Interactive Simulations Supporting Inquiry-Based Learning Science in Secondary

Measuring speed and acceleration

(Suitable for Junior Cycle Physical World)

Force and Springs

(Suitable for Junior Cycle Physical World)

Electromagnetic Induction - Faraday's law

(Suitable for Senior Cycle Physics)

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Introduction

Junior Cycle curriculum in Ireland "places students at the centre of the educational experience, enabling them to actively participate in their communities and in society" by offering experiences that are engaging and enjoyable for them (NCCA, 2015). Inquiry-based learning is considered as a main approach in learning science in which students are encouraged to ask questions and analyse events and phenomena. Science content knowledge and scientific reasoning can be fostered through active pedagogies that support student-centred inquiry based pedagogies (Mooney Simmie, 2022).

In teaching physics to young people, interactive simulations or ICT-enhanced approaches to learning allow students to explore phenomena that can be challenging to experience otherwise in the classroom and/or the science laboratory (Van Vo & Csapó, 2021a,b; 2020). A simulation often includes a physical system represented in different ways, such as pictures, graphs, words, diagrams, and data tables. As students observe connections between representations, how one variable affects another, they can gain a deeper understanding of concepts. Interactive simulations therefore support teaching science to young people for understanding. In addition, simulations allow student to visualize a concrete situation, which can help build psychological models of physical, chemical, and biological systems. By using simulations, students can be assisted to visualize the big ideas and concepts they hear in classrooms and/or read in textbooks.

A simulation can provide young students with engaging, hands-on, active learning opportunities. Teachers and student can experience a sense of control when exploring scientific concepts and phenomena through interactive simulations. Additionally, simulations are great tools to help students recognize and visualize how equations relate to observations and measurements. Using a simulation, the students can readily vary parameters and see in real time the effect of these variations. Such virtual experiments are likely to save a lot of time and financial resources in comparison when doing live experiments in the science laboratory. At the same time, we are not recommending here that teachers and student should somehow stop laboratory experiments, just that ICT-enhanced simulations have multiple advantages for teachers and students as they learn the big ideas and concepts underpinning science curricula and test them in a virtual platform. Simulations can support teachers in most activities from teacher demonstration experiments to student investigation experiments, both at home and at school. Empirical studies reveal that students' hands-on experience both virtually and physically with such phenomena can support science for understanding and the deep learning of many important and challenging physics concepts (Hake, 1998).

In this EPI•STEM-HEA booklet, we introduce a brief of inquiry-based instruction, followed by upskilling in physics content knowledge and providing guidelines and pedagogical strategies as exemplars for applying interactive simulations in teaching some notable concepts in the physical world section of Junior Cycle Science Curriculum and the Senior Cycle Physics Curriculum. We introduce relevant concepts of physics in exemplars and as checkpoints. We want sometimes to pitch the content knowledge base at a slightly more advanced level than the content knowledge specified in the science curricula in junior and senior cycle. Our aim here is to emphasise common misconceptions and to work with upskilling new physics knowledge for teachers beyond what presented in the secondary school textbooks. We believe that the greater facility science teachers have with physics ideas and concepts themselves the more confidence they will have in facilitating an inquiry-oriented classroom. We try to link science content knowledge in general to "adapted content knowledge" which are presented in numerous published textbooks at particular grade levels. These may all help to contribute to science teachers 'confidence in teaching aspects of physics in their classroom. Teaching strategies we suggested in each exemplar are to refer to inquiry based learning and instructions. We designed student activity learning sheets for each exemplar. Science teachers will need to take ownership of these CPD resources and adapt the guidelines depended on the factors of context and culture encountered.

Inquiry-based approach in teaching science

An inquiry-based learning process involves four phases in general: Orientation, Conceptualization, Investigation, and Conclusion. (Fig.1.1).

- *Orientation* phase aims to stimulate interest and curiosity about the learning problem. A problem statement or learning topic introduced into the environment, by the teacher, or by the student learners themselves.

- *Conceptualization* is a process of stating theory-based questions and/ or hypotheses. By questioning a domain, we arrive at open research-like questions, and by generating hypotheses we can arrive at testable hypotheses. In this phase, research questions or hypotheses (predictions or intelligent hunches) are formulated.

- *Investigation* is the phase in which curiosity is turned into action in order to solve a learning problem. It may cover three activities: exploration, experimentation, and data interpretation. An exploration involves systematic investigation aimed at finding a relationship between variables, while experimentation activity considers developing and applying a strategic plan for an experiment. Exploration and experimentation usually go together, and the relevant data are collected. Data interpretation is process of making sense of data analysis and synthesizing new knowledge (a formulation of the relations between variables).

- In the *Conclusion* phase, learners address their original research questions or hypotheses (prediction) and consider whether these were answered, supported and/or refuted. Discussion and application are optional phases of the learning process. During this latter phase, communication and reflection between students and teachers are encouraged with respect to what and how well students learned from the selected topics.

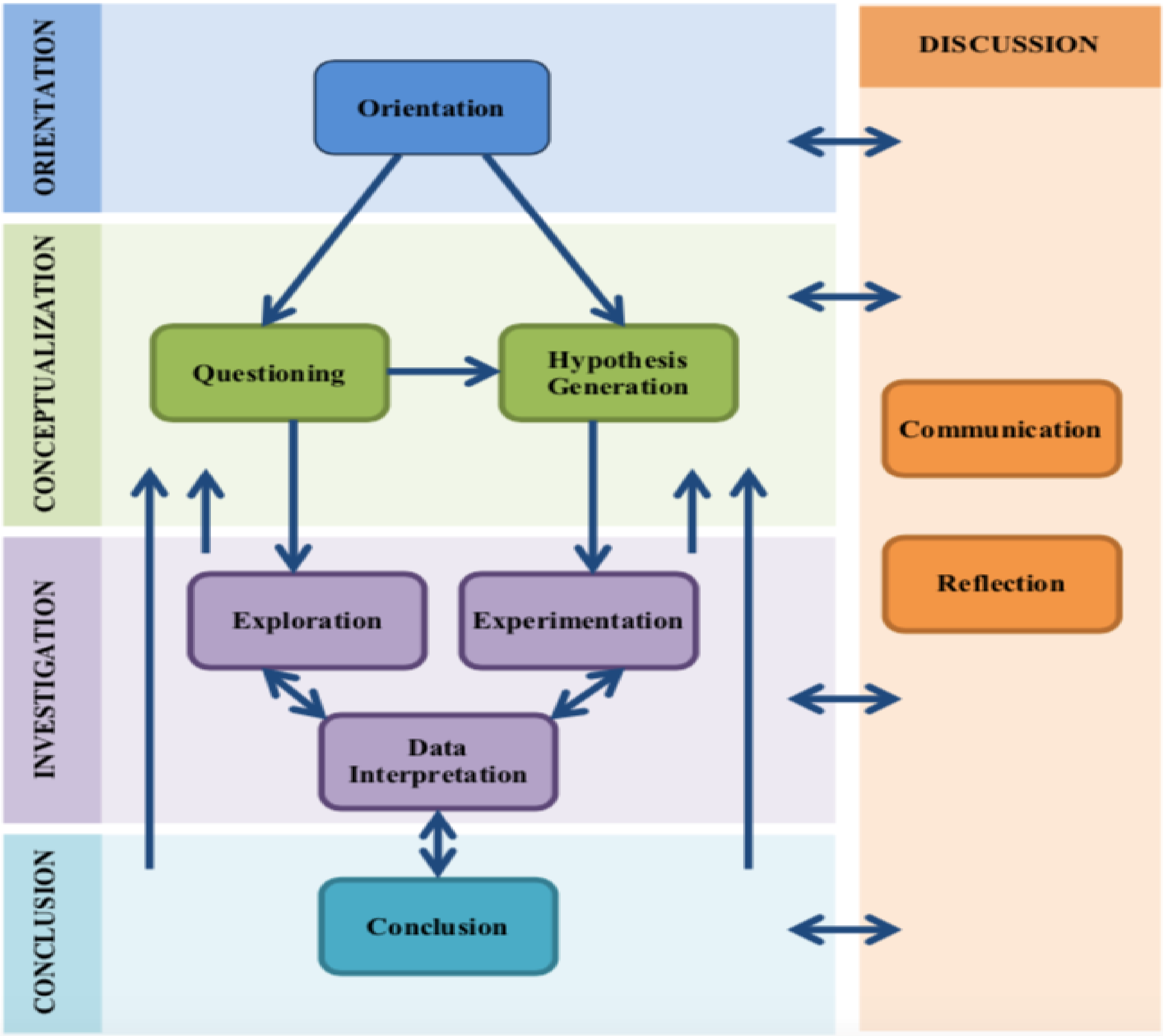


Fig. 1.1. General inquiry-based learning framework (Pedaste et al., 2015)

Investigating speed and acceleration of a linear motion using an interactive simulation

(Suitable for Junior Cycle)

Mechanics is the science of the physical world that deals with the motion of objects. This section in physics, is concerned with measuring and formulating and calculating values in relation to this motion of objects, such as speed, velocity and acceleration. Scientists are very precise about language use and definitions and, in the case of mechanics these precise definitions for different measurements of quantities are supported with mathematical formula. In this way, the section is concerned with defining and measuring certain values [such as speed, velocity and acceleration] and with the instruments and [mathematical] formulae derived for measuring motion.

Understanding how motion is defined and calculated plays a principal role not only in learning mechanics but also underpins many other branches of the physical world. Therefore, the measurement of objects in motion is often introduced in the first part of most physics textbooks. The following section introduces the learning outcomes, states the relevant content knowledge and suggests pedagogical approaches in teaching this topic using our interactive simulation package.

Learning Outcomes

Through the activities, students are able to:

- Identify and measure/calculate distance, time, speed and acceleration.
- Investigate patterns and relationships between distance-time, velocity-time.
- Recognise questions that are appropriate for scientific investigation, pose testable hypotheses, and evaluate and compare strategies for investigating hypotheses
- Produce and select data, critically analyse data to identify patterns and relationships, identify anomalous observations, draw, and justify conclusions.

