Physics in Playgrounds

Contents: A series of structured questions on energy, forces and motion based upon the experiences children gain using swings, slides and see-saws.

Time: 2 periods or more, depending on number of parts used.

Intended use: GCSE Physics and Integrated Science. Links with work on forces, energy, oscillation and translational motion. May be particularly useful during revision.

Aims:

- To complement and revise prior work on forces, energy and motion
- To show that scientific laws apply to everyday experiences
- To link the world of the laboratory to the world of play
- To provide opportunities to practise skills in comprehension and application of knowledge.

Requirements: Students' worksheets No. 705

Although the students using this unit will probably be too old to visit playgrounds, they are likely to have recent memories of their experiences. It would be helpful to visit playgrounds when using the unit, and students could be encouraged to 'revise' by watching or helping young children at play.

There is a general introduction followed by three sections: Slides, Swings and See-saws. These sections can be used independently of each other. The questions in each section vary in difficulty: in general, the questions become progressively more difficult. The See-saw section may only be suitable for more able students.

Other playground activities provide suitable illustrations of physics. Roundabouts, for example, are a good illustration of rotational motion, though much of the physics may be beyond most students at this level.

Notes on some of the questions

Q.3 Students may only answer this at a superficial level. In general, speed is exciting for its own sake, partly because of the risk involved. In addition, for many playground rides higher speeds mean greater forces acting on the body.

Q.4 Public playgrounds are generally built and maintained by the local council. (District Council, Parish Council, Borough Council, etc.) Playgrounds have regular inspection and maintenance by the council. In effect, they are paid for out of rates.

Q.SL6 For a long slide it is possible to reach a terminal velocity where frictional forces (air resistance and surface friction) balance that part of the gravitational pull acting down the slope.

Qs SW1-SW3 As for any pendulum, the frequency of oscillation stays approximately constant, but its amplitude (size) gets less as it slows down. The frequency should be independent of the mass of the child, provided the centre of gravity remains in the same position.

Qs SW6-SW9 A perfectly frictionless swing interconverts kinetic energy and gravitational potential energy without loss. Kinetic energy is at a maximum at the bottom of each swing and at a minimum at the top; for gravitational potential energy it is the other way round. In practice, some energy is lost as heat due to friction, which is why the swing eventually stops.

Q.SW10 Apparent weight (the push of the seat on the child's bottom) is at a minimum at each extreme of the swing, when acceleration is greatest. This can be thought of as the point where the swing seat is 'falling away' from the rider. Maximum apparent weight is experienced at the trough of the swing, where centripetal acceleration is effectively pushing the seat upwards against the rider's bottom.

Q.SW11 The rope is most likely to break at the trough of the swing. This is the point at which the tension in the rope is greatest, for the reasons outlined in the answer to question SW10.

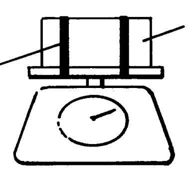
Q.SW12 There appear to be two methods for making oneself swing: (a) the leg swing method, where the legs are thrown forward during a forward swing, and back during a backwards swing; (b) the rope-pull method, where the ropes are pulled to raise the centre of gravity slightly at the beginning and end of each swing. Each method depends on raising the centre of gravity and hence increasing gravitational potential energy, which is transferred to the oscillation of the swing. If the movements are repeated at the resonant frequency, the swing goes higher and higher.

Q.SS3 This question brings out the point that we can detect accelerated motion but not steady motion. The force on the rider's bottom is greatest at the bottom of the oscillation and least at the top.

Q.SS4 Heavier: during A and D; lighter: during B and C.

Further activities

The question of 'apparent weight' can be investigated using an 'apparent weight meter'. This is simply constructed from a top-pan kitchen balance, relabelled if necessary to read in newtons. Select a convenient mass which gives a whole number reading on the scale — a mass of about 2 kg is suitable. Fix the mass onto the pan, for example with strong elastic bands.



The apparatus can then be used to investigate changes in apparent weight. For example:

1 Hold the 'apparent weight meter' steadily and note the reading. Accelerate the meter upwards and note the reading. Accelerate it downwards and again note the reading.

