have spring balance with me, which is a calibrated spring balance, and I can measure the rates of the forces being exerted in order to extend this spring. Let's do a simple experiment. I've got a book here placed on the table.

And I use this spring balance to find out how much force will this book require to move. If you look carefully, as I pull this, the spring is being extended before the book starts moving. And then book starts moving, but the spring goes a little bit back.

With this spring balance, I can determine how much force I applied on the book, which was static before motion and then started moving, and how much force I still need to keep that book moving. From this experiment, I can measure the frictional force, which is the result of the two interfaces-- the forces existing at the interface of the book and the table.

Can you identify why these two-- the numbers were different? In the first case, when book just started moving, the force was small as compared to the force which I needed to move this book. Now why these two numbers are different, first in the case when the book was stationary, and second when it was moving?

I would like you to discuss with your teacher. This is a case of two different frictions involved-- one in the static, and one in the moving or in the dynamic state. Now before we take the break, I would like you to do another exercise. And please take any spring, and you can determine the spring constant.

We know from the Hooke's law extension in the spring is directly proportional to the force being applied on the spring. In our case, it's the weight. I would allow you to do one experiment.

I have made a homemade experiment where I have a scale which can measure the extension in the spring. I can put weights to this spring, and I can measure the extension in the spring. I would like you to plot a graph between the extension of the spring and the weight attached to it.

And then you will see that it will be a straight line. From the slope of the straight line, you can determine the spring constant. Let's do this exercise. And we come back, and discuss more about this.

Welcome back. In the last segment, you were supposed to discuss two things with your teacher. First was the motion of the book, why it needed more force to move. And once it goes in the motion, why it needed less a force.

That is a perfect case of two different frictions. One is the static friction, which is what we would do to-- it's the state to of rest, the force needed to change its inertia from rest to the motion. We can split friction in two parts. One is the static friction, and the other one is the kinetic friction, which was smaller than the static friction. The static friction is always higher than kinetic friction.

In the second assignment, you verified the Hooke's law for a spring where you plotted the weight as a function of extension. And you got straight line. And from the slope of the straight line, you found spring constant of the spring.

Now this spring constant can be different if you have different diameters of the spring. You can do this experiment, but it remains the same for the same spring. It changes if the diameter of the material of the spring changes.

Now coming to the next point, next topic, which is the coplanar forces. I have one diagram showing you in which having log is being lifted by a crane where it uses two strings, which is attached to the ends of the heavy log, and being lifted by the third one. Now there are three forces in terms of tensions involved-- tension one in the one string, tension two in the two, and three three is the tension which is the sum of the T1 and T2.

And T3 is equal to its weight. Now this is a perfect example of coplanar forces. Coplanar forces are the forces which act in a single plane. The number of forces are two or more.

And why we needed to know about coplanar forces, I have a simple experiment for you where what I've done is I have attached two springs to this table, and I want to lift this pencil. And I want to see what happens if I change the length of the one string as compared to the other one, how much springs are being extended.

Now if I hold in such a way that the length of the two branches is equal, the magnitude of extension in the spring is the same. But what happens if I change to length such that the front one, the left one becomes a smaller one, and the back one, or the right one, the shorter one. You can see the extension in the spring. The left one is large as compared to the right one. And if similarly, if I change this in the other direction, I can observe the same thing.

Now this has got something to do with the kite flying. And the kites which we have in our region is a single cord kite. And we need to tie the strings to the kite in such a way that it makes a bridle.

Now this is a bridle where we attach one end to the upper part of the kite. And this is the back part of the kite. And we need this bridle knot over here where the string is being attached.

Now this is very important, the length of the two strings, because it is going to define the launch angle of the kite. Now what does it mean, the launch angle? If I have this string smaller, you can see that this is extended more. And now the pencil is a bit higher on this side as compared to this one.

Now if the air is blowing like that, now it is going to define which surface of the kite-- either this one or this one-- going to have higher or lower pressures. So the way I am holding this pencil, we will have a high pressure surface with this one, and the low pressure surface will be this one. And this will make the kite fly if this one is the top side of the kite.

Now we have done something other recordings of these cases which I've discussed with you with different strings. Let's have a look at those ones. And then we come back, and we will discuss why in one case the kite flew or in the other case it flew even higher, and then in one case it could not fly.

The best season for kite flying is sometimes in February and March where the whole sky is full of kites, and it's celebrating the change of season from winter to spring. Now what I'm going to demonstrate, how the length of the two strings going to affect the flying of this kite. What happens if I have these strings of equal length, or this one smaller than this one-- the back one-- or the front string larger than the back string?