Relevant content knowledge

1. Motion

An object's motion can be defined as its change in position over time. A change in the object’s position from an initial position to a final position is called displacement or distance. An object usually travels inconsistantly, and it can be speeded up, slowed down, stopped or even reversed direction. To describe motion in physics, some central quantities are defined: distance, speed, velocity, and acceleration.

2. Speed and velocity:

In the 100 metres race, the current world record for men's athletics is 9.58 seconds, set by Jamaican Usain Bolt at the 2009 World Athletics Championships (Germany), while

Florence Griffith-Joyner of the United States has set the current women's world record at the 1988 Olympic Trials (US) with 10.49 seconds.

How do we measure the runners' speed? Just a moment after the finish of a race, the time of the runners will be recorded on a score board. If the race was over 100 meters for example, you may think that the speed that a runner ran the entire distance could be worked out using the time. However, you would be wrong in the case. At a rest, as the starter gun fired, the runners ran faster (or accelerated) to get moving. Of course, they may run steadily for most of the middle parts of the race and then accelerate as much as they can for the final lap (Fig.1.2). *Speed is a measure of this distance covered by an object in a certain time.*

Fig. 1.2. Athletics speed up to reach the destination

We ask how fast a particle/object is moving at a given instant, which refers to its instantaneous velocity (or simply velocity). In general, we refer the average velocity of a particle, which is defined as the ratio of its displacement to the time interval. Meanwhile, the average speed of a particle is defined as the ratio of the total distance covered to the time interval. Therefore, speed is different from velocity in that speed does not depend on direction, and *hence speed is always positive*. In many cases, speed might be the same as velocity. In Junior Cycle level, to make the concept understandable for young students, we introduce objects moving in a straight line (one dimension). We also ignore properties such as the vector quality of velocity, so speed is often used interchangeably with velocity. To short, speed is calculated as follows (Fig.1.3):

$$\textbf{Speed} = \frac{\textbf{distance}}{\textbf{time}}$$

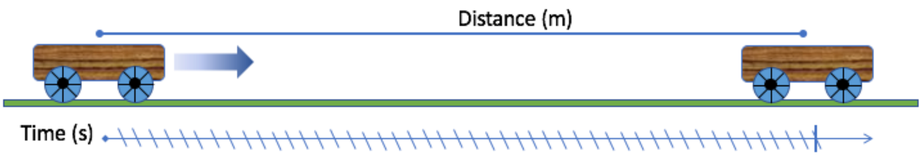


Fig. 1.3. Speed of the trolley is calculated by the distance per time it took during the distance.

Units for speed and velocity:

According to International System of Units (SI), which are founded on seven base units, the distance (length) is measured in metre (m) and time is measured in second (s). Therefore, unit we use for speed and velocity is ***m/s*** or ***ms^{-1}***.

To measure speed of an object, there are several means available. Fig.1.4 shows pictures of equipment used to measure speed in real life and in the Lab. The speedometer in a vehicle is connected to shaft of wheels. It informs the speed of a vehicle when the wheels turn. The speed gun is a kind of radar gun. By comparing the time difference between the incident and reflected ray beam when it fires to an approaching vehicle. It's a system based on the speed of the radar wave and the time difference to calculate the vehicle's speed. Stopwatches have been used for many years to measure an objects' s speed. Stopwatch was started when an object passed the start line and was stopped as a subject passed the finish line. We can use a stop watch manually or automatically [with light gates] to measure time accurately.

Speedometer   Speed gun   Stopwatch

Fig. 1.4. Speed meter, Speed gun and Stopwatch are instruments for measuring speed

3. Acceleration

When the velocity of an object changes with time, the object is said to be accelerating. Acceleration is defined as the ratio of the change in velocity to the time interval. Because velocity is a vector quantity, the change in velocity is understood as the change in both its value and direction. Acceleration is therefore a vector quantity. Like velocity, in physics, it defines the average acceleration and the instantaneous acceleration. In one dimension, acceleration can be in the same or in opposite direction with respect to the direction of motion, or even it is zero. When the final velocity is higher than the first velocity, the acceleration is positive. In contrast, when the final velocity is lower than the first velocity, acceleration is negative (called deceleration). In Junior Cycle Science, we just consider a linear motion in one dimension with a constant acceleration. Therefore, acceleration is calculated using the following mathematical formula (Fig.1.5):

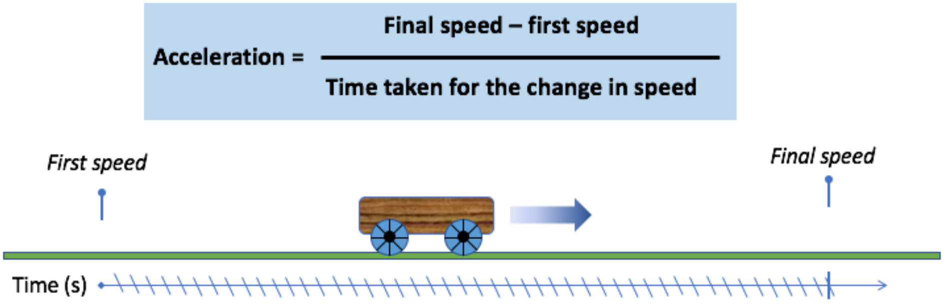


Fig. 1.5. Acceleration of the trolley is rate of change in velocity (speed) to final speed divided by the time taken for the change.

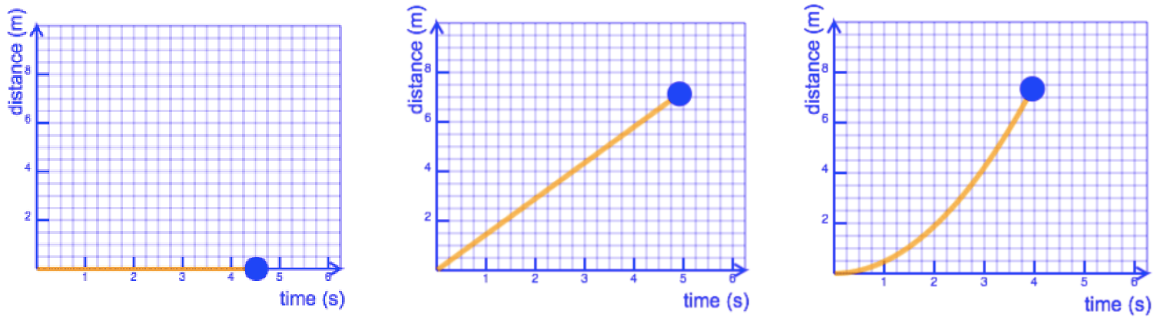
Units for acceleration:

The distance (length) is measured in metre (m) and time is measured in second (s), then unit of velocity is ***m/s*** or $\boldsymbol{ms^{-1}}$. Therefore, SI unit of acceleration is $\mathbf{m/s^2}$ or $\mathbf{ms^{-2}}$.

4. Graphs of motion

Physics does not just use precise definitions and equations to explain how object move, but it also uses graphs. The graphs can visually provide useful information about an object's motion. The shape of a graph tells us information about the relationship between two quantities. Interpreting motion graphs requires basic mathematical knowledge (i.e., how to find slope). Because all of these are visual representations of a motion, it is important to know the frame of reference. Here we note that two people can observe the same event but describe it differently depending upon where they stand (frame of reference). In Junior Cycle Science, we implicitly default that time and position, when observations start, is set zero of the frames. How to set a frame of reference will be introduced in detail at Senior Cycle Science level.

There are three types of graphs in the study of motion: position (distance) - time graph, velocity (speed) - time graph, and acceleration - time graph. Position – time graph includes a vertical axis, Position (in meters) and a horizontal axis, Time (in seconds). It provides information of how far away an object has moved from the observer at any given time. Based on the graph, we can directly determine the position of the object without applying the mathematical formula. For example, at time of 4 s (horizontal axis), we can determine the positions of 0 m (Fig.1.6a), 4.8 m (Fig.1.6b) and 4.5 m (Fig.1.6c). To do this, we draw a line at 4 s (in Time axis), and this line parallels with distance axis. The line meets the plot at a point, then at this point we draw another line paralleling with the Time axis. This line meets the distance axis at a point, so the value of the point is position (distance) that we are looking for. Generally, there are only three possible shapes for a distance - time graph in the Junior Cycle physical world section of motion: flat/zero (Fig.1.6a), diagonal (Fig.1.6b) and parabola (Fig.1.6c).



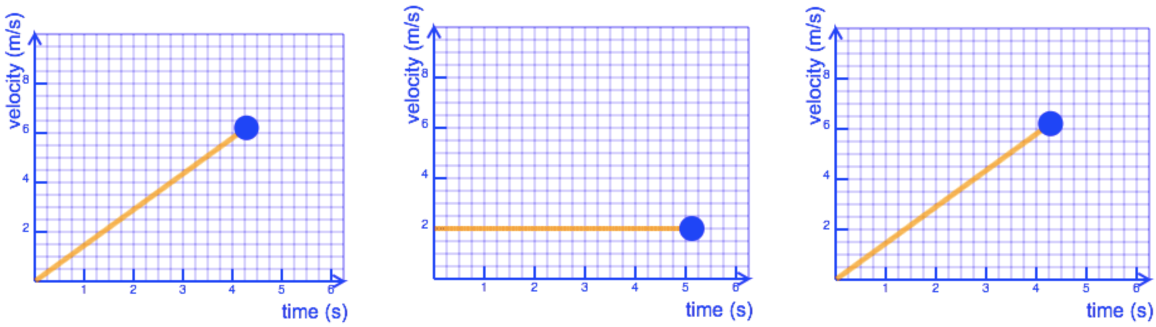
a) The graph shows an object did not move over the time observed

b) The graph shows an object moving steadily away

c) The graph shows an object moving acceleratively

Fig. 1.6. Three kinds of shapes of the distance – time graphs

Similar to distance-time graph, but now the vertical axis is set to velocity in meters per second. This provides information of how the speed of an object has changed over time during the time an observation started. From the graph, we can determine the velocity of an object at any given time. For instance, at time of 4 s, the graphs tell us velocity of 0 m/s (Fig.1.7a), 2 m/s (Fig.1.7b) and 4.8 m/s (Fig.1.7c). In Junior Cycle, we only consider three possible shapes of the velocity - time graph: zero (Fig.1.7a), flat (Fig1.7b) and diagonal (Fig.1.7c).



a) The graph shows an object at rest over time

b) The graph shows the object travelling with a constant velocity

c) The graph shows the object travelling with a steadily increasing velocity

Fig. 1.7. Three kinds of shapes of the distance – time graphs

In physics, we can work out that the slope of the tangent to the velocity-time graph gives the acceleration, while the slope of the tangent to the position-time graph is velocity (Fig.1.8). However, this knowledge is not subject of study in the Junior Cycle science curriculum.

