1 Introduction

Playgrounds are full of physics phenomena and can be seen as physics teaching laboratories for all ages (figure 1). Small children experience the periodic changes between feeling heavy and light as a swing moves to and fro. Preschool children know the effect of friction on slides such as wearing their rain gear on wet slides which allows them to move fast down the slide, or alternatively drenched denim jeans which slow them down. Parents pushing two children may find them becoming out-of-phase. They may also ponder about the best way to stop the motion of a swing.

Playground experiences do not automatically turn into an understanding of physics. However, with small interventions over several years, these experiences may be connected to physics concepts and a growing insight of the underlying physics involved.

Even a small playground provides opportunities for a teacher to create memorable lessons, e.g. using a climbing apparatus or a net to drop objects from high up, and bringing simple toys to swings and slides for several surprising investigations. Section 2 discusses how a playground can be used for an outing focusing on observations and discovery. Later sections present examples more detailed investigations of different topics, as well as investigations on larger playgrounds, with other equipment that can be useful for physics investigations, such as carousels [1], and possibly small trampolines [2, 3, 4].

For school outings, preparation and follow-up in the classroom are essential complements to the discussions during the visit [5, 6]. Focusing on one activity at a time makes more sense than trying to perform all possible experiments: The playground will remain accessible for revisits! The articles [7] and [8], summarized below, give examples of how middle-school teachers integrated experiments on slide friction and investigations of falling objects into lesson sequences.

Fig. 2 Preschool teachers comparing different falling objects, e.g. investigating whether the orientation of sticks influences the time needed to reach ground. The teacher is lying on the ground to reduce the effect of parallax error.

1.1 How do I explain?

Children ask many questions. A common concern is an uncertainty about how to answer the question 'Why?'. However, not everything needs to be explained directly. In some sense, physics does not *explain*, e.g. how a smaller and larger ball can fall together, but instead *describes* the phenomena in terms of physical laws. The acceleration of a ball is obtained by combining Newton's second law $\mathbf{a} = \mathbf{F}/m$ with the gravitational force on an object, $\mathbf{F} = m\mathbf{g}$, giving $\mathbf{a} = \mathbf{g}$ independent of mass. At some stage, even physicists resort to the answer 'Because!' to persistent questioning 'Why?'.

The best answers to student questions may be in the form of new questions that stimulate student's curiosity and encourage them to keep investigating and to finding connections to other phenomena! Wynne Harlen [9] discusses the use of 'productive questions' - questions to capture students' attention, make them try out or compare or reason out their finding. Knowledge of the relevant physics is used to guide the questioning to help students investigate and discover.

1.2 An inquiry-based science learning environment – ISLE

The investigations may take inspiration from the ISLE – Inquiry-based science learning environment [10] approach. Encourage students to start by doing initial observational experiments and then describe their observations carefully. In the next stage, students should work together to generate as many possible explanations as possible for the observations [11]. Working together makes students less prone to want to prove their own explanation, and more eager to share in developing the continued experimentation. When a number of possible explanations have been generated, it is time to find ways to discuss together how the different suggested explanations may be tested – and possibly falsified. This approach can work for many of the experiments suggested in this chapter.

To support the teacher's discussions with children, pupils or students, the later parts of this chapter discusses relevant concepts in some depth.

2 Observe, compare and discover

Climbing apparatus, slides and swings are found in most playgrounds, and offer many opportunities for investigations with surprisingly fruitful results. One approach can be to ask students to find objects that can fall, roll, slide or swing side by side. This section presents suggestions for initial investigations with a focus on observations, comparisons and discoveries. The results are discussed in more detail in later sections.

Fig. 3 Preschool teacher ready to simultaneously drop an autumn leaf and a stick.

2.1 Falling objects

Is it true that heavier objects always fall faster than lighter objects? Start by dropping two balls at the same time and observe the landing. Did they move as you expected?