It is going to affect the angles which it is making with the main cord. We can have three different pieces where these two angles are the same, or this angle is smaller than this angle, or this angle is greater than this angle, which is making to the length of this cord. OK, let's do it.

The kite has started flying. And it's very stable. It seems to be very stable. It is being dragged by air.

I can do all kinds of maneuvering with it. But pulling the strings here and there, I can make it cycle. I can pull the string, and then it goes up. Now you see the kite is being flown.

OK, we have now the second case. In this one, that length of the front cord is too short as compared to the back cord. This one has gone higher much quickly.

And if I pull the string, it will go even further higher. And I right on top of me. So here, the lengths of the cords are quite different. The front one is very short as compared to the back one, so that's why it's going up much rapidly to the skies.

Now my colleague is going to try the third case, when the back cord is smaller than the front cord. And let's see if he is able to fly it. Why he has not been able to fly this kite despite trying many times? The length of the back cord is smaller than the length of the front cord, which makes the angle of the back cord is smaller than the angle of the front card. And you can resolve these tensions in the three strings-- the main cord and the two branches-- and you can see where is the net direction of force going, which is actually pulling it down against the air drag.

Welcome back. You have seen and I'm sure you have observed the right why in some cases the kite would not fly, and in some cases it flew very well. Let me explain it to you once again.

We have seen-- I have a bridle attached to this kite. Now what happens if I have the lengths of the two cord the same, and what happens is if I make it upward right, it does not make any angle with the wind. There is not launching angle, so the forces acting-- there's only drag, which is taking this kite away, which I can feel in the tension of the string.

But there is no lift available, because the kite does not make any angle with the wind. But if I shorten this length, and I pull these strings, I can see this now. This kite is making angle with blowing wind.

Now it has not only has it got drag force acting on it, but it has got upward lift, as well, because now it has got a higher pressure area downward, and a low pressure upward, over which makes it up. And in the third case, now the kite is like that, and it is never going to fly, because all the high pressure area is on the upper surface, and the lower surface is low pressure area, and the kite goes down.

Now this is how critical this is to have this bridle attached, and how much important this is to have the lengths of the two branches of the bridle to have right in order to make this kite fly. We have made an instrument to measure the tension in the string as a result of the drag force being applied on the kite due to blowing air or wind.

This is very simple instrument set up. You can make in your home or in the lab. I've used a calibrated spring and the pulley, and then I attached this string to the other end of the kite.

And when the kite was flying, I left it alone, and I measured the readings on the scale as the kite was flying. We have done some recording, and we have measured. We were fortunate enough and lucky enough that we could measure displacement in the spring as a result of the drag force applied on a flying kite.

So you have seen the flying kite, and then you have seen the spring being extended as the kite was flying. We noted these values, and we determined the wind velocity using the drag force equation. the values which we used were drag coefficient for kite shape is 0.9. Rho, which is air density, was 1.644 at 30 degrees Celsius, which was the temperature of that day.

We had used the area of the kite, which was 0.212 meters squared. As you notice, the spring showed a variation in the range of 2 to 3 newtons. From here, we determined the wind velocity, which came out to be in the range from 3.5 to 4.4 meters per second.

Very important is the air density, which is a strong function of temperature. Before you want to do calculations, you need to know the air density on the particular day, and you need to know the temperature. You cannot take randomly the value of air density. It is a very strong function of temperature. So you must know the temperature out there, and then find out the air density as a function.

In this module, we learned about the basic principles of aerodynamics. On any flying object, we learned about the forces which were exerted on the object by the medium, the aerodynamics forces which is resultant of the lift and the drag. We knew that the drag force-- it's dependent on the shape of the object, and it also depends on the lift, which is a force in the upward direction, depends on the differential of the pressures on different faces on the surfaces of the object.

In this module, we also used the spring. We determined the spring constant. We used the spring to determine the force, particularly in the end, the force being exerted on the kite by air was determined by using the spring, and then we use a formula of the drag force to determine the velocity of the wind.

Before we end, I would like you to think of about more examples where one experiences the drag force of air. For example, ice skater skating at a very high speed, the posture of the skater is to avoid the drag offered by the hair when you're moving at such a high speed. Before I go away, I would like to share you that kite flying is like a passion in my part of the world-- that is in Pakistan.

And we celebrate a festival known as Basant, usually in middle February or end of February, which marks the end of one season and the start of another season-- that is from winter to spring. And during those days, the whole sky is full of colorful skies. People celebrate by flying the kites, by fighting the kites in the sky.

It's a wonderful scene to be observed. I hope sometime you can visit Pakistan and see this festival. Thank you very much.