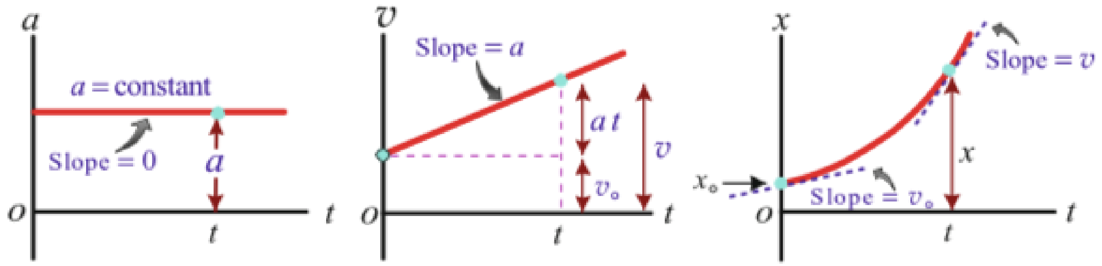


Fig. 1.8. Relation between the quantities in motions

Using an interactive simulation in teaching quantities of a motion

Presently, we are developing online resource package to support science teachers not only to update content knowledge but also to support upskilling in pedagogical content knowledge. In this part, we propose using simulative scenarios regarding inquiry-based approaches. This package is available online. In general, the package includes an interactive simulation with an instruction, relevant content knowledge and inquiry-based activity student sheet (Fig. 1.9). We introduce guidelines for science teachers.

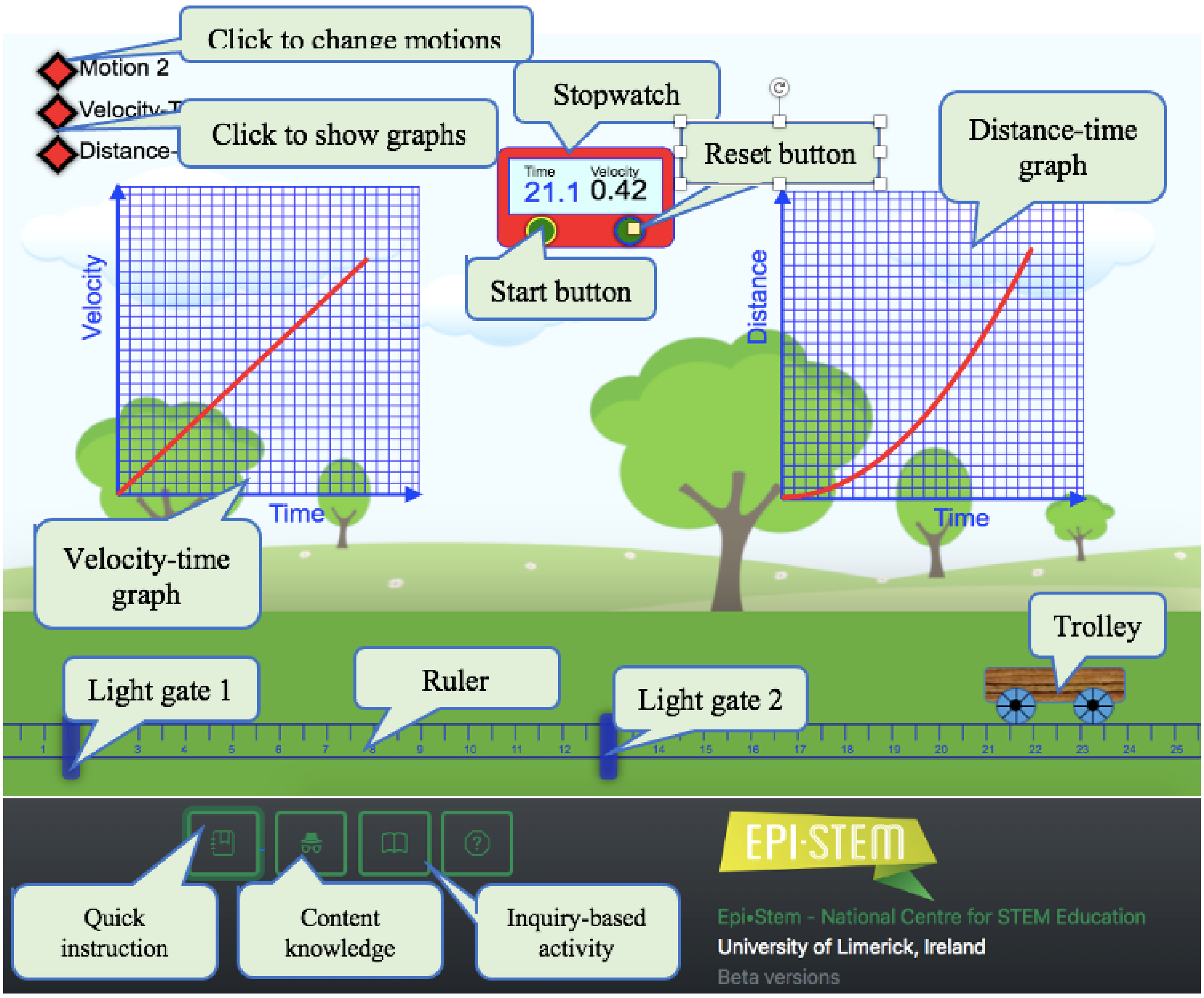


Fig. 1.9. The screenshot of the speed, velocity and acceleration simulation package

To access online version (click Link or scan QR code)

Fig. 1.10. The Orientation phase in the simulation package

Activity 1. *Conceptualization of motions*

- The teacher can introduce motion or ask students (see Student Sheet below).
- After student's respond to the questions, the teacher corrects the responses, and reminds students of the accurate definition *"Speed is a measure of this distance covered by an object in a certain time"*, including the formula and unit of speed.
- The teacher can introduce the accurate definition "*Acceleration is defined as the ratio of the change in velocity to the time interva*l." and revise the first speed, final speed, and the unit of acceleration.

Activity 2. Investigating the relationship between speed and time, between distance and time of motion 1

Note: The teacher and students can conduct virtual experiments together in classroom. Teachers can print the student sheet enclosed as handout for students in classroom.

- To investigate motion 1:
  + Place the trolley in right position
  + Click on the Start button
  + Read the time and speed from the stopwatch
  + Measure the distance travelled with the ruler.

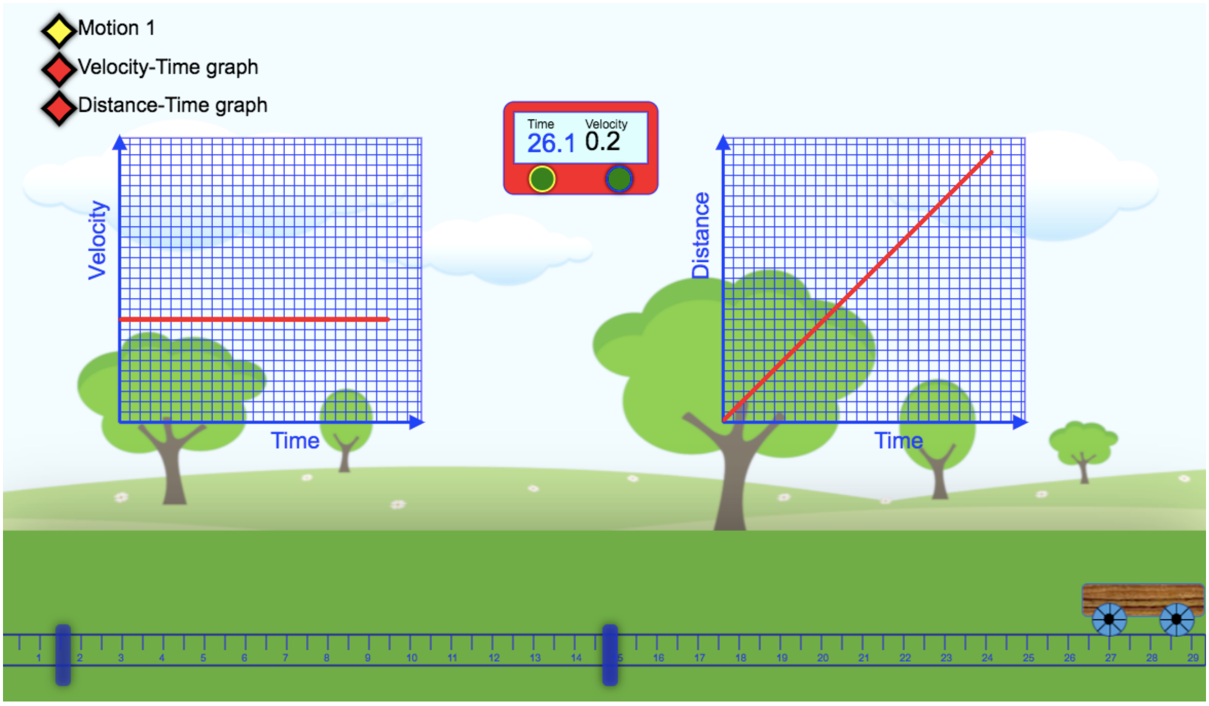


Fig. 1.10. The screenshot of investigating Motion 1 in the simulation package

- After students complete the data collection, teachers can ask students to draw the distance-time graph and velocity- time graph (horizontal axis: Time in seconds). When students finish their tasks, teachers can compare the results of students with the graphs in the simulation (click on the "velocity-time graph" and "distance-time graph" to show/hide the graphs).

