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MOTIONAL VISUAL ILLUSIONS ON-LINE

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The inclusion of some of the amazing visual phenomena associated with particular trajectories of moving objects, can significantly enhance physics courses at both high school and at university. We describe three particularly interesting motional visual illusions which we regard as having a significant educational impact, namely, the "third coin" illusion, the "rotating" Pulfrich stereo-effect, and the "spinning ring" illusion. Computer simulation and animation of these "motional" visual effects allow students to gain a deeper understanding of these phenomena, while participating in exciting and educationally useful investigations. Having these illusions available as `on-line' presentations is a useful way of bringing these phenomena to a wider audience.

1 Introduction

The progressive downturn in the numbers of students learning physics both at high school and at university is widely discussed [1,2]. In order to reverse this trend it is necessary, in our view, to try and make the subject more interesting, relevant, and if possible, even exciting. To this end, teachers should consider making use of particularly intriguing processes and interesting effects. Certain visual illusions can be particularly useful in this regard.

The world of optical illusions is a huge resource for teachers; for example, the powerful illusions associated with the hot air of deserts, or the boundless imagination of Maurits Escher, evoke keen interest and delight, as evidenced by the increasing number of visual illusions available on the internet [3]. Indeed, visual illusions have been the subject of study in many different research fields, for example, mathematics, cognitive psychology, and physics. In view of the public interest in this area, the physics and mathematics associated with visual illusions could usefully have a higher profile in the classroom [4,5].

In order to promote the multi-disciplinary educational value of visual illusions associated with moving objects, we have developed on-line animated explanations and computer simulations of some of the more spectacular motional visual illusions.

2 The “third coin” illusion

This amusing "motional" illusion is easily demonstrated, and one needs no special facilities or training. In M.Gardner's book, the effect is presented as follows: "It is easy to show an interesting optical illusion with two coins. Hold the coins between your forefingers as you see in the picture. Rub the coins against each other. A third coin will appear between and below the other two. This is because your eyes keep the images of the two coins in their lowest positions. But nobody can explain well enough why the third coin always appears below and never above the real coins" [6] – see Fig.1.

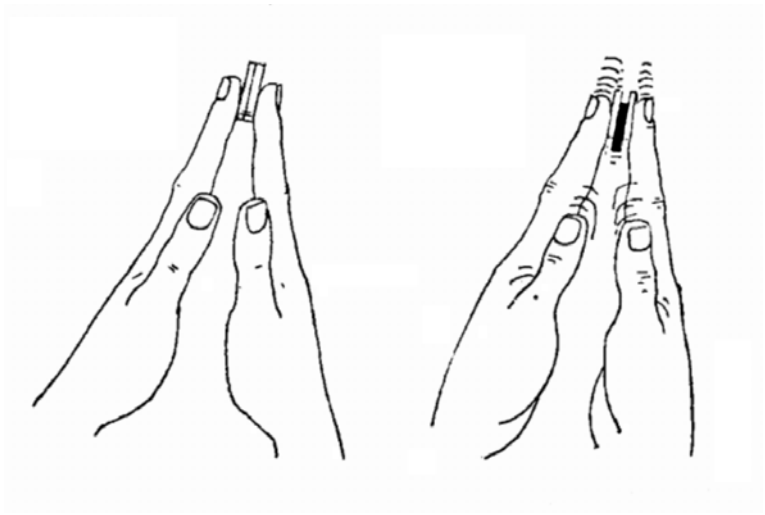

Figure 1. The third coin illusion, as presented in [4].

The final challenging comment stimulated us to develop a computer model showing the cyclic motion of the coins, together with an account of their transverse (horizontal) displacement, which although not mentioned in the book [6] is a crucial aspect of the illusion. Fig. 2 illustrates the kinematics of this effect. It is easy to observe that given the geometry of this experiment, an image of the third coin must "appear" on the symmetry axis, at the lowest position of the coins 1 and 2. To view an on-line computer animation of this illusion visit the educational web-site [7].

