

# Things Are Never Quite the Way They Seem

By Nawwaf Abu-Aqeel

## Segment 1

Hello everyone, my name is Nawaf Abu-Aqeel and I am a math teacher at Al Ahliyyah school for girls in Amman – Jordan. Today I am going to talk about some particular effect of frequency which is called the stroboscopic effect. In order to understand this effect:

(I am standing next to the operating fan)

This fan has three blades, I wrote a word on one of the blades and as you can see, the blades are rotating so fast that nobody can read the word I wrote on one of the blades. Now at the end of this module, you will be able to read that word. Now, I want you, in order to do so, to discuss with your teacher and with each other, some effects of the frequency; the definition of the frequency, the definition of low and high frequency, and to give examples of some periodic phenomena and their frequency. I'll see you in a couple of minutes...enjoy it.

## Segment 2

Welcome back, I am sure that you found some examples of high frequency and low frequency phenomena. One of the examples that you can give is a car wheel which is rotating slowly or very fast. When it is rotating very slowly, it is called a low frequency phenomenon and when it's turning or rotating very [fastly] we call it a high frequency phenomenon. Ok, let's now turn on this light bulb (on the bench, a small lamp and a LED are mounted and connected to AC power supplies). Electricity in Jordan is about 230Volts and of frequency of about 50 Hz, Which means that if this is an AC, alternative voltage, the light should be going ON and OFF. Now, if you look at it, I do not see it going ON and OFF, can you explain that?...Now, let's take another example, look at this LED, light emitting diode, it is a red light emitting diode, I'm going also to turn it ON and observe what is going on...your eye can catch when the light is ON and when the light is OFF...now let me just increase the frequency...just gradually...what is going on? What do you observe? Now, let me increase it again...let me increase it further...look what is going on...look at that, now, let's increase the frequency further...here you go...what do you see? The LED is not blinking no more...can you explain that? When I was at low frequency, my eye could catch the ON and the OFF of the light ...now it cannot can you explain that? Now in order to help you, let me just explain to you what an AC is...an AC voltage is something like this [ I am drawing, on a white board, two axes and a sinusoidal signal], the AC voltage is on the vertical axis, let's call it V and it is measured in volts. On the horizontal axis, we have the time...and let's say the time in seconds. Now, an

AC voltage is a signal which is a sine signal like this (drawing signal on the white board)...it goes up and then down and then it goes up again, now this is very approximate...I know...we have very particular points on this graph; this point..let's call it zero...and this point, point A then we have point B which is at zero voltage and then we have point C which is another maximum voltage but on the negative side and then we have another zero voltage over here. As you can see, this signal would continue on, ok?, so this form will repeat for ever as the light is ON...Now I hope that , this will help you to discuss with your teacher and with each other, why the light was ON and OFF for the LED...ok...and I could see it but not for the light bulb. I'll see you in a couple of minutes, enjoy it.

### Segment 3

Let's make a toy together, it is a very simple toy...you just take a small cardboard like this one..ok?...and then you just fold it in two ...like this..just fold it and then you draw whatever you want ...let's say I'm "gonna "draw a cage over here ...on this side, and a bird on the other side ..or a ball...football or whatever it is and a football player on the other side about to kick the ball then use some adhesive tape...to tape it...to keep it folded and then just insert a toothpick or a stick over here in order to be able to rotate the toy...and it comes finally like this...ok?...the cardboard, adhesive tape, the toothpick, the cage and then the bird on the other side. Now try to rotate this toy...put it like this and try to rotate it...what do you observe? Try to rotate it like this...ok..now I'll leave you for a couple of minutes to discuss what do you see and then we'll discuss what is going on...ok? Enjoy it.

### Segment 4

Welcome back, if you tried the cage and the bird, you must have noticed that When I rotate this toy between my fingers like this ...I see the bird in the cage! Did you notice that? Good...let's now try another toy, here's a blank disc, as you can see you have like frames over here and you can draw whatever you want ...an object , let's say that is in different consecutive positions...it is like a horse, let's say or it could be a car or whatever. Now this disc is like this one...here's the disc...we take the example of a running horse , the horse is in different positions as you can see and these are still positions, the horse is not moving, right?! Ok, now , let's see this toy....so the lower part of the toy is just a rotating disc [spinning the disc]..ok? and the upper part is ...the upper part of the toy...it is like plane mirrors...ok? Arranged in this form. If you put it over here (upper part on lower one) ...here you go...and now if you rotate the disc, these mirrors ...ok? Will constitute the frames and if I rotate the disc, I will see the horse running..look at this..[spinning the disc]...can you see that? Let's try it

again, again...alright ...I think you understand the thing over here and the concept behind this. Now, why do I see the horse running while I have only still images? It is simply a question of frequency. When the frequency of some rotating phenomenon or periodic phenomenon exceeds some critical value of the frequency that the eye can not catch, for the eye, this motion will seem as fluid and continuous. And this is exactly the principle of movie-making ...making films. Now on the inverse, I can also freeze the motion of a fast rotating object, how do I do that, I use a device which is called a stroboscope.