- To investigate motion 2:
+ Click on Motion 1 to turn into Motion 2
+ Move and place the trolley in the right position
+ Click on the Reset button to reset the value of stopwatch
+ Repeat the steps as with Motion 1.
- Teachers can compare the properties of graphs between motion 1 and motion 2 (Fig.1.11).

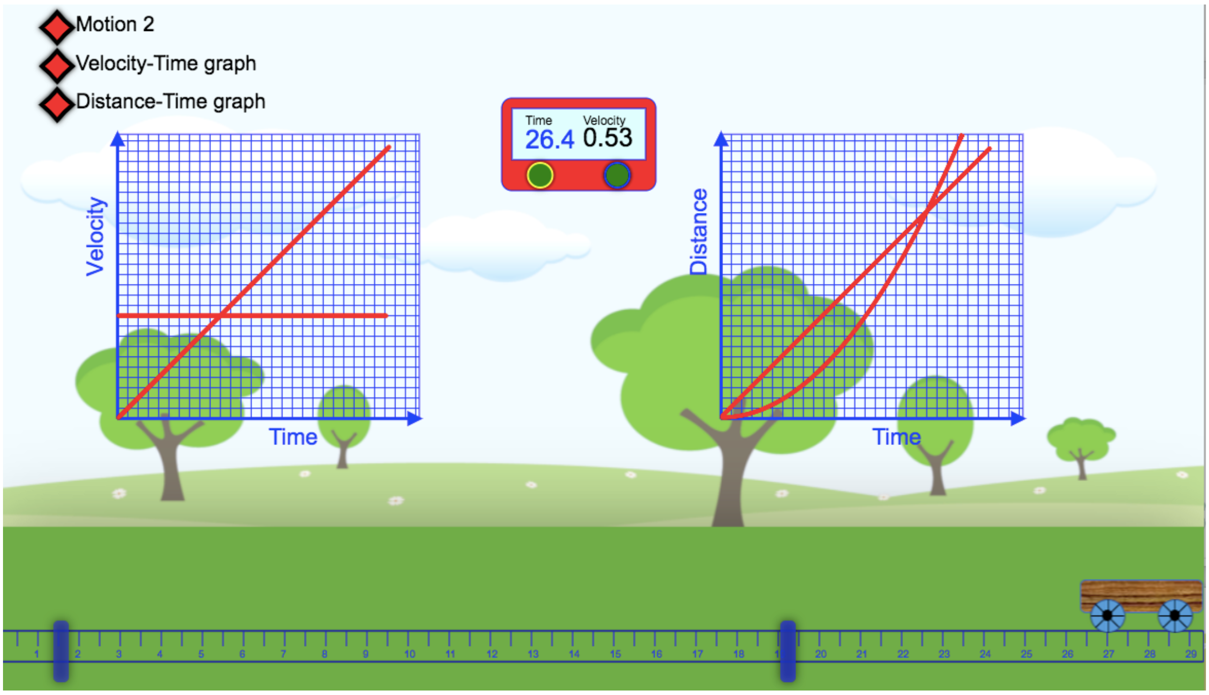


Fig. 11. Simulation plotted the graphs of two motions

- Teachers can explore other features of the interactive simulation package on the website.

Student learning sheet

Investigating speed and acceleration

Name: _________________________________Class: ___________

Introduction

Every day, we are surrounded by many types of motion. Several means of transportation are available for people to travel from one place to another: airplane, train, bus, car, or bicycle. These tasks aim to investigate the relationships between the qualities of a motion by interactive simulations.

To access the simulations with this link or scan QR code above.

Activity 1. Observe different motions around you, which is the fastest one among them? How would you describe this one as faster than the other?

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Activity 2. Relationships between distance and time, between velocity and time of Motion 1

- Your predictions: Is there any relationship between distance and time? In what way do they relate to one another?

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Is there any relationship between velocity and time? What is this relationship like?

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- Assess the online simulation (link) and conduct an experiment with Motion 1 (click on "Motion 1").

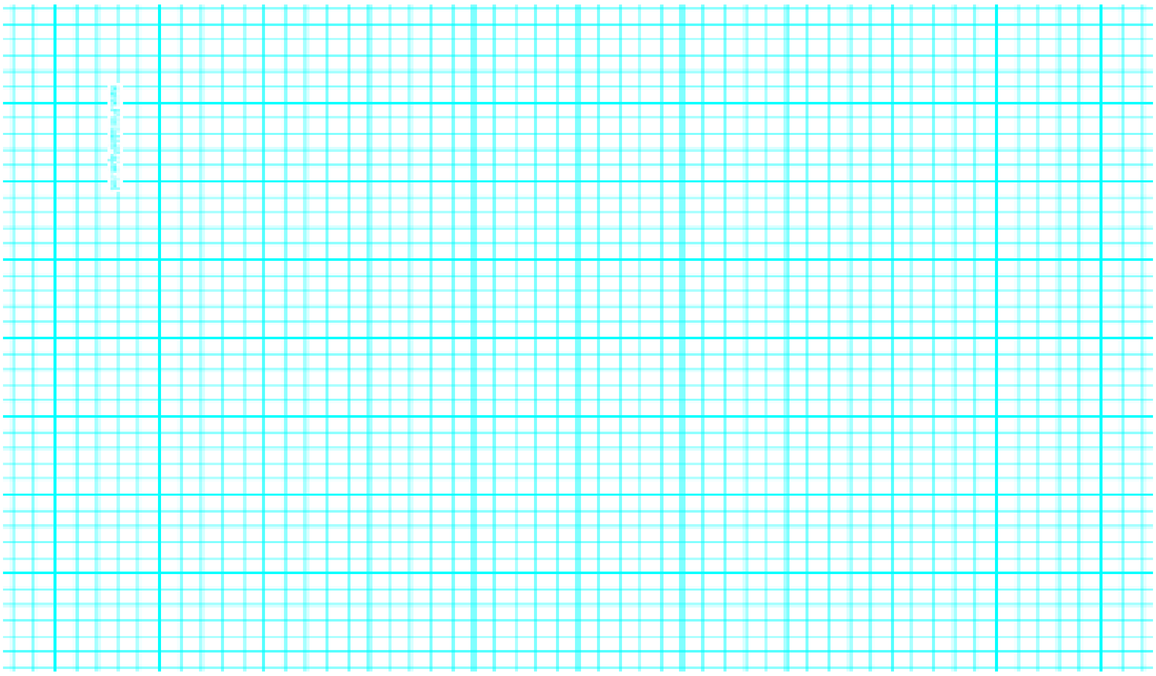
- Observe the motion and read the time, speed and measure by conducting an experiment with the simulation. Complete the table of data:

Table 1. Dataset of Motion 1

Distance (m)					
Time (s)					
Velocity (m/s)					

- Based on the data table, draw a graph to illustrate the relationship between distance (y-axis) and time (x-axis).
- Examine the plotted points on the graph paper.

Fig. 1. The distance-time graph of Motion 1



From the graph, which line shapes can you include? How does distance and time relate?

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Calculate the acceleration of this motion

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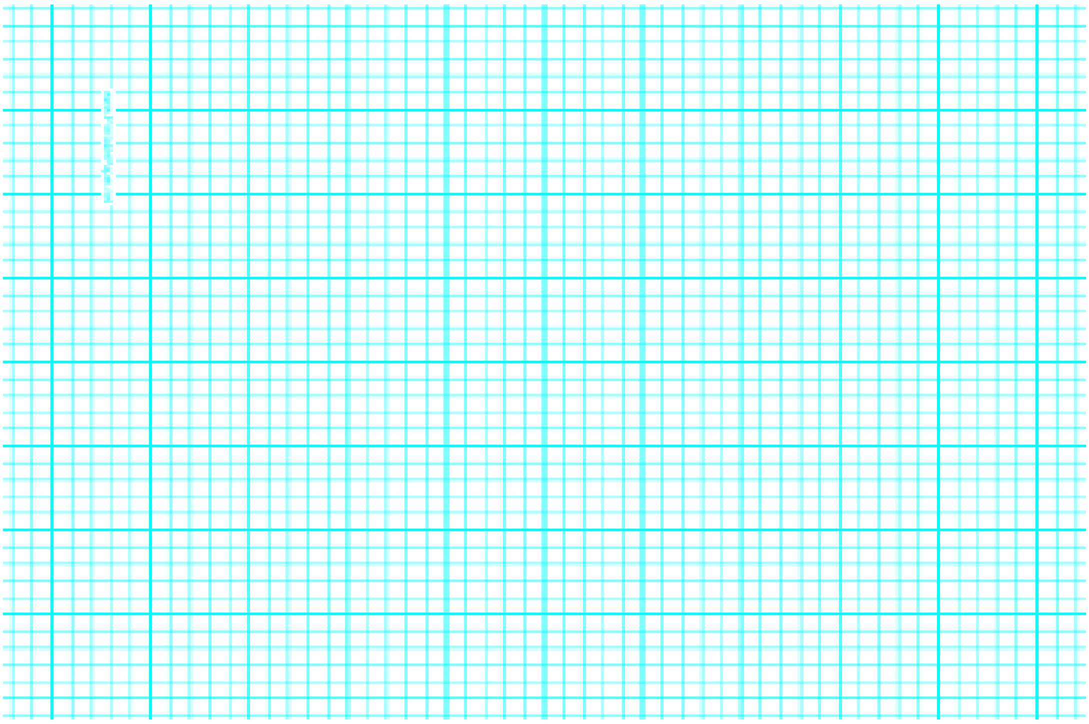
Fig. 2. The velocity-time graph of Motion 1



Which line shapes can you include from the graph? What is conclusion about the relationship between velocity and time

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Activity 3. Relationships between distance and time, between velocity and time of Motion 2 (*Note: This activity can be given as homework for students*)

- Your predictions: Is there any relationship between distance and time? In what way does it relate to one another?