2 Make a model swing using, for example, an old cardboard box. Put the meter in the swing and use it to check the answers to question SW10. Further questions to investigate:

   (a) Does the apparent weight ever equal the real weight? If so, where?
   (b) How much bigger than the real weight is the greatest reading during a swing?
   (c) How much less than the real weight is the smallest reading?
   (d) Try to draw a rough sketch graph of the change of apparent weight during one half swing left to right.

3 Field work:
   (a) Take the 'apparent weight meter' to a playground. Take it onto a swing and carry out the same readings as in (2) above. Take it onto a see-saw and use it to check answers to question SS4.
   (b) Try taking the meter on other 'rides', for example, in a lift.

Acknowledgement Figures2, 3 and 4 drawn by Laurie Fahy.

PHYSICS IN PLAYGROUNDS

Playing in a giant's laboratory

You can probably remember your visits to children's playgrounds when you were younger. Maybe you still go for a quick slide or swing occasionally. Either way, you will know that playgrounds can provide children with the excitement of speed and strange forces.

There is a lot of physics to be learnt in playgrounds. Swings, slides, see-saws and roundabouts enable you to experiment with equipment large enough for a giant's laboratory.

Answer questions 1 to 5.

Figure 1 A large children's playground

Questions

1 *Where is your nearest playground?*

2 *Which was (or is) your favourite piece of playground equipment? Why?*

3 *Playground rides are generally more exciting (and more dangerous) the faster you go. Why is this?*

4 *Playgrounds are expensive to set up. Once set up, they need regular repair and maintenance. Who pays for your local playground?*

5 *Why do adults think it is worth the expense of providing playgrounds? What benefits do they think children get from them?*

Slides

Figure 2

Questions

SL1 *You need energy to climb to the top of a slide. Where do you get the energy from?*

SL2 *What has happened to the energy used for climbing by the time you have reached the top?*

SL3 *What force causes you to move and accelerate down the slide?*

SL4 *What would happen if the slide were steeper? Why?*

SL5 *Name the forces which oppose your motion down the slide.*

SL6 *If the slide is long and shallow, you may eventually stop accelerating and reach a constant speed. Explain why this happens.*

SL7 *What has happened to all your energy by the time you have stopped at the bottom of the slide?*

Swings

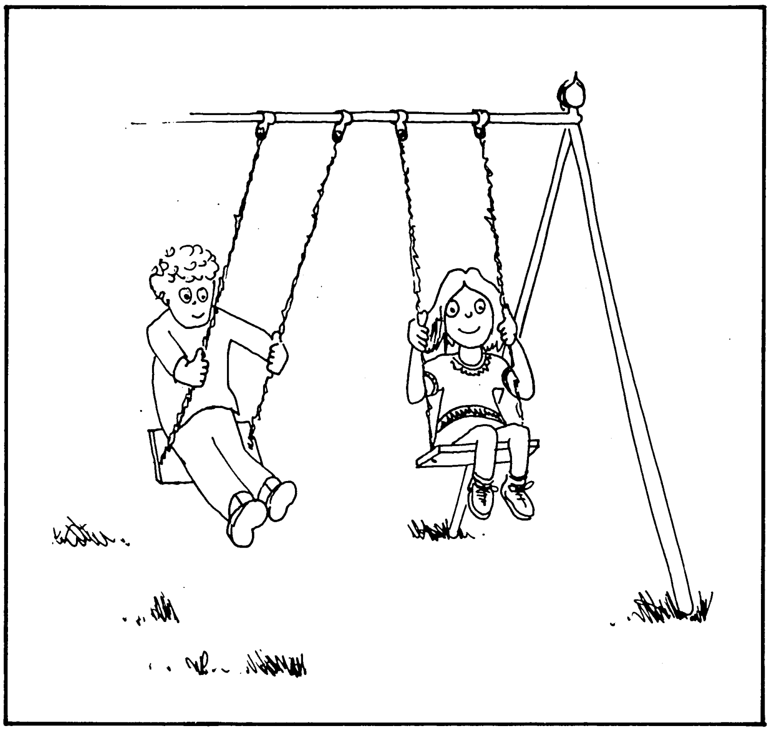


Figure 3

Questions

SW1 When a small child is pushed on a swing, does the swing oscillate with a constant frequency?

SW2 If pushing is stopped, what happens to:
(a) the size, (b) the frequency of the oscillations?

SW3 If a heavier child uses the swing is its frequency of oscillation (a) less, (b) the same, (c) more?