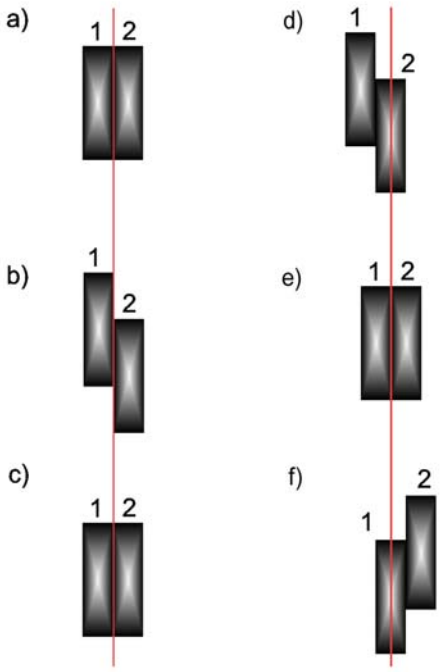

Figure 2. Computer simulation of the third coin illusion: coins oscillating with (d-f), and without (a-c) horizontal displacement.

3 The “rotating” Pulfrich effect

The Pulfrich stereo-effect is perhaps one of the most impressive motional visual illusions. There are two forms namely (a) the standard pendulum effect, and (b) the more spectacular `rotating' effect.

In the standard pendulum effect, a simple pendulum-bob (approximately 1 metre length) swinging back and forth from side to side, is observed binocularly with a neutral-density optical filter (OD approximately 0.8-1.0) in front of one eye. If the observer tracks the pendulum bob carefully, then the pendulum-bob will appear to move along an elliptical trajectory in a horizontal plane. Furthermore, the direction of the illusory motion depends on which eye is looking through the filter: when the left eye is filtered the bob appears to move clockwise; when the right eye is filtered the bob appears to move counter-clockwise.

The illusion is named after the German physicist Carl Pulfrich [8], who hypothesised that the phenomenon is related to the small increase in the eye-brain time delay (say 10-15 ms) associated with the dimmer retinal image seen by the filter-covered eye. As a result of this small time delay, the sequence of paired images actually perceived by the brain originating from the left and right eyes are in fact related to different moments in time, and thus to slightly different spatial positions of the moving pendulum. Binocular fusion of the two brain images results in the pendulum bob appearing to be displaced out of the plane of the real pendulum.

There is a well developed and systematically updated Web site devoted to both history and research of the Pulfrich effect, which includes diagrams and animated explanations [9].

However, an even more spectacular but less well known Pulfrich effect is the "rotating" version of the illusion [10]. If an object is made to rotate anti-clockwise in a horizontal circle and viewed binocularly with a filter in front of the left eye, the apparent direction of its rotation will be seen to depend on the observer's viewing distance, angular velocity of rotation and optical density of the filter. An interesting aspect of the "rotating" Pulfrich effect is that it can be used as an experimental tool for determining the latency (delay) time associated with the filter and lighting [10-12].

The geometry of the "rotating" observational scheme is explicitly explained by Nickalls' theorem [13, 14]. Our computer animation of the "rotating" Pulfrich phenomenon (see Figs 3, 4) was designed using Maple 6, and describes the amazing size effects, "transverse" Pulfrich illusion, off-axis schemes of observation and other effects (see on-line example at [7]).

Figure 3. The "rotating" Pulfrich illusion, showing the size effect.
1 – true position of the rotating object;
2 – delayed position seen by the filtered eye;
3 – apparent position of the object.

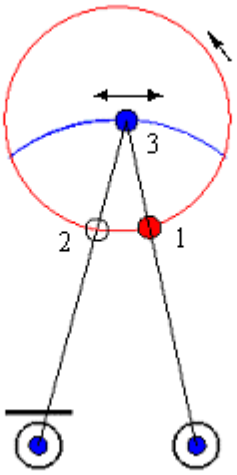

Figure 4. Critical `transition' configuration, when the object appears to be oscillating back and forth along a line.

4 Conclusion

The motional visual illusions described here have been shown to have a useful educational application. The involvement of university students majoring in biology, physics, medicine, chemistry in their studies was found to be active and creative.

5 Acknowledgements

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