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Is there any relationship between velocity and time? What is the relationship between them?

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- Access the simulation and conduct an experiment with the Motion 2 (click on "Motion 2").

- Observe the motion and read the time, speed and measure distance in the simulative space. Complete the table data:

Table 3. Dataset of Motion 2

Distance (m)					
Time (s)					
Velocity (m/s)					

- Draw a graph to illustrate the relationship between Distance (y-axis) and time (x-axis).
- Examine the plotted points on the graph paper. Is there any line shape in the graph that can be included? In conclusion, what is the relationship between distance and time?

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Fig. 3. The distance-time graph of Motion 2

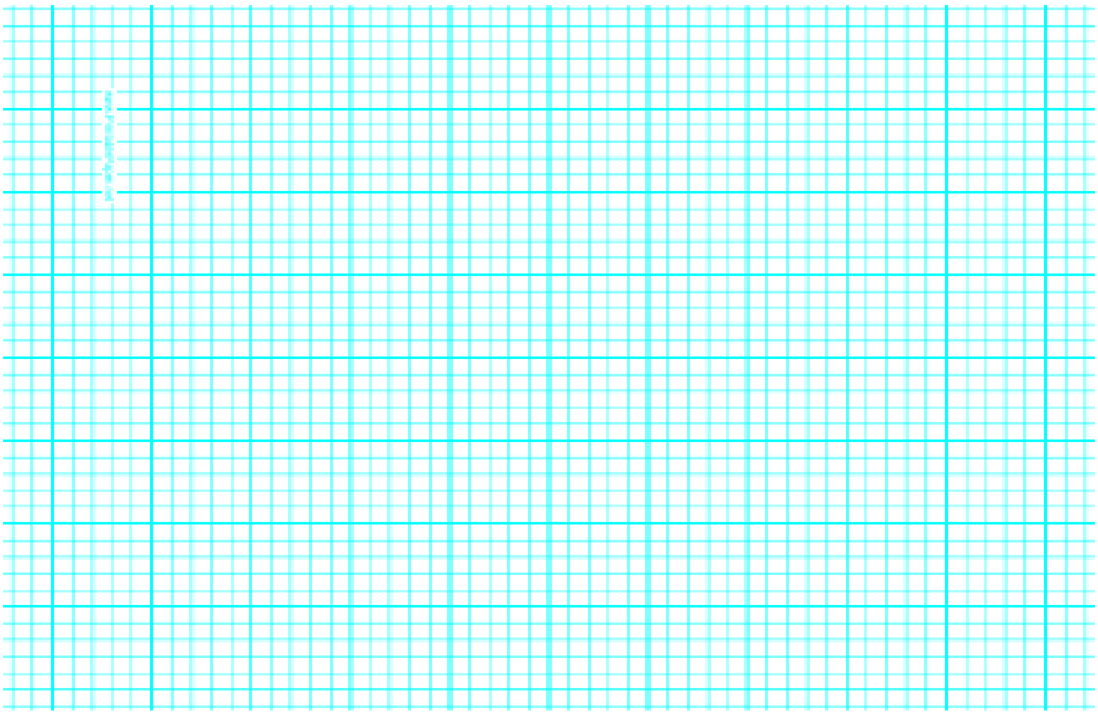
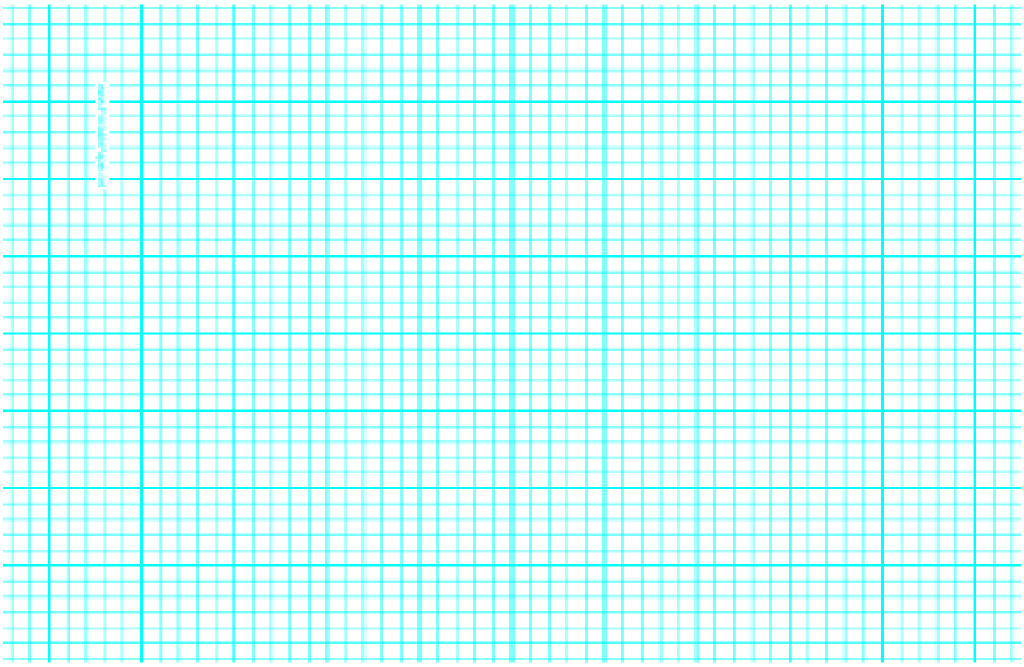


Fig. 4. The velocity-time graph of Motion 2



Which line shapes can you include from the graph? How does velocity relate to time?

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Calculate the acceleration of this motion

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Using an Interactive Simulation to investigate the relationship between the extension of a spiral spring and an applied force

(Suitable for Junior Cycle)

This exemplar will introduce teaching guidelines to conduct virtual experience within PhET to investigate the relationship between the applied force, spring strength and displacement. These activities link to the Junior Cycle Physical World. Teachers can apply it in classroom instruction, homework activities and assessment. A student learning sheet is enclosed in this exemplar.

Learning Outcomes

- To identify the relationship between the applied force, spring constant and the extension of spring
- To design and build a simple mechanical experiment
- To identify dependent and independent variables in control of variables in an experimental system
- To use appropriate measuring instruments to collect data, analyse and interpret data and draw conclusions

Relevant content knowledge

1. Force:

A force is a push or pull on an object that can change the state of the object's motion. If a force applies on an object, it can cause:

+ An object can change from a stationary state to travel.

+ A moving object can move more quickly, move more slowly or change the direction of the object's motion.

Force has magnitude and direction, so it is vector quantity.

Units: The SI unit of force is Newton (N). Force is represented by the symbol *F*.

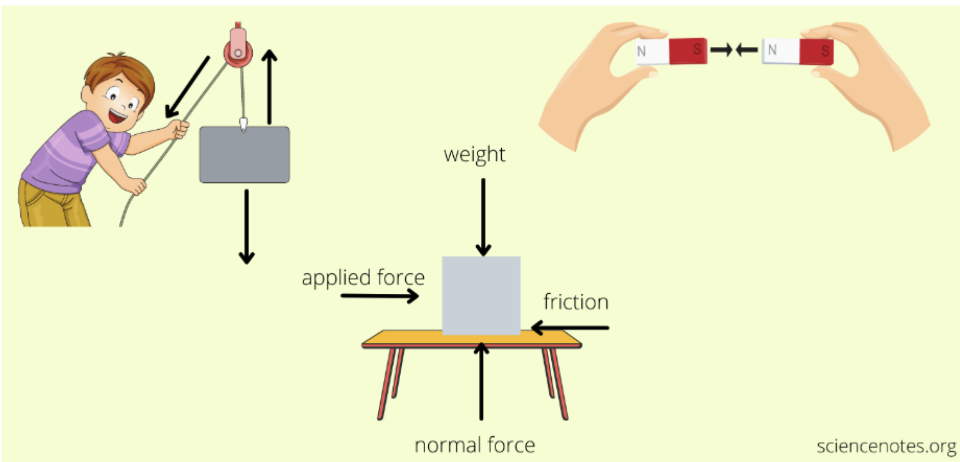

Fig.2.1 Illustration of some common forces

All forces in the universe are classified into four fundamental interactions. The gravitational force acts between masses. The electromagnetic force acts between electric charges. Strong and weak forces act only at very short distances and are responsible for the interactions between subatomic particles (i.e., nucleons and compound nuclei). All forces found in nature derive from these four fundamental interactions (Fig.2.1).

2. Weight and mass

The weight of an object is defined as the force of gravity on the object. Weight is the acceleration due to gravity multiplied by an object's mass. It may be calculated as mass times the acceleration of gravity, w = mg. For the Earth, the weight of an object is the force pulling an object towards the centre of the earth. At ground level, the acceleration due to gravity is around 9.81 m/s^2. It is noted that the acceleration of gravity can change due to location and height of the object in comparison with the ground we observe. With the same object (i.e., 1.0 kg), on the moon its weight is six times lower than on the earth, even though its mass is still 1 kg.

In Junior Cycle level, it is important to explain the concept in a way that young people can readily grasp and understand. Acceleration of gravity, is therefore chosen as 10 m/s^2, so we introduce a simpler formula to covert mass to weight:

weight (in newtons) = mass (in kilograms) × 10

3. Forces in springs (Hooke's Law)

The forces in springs, modelled by Hooke's law, are produced by electromagnetic forces. If a spring is compressed, a force with magnitude proportional to the decrease in length from the initial (equilibrium) length is pushing each end away from the other. If a spring is stretched, then a force with magnitude proportional to the increase in length from the equilibrium length is pulling each end towards the other. In other words, the force of the spring is directly proportional to the extension of the spring.