We can actually use a device called a stroboscope, it is a flashing device [turning the stroboscope ON]..that gives flashes per second. I can adjust the number of flashes which means the frequency as I want ...I can increase it or decrease it. Now, if I have a fast moving phenomenon or a rotating phenomenon, I can freeze the motion of that phenomenon if I can find the right frequency of the stroboscope. That means, if I match the frequency of the rotating phenomenon I can freeze the motion. Now, that means that frequencies or certain frequencies can induce illusions for the eye. Can that be dangerous in some situations? I want you for the next couple of minutes to think about some phenomenon and to see if the frequency of that phenomenon is dangerous or not or could it be dangerous or not...think of some rotating objects you have so many around you, I'll see you in a couple of minutes.

### **Segment 5**

Welcome back, I think that you have come up with some examples...it is like a vertical saw or a drill or any other example actually...but now let's get back to our problem. We have here the fan and I told you that I wrote a word on one of the blades and we can still not read that word. Now using this stroboscope, we will be able to read that word...Watch with me [ turning the stroboscope ON and adjusting its frequency] the stroboscope is ON and now I'm "gonna" increase the frequency of the stroboscope until I can freeze the blades. Here...do you see it can you read the word? GOOD...excellent....ok...so now that we finished with this, I'm "gonnan" tell you why this phenomenon can be dangerous. Now let's imagine that you are in the carpenter shop and there is a vertical saw and the vertical saw is rotating at the same frequency as the light of the shop. Now if the light of the shop is matching the frequency of rotation of the vertical saw, the saw will appear still, exactly like this blade and you might harm yourself if you get close to that saw. Thank you, that is it for today and hopefully I'll see you another day and a next time, thank you.

### **Segment 6 (Teacher's Guide)**

Hello fellows, I hope that you will enjoy this module today. This module is about frequency and the stroboscopic effect. The main point of this module is to show that

resonant light frequencies might cause dangers in some situations. So during the first break, try with your students to define the terms : frequency, low frequency, high frequency and take some examples of phenomenon that is rotating let's say or periodic. During the second break, we used a light bulb and a LED, light emitting diode, and we used different frequencies for the LED so we control the frequency and for the light bulb, we just used the main frequency which is about 50 Hz. Now you can make use of this graph [showing a sine signal on laptop] over here, which is an AC voltage as you can see and it is actually in segment 2 also if you can see it before and explain to the students that at points A, B and C, which are the intercepts with the x-axis which is the time axis, the voltage drops to zero which means that there is no light. You can also connect the frequency to the period of the signal to explain why at low frequency we can see things blinking, going ON and OFF and why at high frequency when the period is very small, we can not see them so we see them always ON. In segment 3, the students know by now that beyond a certain frequency the eye can not catch images. The toy that the students can easily make and it is explained in details in segment 3 so I am not going to re-explain it again...I am talking about the toy with the cage and the bird. When you turn it actually at a high speed of rotation, you can see that the bird is in the cage, you have to explain to the students the persistence...I am sorry the persistence of the eye which means that when the image comes to the eye, the eye retains the image for a fraction of second ..now..before that image can leave, another image will come on it actually so the eye will see a fluid continuous motion and that is exactly the principle of movie-making and films.

For segment 4, if you do not have the mentioned toy, I mean the running horse, and it is also explained in details in segment 4, you can still, with your students invent another toy for the same purpose and it is exactly the same thing. The toy is this [showing the toy] you just take a notebook like this, a small one or a big one or a large one, it is ok. Now, inside you have just to draw some objects like a heart over here [showing pages from the notebook] and the heart in another position like it is flying and so on and then you might get to draw a cat which is trying to catch that heart in different positions also. Now if you flip this notebook like this [flipping the notebook] you should see the cat running after the heart and it is the principle of movie-making.

Now, even if you do not have a stroboscope, students can see how it is used by watching the module. Your role is to explain to them that if the frequency of the stroboscope matching the frequency of the rotating phenomenon then the image will be still, it is like you are freezing the rotating object. Now explain to them also that, you have many frequencies where you can freeze let's say the blades of the fan but the frequency of rotation of the blades is the frequency matching the highest frequency of light coming from the stroboscope that freezes the blades. Now if you do not have a stroboscope, you can still make one with your students, this part is called the extension of the module. This part can be done separately and later on when students have time. Make your own stroboscope: [ showing image of a disc] you can make your own stroboscope using a plastic or metallic disc, make equally separated sectors, 10 or 12 sectors as you can see on the image, use a small DC motor to rotate or

rotate it manually . In a dark room, use a light box to shine your disc and rotate it ,  
You have then a handmade stroboscope. Try to find out the speed of rotation of the  
blades of a fan using your stroboscope and I am telling you that you need some basic  
mathematics to do that. Thank you very much, I hope that you will enjoy this module,  
bye bye.