SW4 What difference do you feel between pushing an empty swing and pushing a swing with a child on it? Which swing has the greater inertia?

SW5 Suppose you want to measure a swing's period of oscillation using a watch with a second hand. Explain why it is:
(a) difficult to time just one swing accurately
(b) more accurate to time 20 swings and find the average
(c) better to start timing as it passes through the middle of its swing, rather than starting at either end.

SW6 When you pull a swing back, ready to release it, you are transferring energy to the swing. This is because you have done work to raise the swing. What form of energy does the swing possess in this state?

More questions on the next sheet.

Questions

SW7 (a) When the swing is released, what causes it to move downwards?
(b) Why does it not stop at the bottom of its swing?
(c) Why does it climb equally high on the other side?

SW8 At what part of its oscillation does a swing have:
(a) greatest velocity
(b) zero velocity
(c) most kinetic energy
(d) no kinetic energy but maximum gravitational potential energy (g.p.e.)?

SW9 What can you say about the total of
k.e. + g.p.e.
for the swinging system if the oscillations remain the same size?

Questions SW10, SW11 and SW12 are harder.

SW10 If you swing really high, the speeding up and slowing down of the swing during its oscillation makes your weight seem to change. During which parts of its oscillation do you feel:
(a) almost weightless; (b) heavier than usual?
Try to explain why you have these sensations at these times.

SW11 Suppose a swing has a frayed rope. At what point in its oscillation is the rope most likely to break? Why?

SW12 Children eventually learn the art of swinging themselves without being pushed. What do you have to do to keep yourself swinging? How does it work?

See-saws

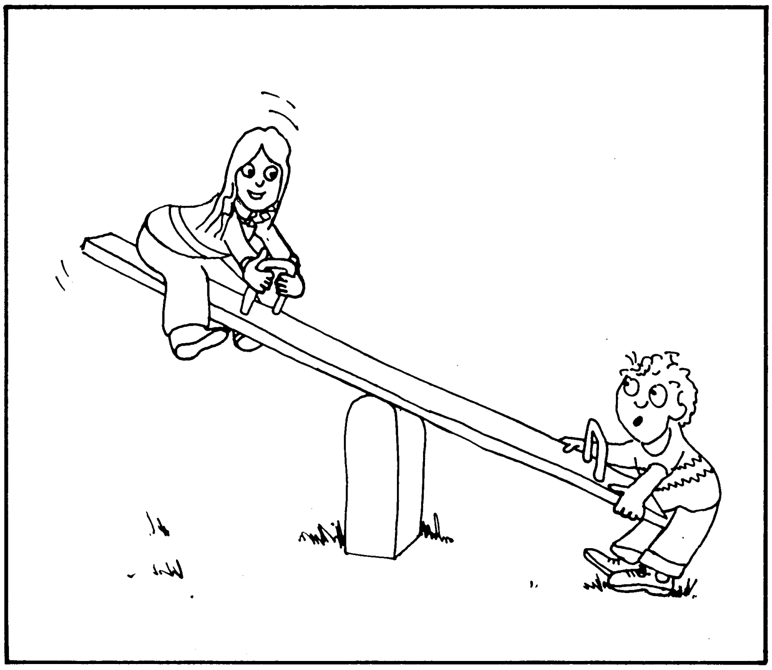


Figure 4

Questions

SS1 *People of the same weight can balance on a see-saw by sitting at the same distance on opposite sides of the pivot.*

- *(a)* *How can two people of* different *weights arrange to balance?*
- *(b)* *What physical quantity must have the same value but opposite sense on both sides of the pivot?*

SS2 *See-saws can be dangerous if children play too vigorously. You may remember having to hold on tight at the top of the see-saw's movement to stop yourself leaving the seat. Explain why this happens.*

SS3 *Imagine you are riding on a see-saw with your eyes closed.*

- *(a)* *How can you tell you are not on a steady seat?*
- *(b)* *Describe how the force between your bottom and the see-saw varies as you move.*

SS4 *Your motion on a see-saw can be divided into four stages:*
A — accelerating as you push off
B — decelerating upwards as you near the top
C — accelerating downwards from the top
D — decelerating downwards as you near the ground.

During which parts of the motion do you feel:

- *(a)* *heavier than normal*
- *(b)* *lighter than normal?*