Mathematically, Hooke's Law is stated as follows:

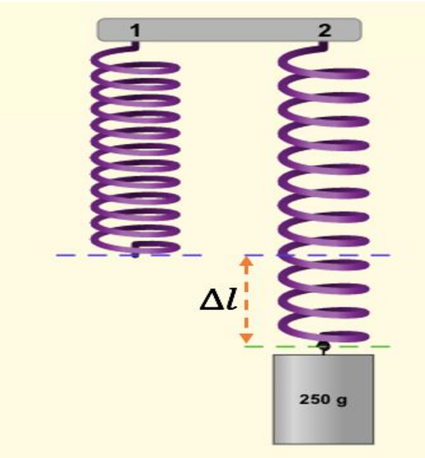

Fig. 2.2 Extension (Δl) of the spring caused by weight of the mass

$$\mathbf{F = k \times \Delta \mathit{l}}$$

Where: k is spring constant, Δl refers to the displacement of the spring, i.e., the difference between the current length and the rest length. The rest length is defined as the length of the spring in a state of equilibrium (Fig.2.2).

Experiment 1. Relationship between the extension of a spring and the applied force Experimental activities

- Access the PhET Simulation (click link). In the space of Interactive Simulation, there are two springs, three different masses (50 g, 100 g, 250 g) and a ruler in centimetres. The weights and ruler can be moved by a drag-drop method, while spring strength can be adjusted in the control board in the top of the screen (Fig. 2.3). Noted that spring strength = k^{-1}, k: spring constant. Resting positions, unstretched length and moveable line can be visualized by selecting the radio buttons accordingly on the right top of the screen. In this experiment, we use one spring and fix its spring strength at a particular value you select.

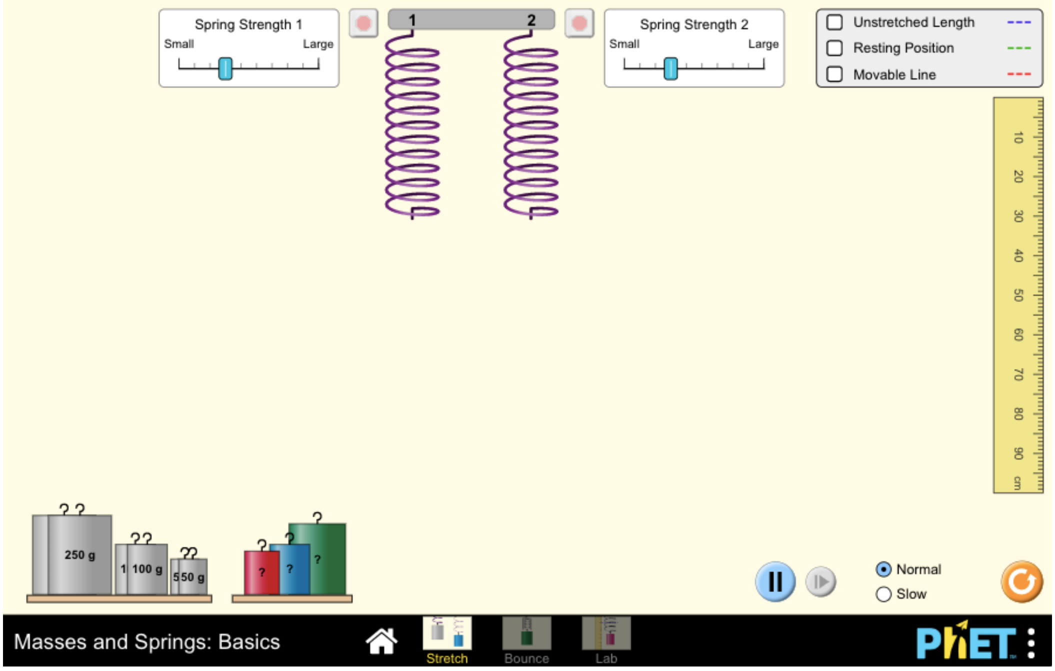

Fig.2.3 The screenshot of the virtual space of the Interactive Simulation

- Set spring strength at a particular level (i.e., set at the third line).
  - Move and place a 50 g mass on the holder of the spring selected.
  - Check on the resting position and unstretched length buttons
  - Move the ruler to an appropriate position to measure the extension of the spring (Fig. 2.4).
  - Write out the values on the table data.

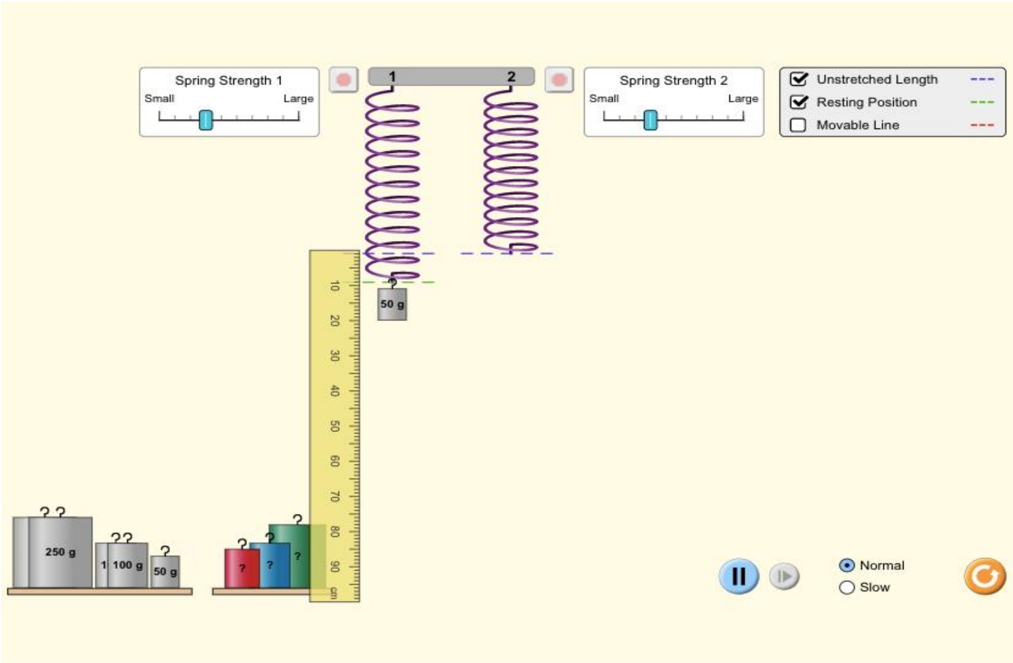

Fig. 2.4 The screenshot of measuring the extension of the spring

- Remove the 50 g mass and place the 100 g mass on the holder of spring.
- Repeat the procedure and record the values on the table.
- Continue this procedure with 250 g mass and write the values in the table.
- Draw a graph to illustrate the relationship between the extension of the spring and applied force.

A sample of data in the virtual experiment.

Mass (g)	50	100	250
Applied Force (N)	0.5	1.0	2.5
Extension (cm)	9	17	42

Table 2.1. Sample data set (note: spring strength is set at the third line level)

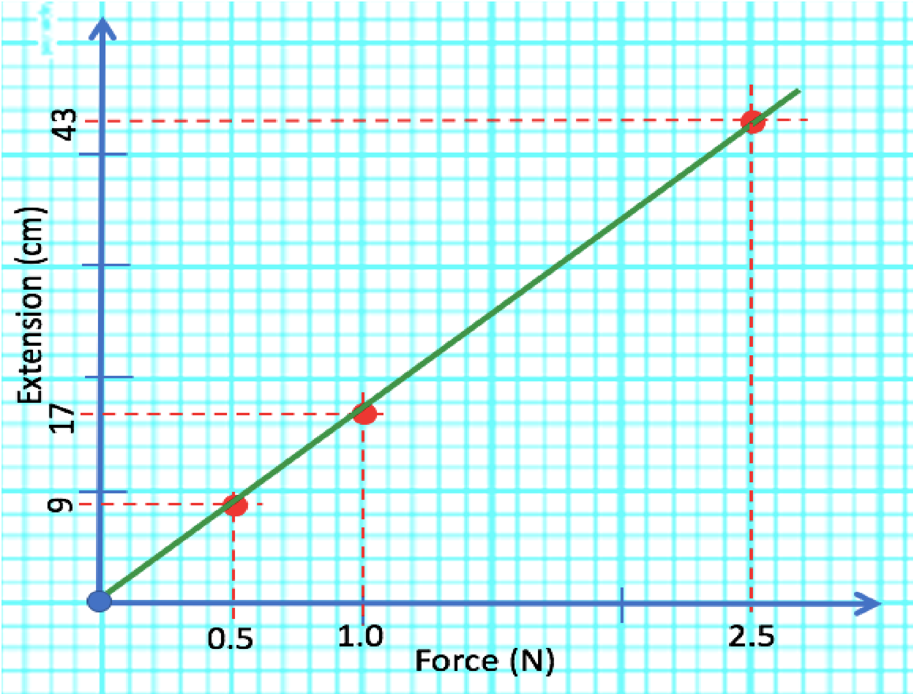

Fig. 2.5 Extension plotted against force applied

Conclusion: Force of the spring is directly proportional to the extension of the spring.

Experiment 2. Effect of spring strength on the extension of a spring and an applied force

Experimental activities:

All steps are demonstrated similar to the first experiment, but we use two springs with different spring strengths (i.e., the first spring strength is set at the second-line level. The second spring strength is set at the fourth-line level (Fig. 4).