Dropping different objects and comparing their motion works well in the classroom - but doing it from a climbing net or the top of a slide may create more long-lasting memories, while emphasizing that physics works also outside the physics classroom. Table 1 presents a suggested instruction, which can be used or as a template for worksheets where you can add photos from your local playground. It can also form the basis for oral instructions to the group(s). Figures 2 and 3 show preschool teachers comparing different pairs of falling objects.

Table 1 Investigation on a climbing frame. Bring balls and a few other objects and climb to the top of a slide or climbing frame.

Instructions	**Notes**
Drop two balls together. Compare their motion. Describe your observations.	
Drop a ball and a small stone or stick. What do you expect to happen when you drop them together? Perform the experiment and describe the results.	
Drop a stone and a leaf or another light object: What do you expect? Perform the experiment and describe the results.	
Chose other pairs of objects: What do you expect? Perform the experiment and describe the results.	

2.1.1 Very light objects

Although moderately heavy objects fall together for short distances, very light objects lag behind. Since this everyday experience contributes to the common conception of gravity, it is worth spending some time examining the fall of light objects. Picking up a leaf or a bird feather on the playground for comparison with a stone or ball, can give a comparison without surprises (figure 3). More detailed investigations may be better performed in a classroom, where wind is less likely to disturb the experiments. One common demonstration is to bring large coffee filters from the teachers' lounge and compare the fall of one single filter with a double filter, and to try drop them so that single and double filters land together.

Fig. 4 A swing set with several swings can be used for many different investigations.

2.2 Swings

Playground swings offer a wide variety of investigations and demonstrations. The investigations of forces are analogous to the investigations in amusement park pendulum rides, although bringing equipment along is less problematic on a playground. Experiments involving energy transformations are difficult to perform in amusement rides, and playground swings also offer more possibilities to study factors influencing the period.

2.2.1 Forces in swings

Close your eyes and try to remember what it feels like to be in a swing, moving to and fro, with varying force between the swing and your body. Note how the experience of the body changes between feeling lighter and heavier than normal. Can you feel when you pass the lowest point or when you turn in the highest points? How would you expect the water level to move if you were to take along a mug of water or a half-filled bottle on the swing? With simple equipment you can get a visual illustration of the forces as indicated in figure 5 with instructions in table 2. The forces can of also be measured with a smartphone accelerometer app, as discussed in the chapter about pendulum rides.

Table 2 Investigations of forces in a swing. Bring a short slinky spiral toy (figure 5) and a bottle partly filled with coloured liquid.

Instructions	**Notes**
Hold a short slinky in your hand next to the swing just outside the chain. Ask a friend to observe the slinky changing length as you swing. During what parts of the motion is the slinky shorter than at rest? During what parts of the motion is the slinky longer than at rest?	
Place the bottle with liquid on the seat of the swing or hold it next to the seat and start swinging. Stop adding energy and let the swing move freely. Observe the liquid and describe your observations (see figure 6).	
Alternatively, let the bottle lie down on the bottom of a basket swing. How do you expect the liquid to move as you start the swing? Perform the experiment and describe the results.	

Fig. 5 Using a spiral toy to illustrate the forces acting while you swing.

Fig. 6 Swinging with a bottle partly filled with coloured liquid.

2.2.2 Twin swinging, sibling swinging and periodic motion

Children sometimes talk about twin swinging, where two children swing together, next to each other, moving back and forth in synchronised motion. Similarly, sibling swinging describes two swings moving in opposite directions, completely out-of-*phase*, as depicted in figure 7.

Figure 8 shows two preschool teachers ready to investigate if it is possible to twin swing with an empty swing. If they let go at the same time, they will be in phase as they start. The angle is approximately the same, corresponding to both swings having approximately the same *amplitude* at the start. If they return together, they also have the same *period*. Typically twin swinging can work with two similar swings and often also with an empty swing, although you may need to lower the centre of mass of the loaded swing by adopting a lying down position while swinging.

Twin swinging involves the same amplitude and phase, but also the same period. These concepts relating to periodic motion are thus relevant for children in playground swings.