This segment is for teacher. I would like to discuss a few things which teachers should be able to discuss with students, which have got more details and more examples for teacher to help in discussing with students. We started with the number of forces being exerted in a medium on a solid object, like a plane or a kite.

And then we wanted students to make a free body diagram. A free body diagram is a very simple way of identifying the forces and their directions. It helps students to find out the number of forces being exerted on a body, and then resolve then into components and find out the resultant, the net force being exerted on the body.

I would like you to give more examples to students do draw the free body diagram-- for example, a book resting on a table. One of the simplest examples where we have only two forces involved-- one, weight of the book due to gravity, and the other one is the reaction which is normal to the book in the upward direction. We can have an object stationary, resting on an inclined plane.

There we can also make a free body diagram. This will help students to understand more about the forces, and how to resolve those forces, and how to determine the net resultant force, if there is a motion. If there is a motion, then Newton's Second Law can be applied to determine the acceleration of that object once we know the sum of all the forces.

In the next, what we did is we used the springs to determine the force exerted on some body. We started with the book, and then we proved the Hooke's law. And then finally, we used the spring balance to determine the drag force.

I would like you to suggest to students to design some simple experiments. For example, if we have a pedestal fan with variable speed. We can have a plane which we can expose to the fan, and we can determine by the extension in the spring how much force is being exerted on the plane. We can change the size of the plane. We can change-- and we can look at the effect of the area on the force being applied on that plane.

Now finally, we discussed what happens to the flow patterns of air if we have different shaped objects. I'm showing you a slide where different shaped objects are being placed in a blowing wind, or in a wind having certain velocity. You can see the wind patterns formed due to these objects are different.

We move from a laminar flow to a turbulent flow where the Reynolds numbers changed. I would like you to discuss with students what is a laminar flow, or a turbulence-free flow, and what is turbulent flow, and how it helps in flying the plane or in kite flying. One more thing which I did not mention, and I mentioned very briefly-- that it's not only the pressure difference which makes the planes fly. Newton's Third Law also takes place there.

What happens, we have wings having certain angle of attack angle of the launch angle, so when the wind comes in, it strikes it, changes the direction. So when it changes the direction, goes down. As a result, it pushes the airplane upward. So it's the difference in the pressures of the lower surface and the upper surface, and Newton's Third Law, which is due to the change of direction of the wind, which makes the airplane fly. That you can explain more to the students once this module is over.

Finally, I'm showing you a complete free body diagram of a kite where different forces are identified, which are acting on the kite. You can see those forces are the aerodynamic force, which is the resultant of lift and the drag. There's a center of gravity. One point, which I've not discussed-- which may be a bit complex-- is the center of pressure. If you like, you can discuss with the students. I'll come back to it later on.

We have got bridle point. And then there's a very important angle of the bridal point with the line. The tension in the string, which is the result of the aerodynamic force being applied on the kite.

Now center of pressure is very much similar to the center of gravity. When we have a mass distributed in a certain volume, we determine the center of gravity where effectively the weight of the body lies. The simular is the situation when we have a body submerged in a medium-- in a fluid or in air.

Then the pressure by the medium is exerted on all the surfaces. So this center point is the point where one can feel the pressure of the medium on the object. So these were the points which I would have liked you to discuss with students.

Finally, I give you two examples. If kite flying is not available, you can use the frisbee. Frisbee works on the same principle. If we throw a frisbee-- a spinning frisbee-- it creates a pressure difference. We have got a lower pressure on the upper surface, and a higher pressure on the surface, which makes frisbee to fly.

And of course, when we launch the frisbee, we can also control its launching angle, and we can define how high it can go either against the wind or in the wind. This can be a perfect example. And I'm sure in this example we have control over the launch angle of the frisbee, as well.

Another example, which is a very good example of the drag force, is the rain drop. The rain drop-- let's assume of a few tens of grams-- falling from around a few kilometers-- let's say 2 to 3 kilometers-- from the sky when it comes down. It can have a huge impact.

But what happens is that as it starts falling down, there is a drag force of the air resistance which acts against its downward motion. And at one point, this drag force becomes equal to the weight. And at that point, the value of acceleration goes to zero. And now at that point, it reaches its terminal velocity, and it cannot go beyond this velocity. And that saves us from that huge impact of collision, which it can make if there is no drag force acting on it.

One more example, which is very interesting, is of skydivers. When skydivers, when they do some maneuvering in the sky while they have dived from the plane, they would like to have as much as frontal area exposed when they are falling so that they can get to the terminal velocity as early as possible. This is another example of the drag which the skydivers are facing.

I hope this module was quite interesting for students, and they have learned. And I have given you some more examples, which you can share with students in detail. Thank you.

[MUSIC PLAYING]