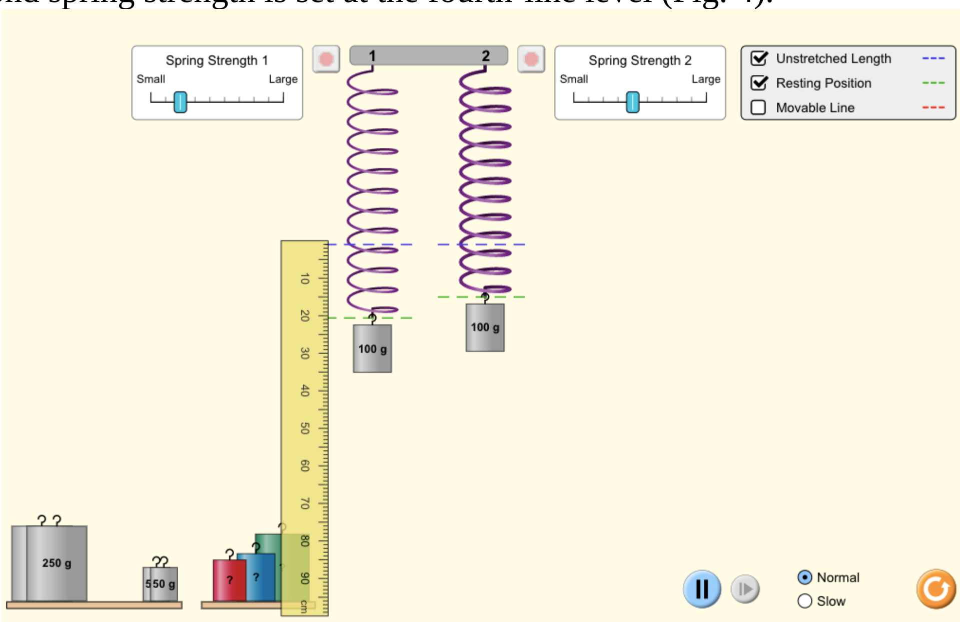

Fig.2.6. The screenshot of exploring the extensions of the springs following the spring strength

We add one new row for Spring 2 in the table data. Draw plots to illustrate the relationship between the extension of the spring and applied force of each spring in the same graph. The teacher asks students to interpret the data and reach conclusions.

Table 2.2 demonstrates a data table from Experiment 2:

Mass (g)	50	100	250
Applied Force (N)	0.5	1.0	2.5
Extension 1 (cm)	10.0	20.0	49.0
Extension 2 (cm)	7.0	14.0	35.0

Table 2. 2. Sample data of Experiment 2

*** Note:** The first spring strength is set at the second-line level. The second spring strength is set at the fourth-line level

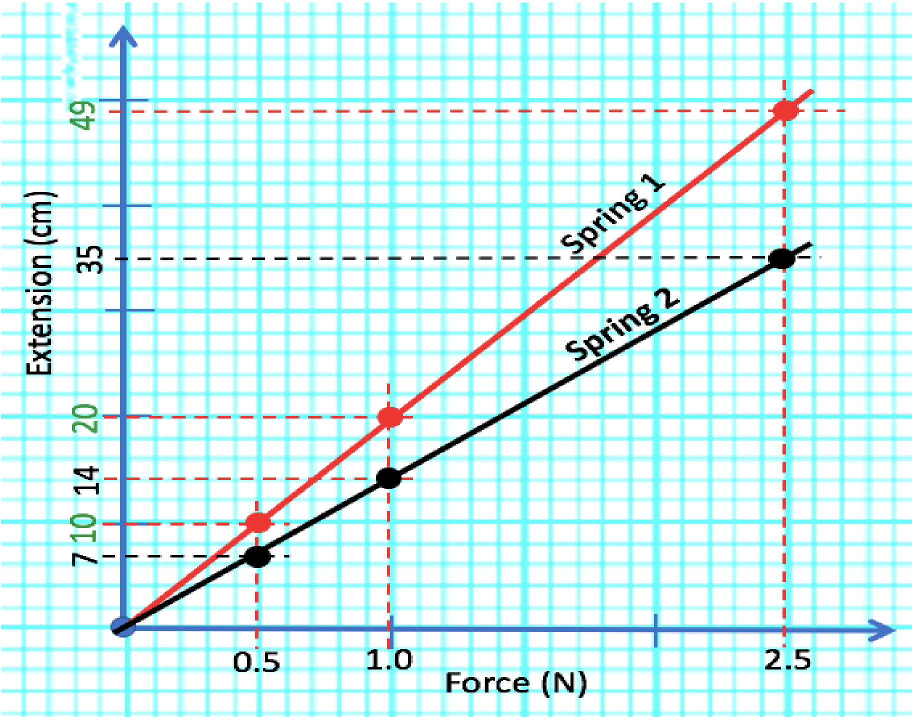

Fig. 2.7 Extension plotted against force applied of two different springs

Conclusion: The spring strength impacts the extension of the spring. With applied force, the extension of the spring is directly proportional to the spring strength.

Student learning sheet

Mass and Spring

Name: ____Class: ___________

Introduction:
Hooke's law is a law in physics that describes the relationship between the force needed to extend or compress a spring scales and distance. It is named after the British physicist Robert Hooke, who sought to demonstrate the relationship between forces applied to springs and their elasticity in the 17th century. This law still plays an important role in modern physics.

Activity 1. Weight and mass
Calculate the weights of the objects of masses of 50 g, 100 g and 250 g.

50 g $\rightarrow$ N

150 g $\rightarrow$ N

250 g $\rightarrow$ N

Activity 2. Relationship between the extension of a spring and the applied force

- Assess website Interactive Simulation, choose spring
- Set up a suitable experimental system
- Your predictions: What is relationship between the extension of the spring and the applied force?

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- Conduct the experiment and complete the data table 1.

Table 1. Sample data set for activity 2

Mass (g)			
Applied Force (N)			
Extension (cm)			

- Based on the data table, draw a graph to illustrate the relationship between extension of the spring (y-axis) and applied force (x-axis).
- Examine the plotted points on the graph paper. Which line shapes can you include from the graph? What is conclusion about the relationship between the extension of the spring and the applied force

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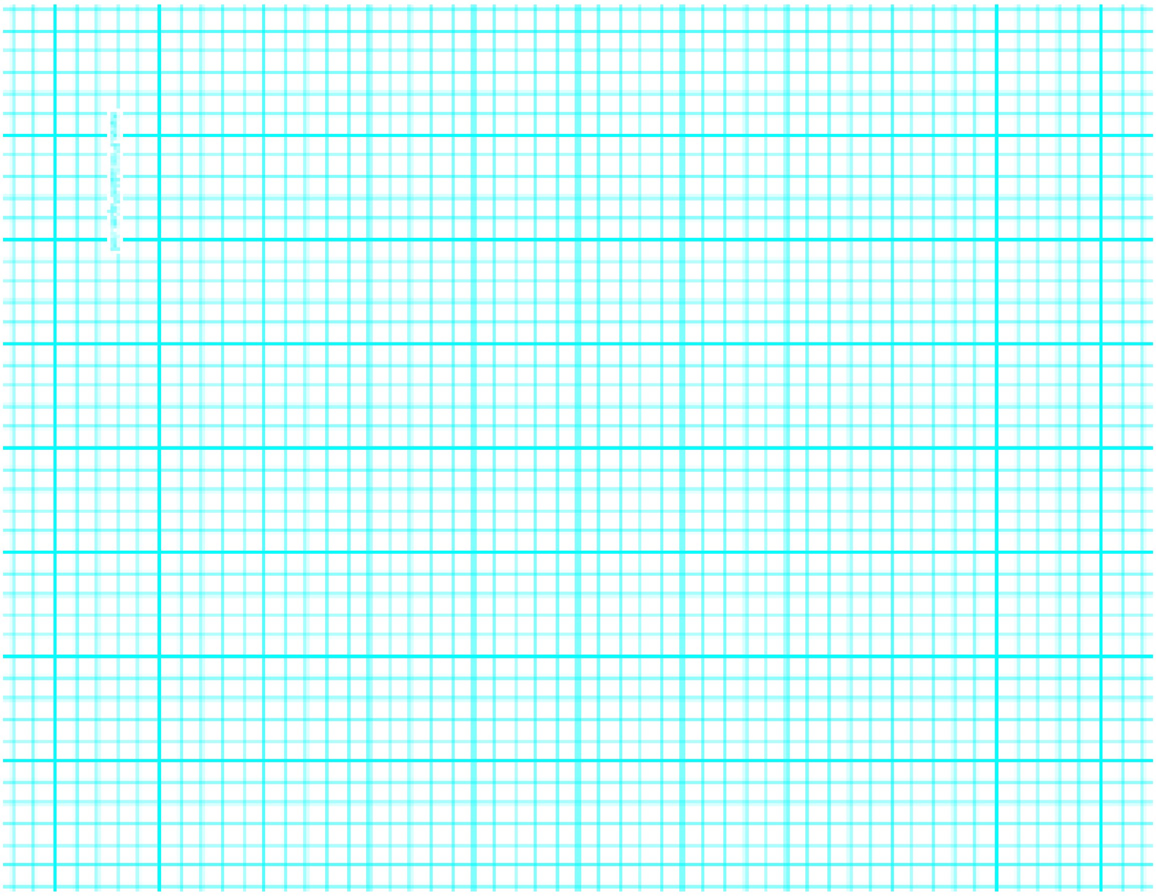
Fig. 1. Extension plotted against force applied



Activity 2. Effect of spring strength on the extension of a spring and an applied force

- Set up an experiment to use two springs with different spring strengths.
- Your predictions: Is there any different effect of spring strength on the extension of the spring if the same force applied on?

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- Conduct an investigation and write the data you collected into Table 2.

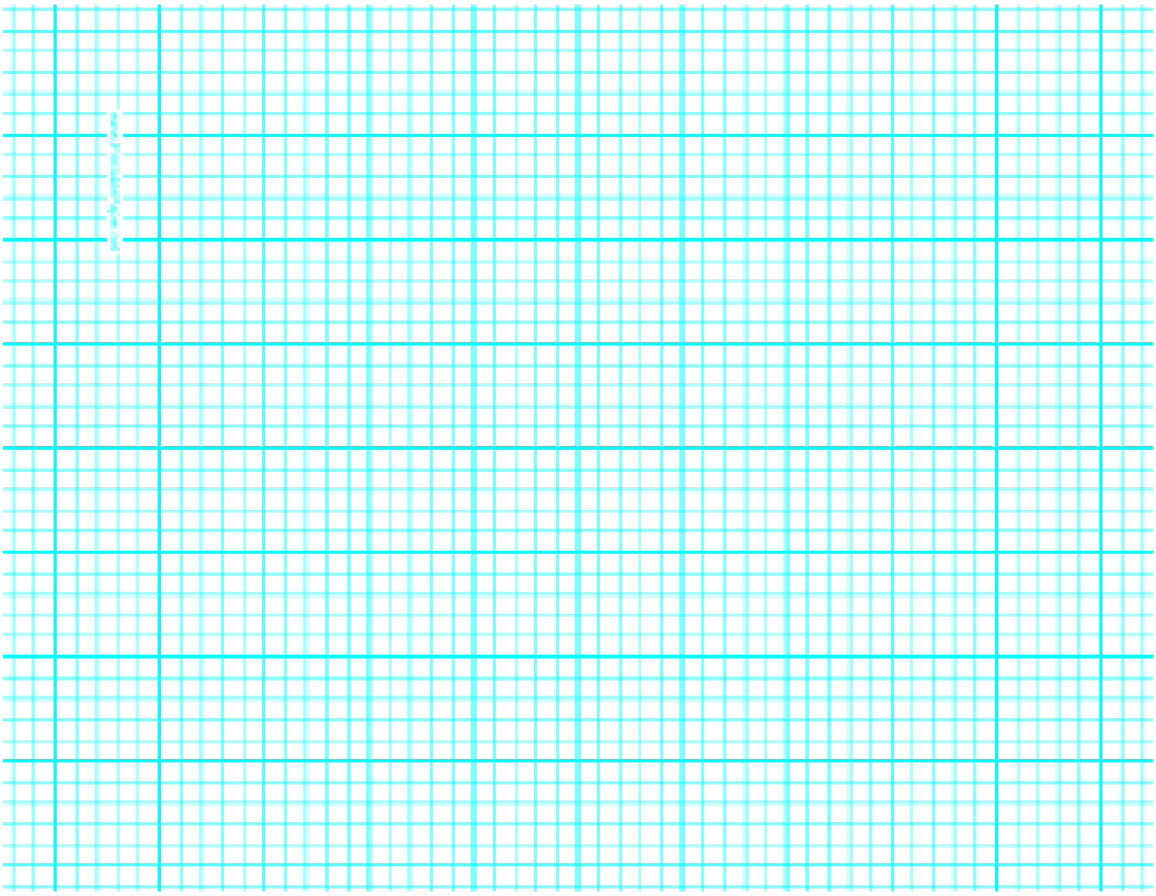
Table 2. Data table for Experiment 2

Mass (g)			
Applied Force (N)			
Extension of spring 1 (cm)			
Extension of spring 2 (cm)			

- Draw plots to illustrate the relationship between extension of the spring and applied force for spring in the same graph.
- Interpret the results and reach conclusions as follows:

+ Which are shape lines of the two plotted data?
+ Which spring has its spring strengths higher?

Fig. 2 Extension plotted against force applied of two different springs



Investigating electromagnetic induction – Faraday's laws with Interactive Simulations

(Suitable for Senior Cycle)

This section introduces guidelines of applying an Interactive Simulation (PhET) as an inquiry-based learning approach for teaching electromagnetic induction and Faraday's Law. Teachers can draw from this instruction for inquiry activities and use it as a teacher demonstration experiment or a student experiment. A learning activity sheet for inquiry activities is attached and can be useful for classroom activities.

Learning Outcomes

- Identify the conditions to create an electric current in a magnetic field by observing effects on the electric current when the magnet moves through the coil
- Identify the relationship between the speed of the magnet and magnitude of the electric current
- Recognize the direction of the electric current depend on the way the magnet moves (i.e., right side, left side)
- Recognize the impact of the coils (i.e., big vs smaller coil) on the magnitude of the electric current.

Research question:

- Which conditions are the magnet field able to generate the electric current?
- Which factors impact the electric current (or voltage)?

Relevant content knowledge

A movement in a conductor can be detected when an electric current in the conductor is moved through a magnetic field. Conversely, an electric current in a conductor can be generated when it is put in a particular position and the magnetic field is varying; or when the magnetic field is stationary, and a conductor keeps moving. This phenomenon is called electromagnetic induction. The current produced in the conductor is called an induced current, and the voltage created across the conductor is known as an induced voltage.

The English scientist, Michael Faraday (1791-1867) discovered the Law of Electromagnetic Induction (Faraday's Law) in 1830. To understand quantitatively Faraday's Law, we need to grasp the concept of magnetic flux.

Magnetic flux

Magnetic flux is measured as the total magnetic field passing through an area. The area can be made any size and oriented any direction relative to the magnetic field.

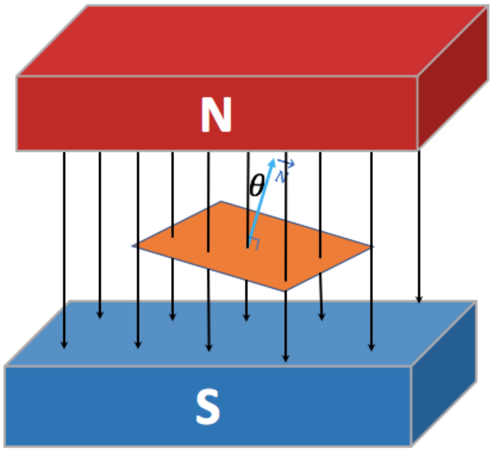


Fig.3.1 Magnetic field lines through a selected area.

If we visualize a magnetic field as field lines, field lines pass through the given area contributing to magnetic flux. The angle at which the field line intersects the area is considered. If field lines pass through at an angle in the same area, it will only contribute a small amount of magnetic flux. In general, the magnetic flux of a magnetic field ***B*** through flat surface with area ***A*** is

$$\Phi = BAcos\theta$$

with θ is an angle between the normal to the surface and a magnetic field vector (Fig.1).

For Senior Cycle physics, we investigate cases in which the surface is perpendicular to the magnetic field, the angle is zero ($cos\theta = 1$). Therefore, the magnetic flux is

$$\Phi = BA$$

The SI unit of magnetic flux is the Weber (Wb). The SI unit of magnetic field is Tesla (T), and area is meter square (m^2).

Faraday's Law

The magnitude of the induced voltage in a conducting coil is equal to the rate of change of the magnetic flux through the coil

$$E = n\frac{Change\ in\ flux}{Time}$$

Where:

- E: inducted voltage
- n: number of turns in a coil.

Lenz's Law

Regarding the direction of the electric current in the coil, Lenz's law states that the polarity (direction) of that induced voltage is such that it opposes the cause of its production. Based on Faraday's law and Lenz's law, the induced voltage in a coil of n turns of the same area is given by:

$$E = -\ n\frac{d\Phi}{dt}$$

Where:

- E: inducted voltage (V)
- n: number of turns in a coil.
- Φ: magnetic flux (Wb)
- t: time (s)

Applying Interactive Simulation in inquiry-based learning (link)
Experimental activities
Activity 1. Conditions to create an electric current

- Put the magnet at a position far away from the coil. Does the bulb light up?
- Put the magnet near the coil or inside the coil. Does the bulb light up?
- Move the magnet toward the coil. Does the bulb light up?
- When we move the magnet through the coil. Does the bulb light up?
- Ask students what conditions generate an electric current in each case.

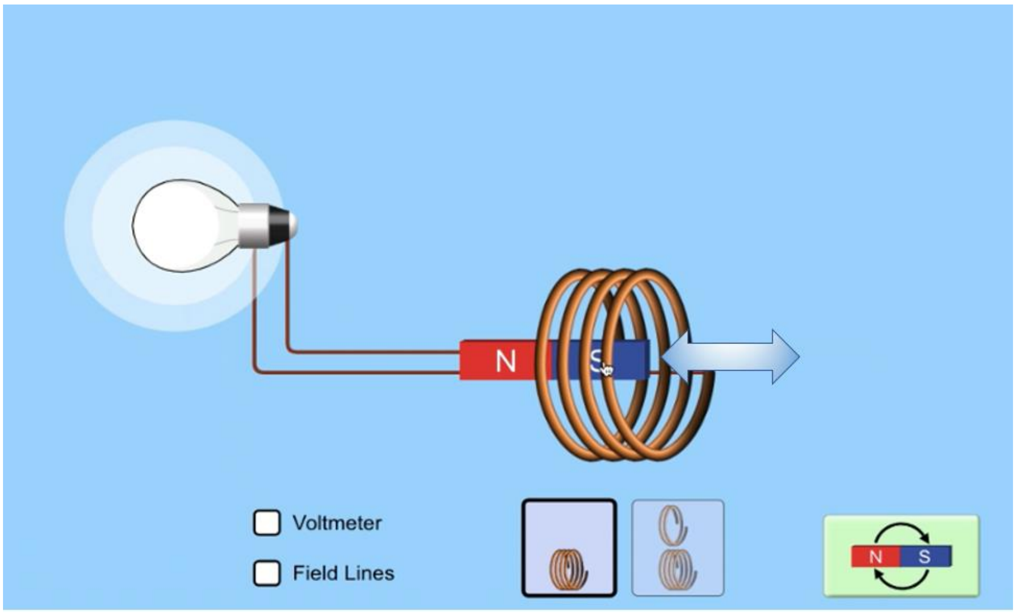


Fig. 3.2. The bulb seemed to light during the time when the magnet is moving

***Activity 2*. Relationship between the speed of the magnet and magnitude of the electric current**

- Click on "Voltmeter" to add a voltmeter for measuring the magnitude of voltage created in the circuit.
- Move slowly the magnet towards the coil: Ask students to observe the brightness of the bulb and the magnitude of the Voltmeter
- Move the magnet faster through the coil: Ask students to observe the brightness of the bulb and the magnitude registering on the Voltmeter

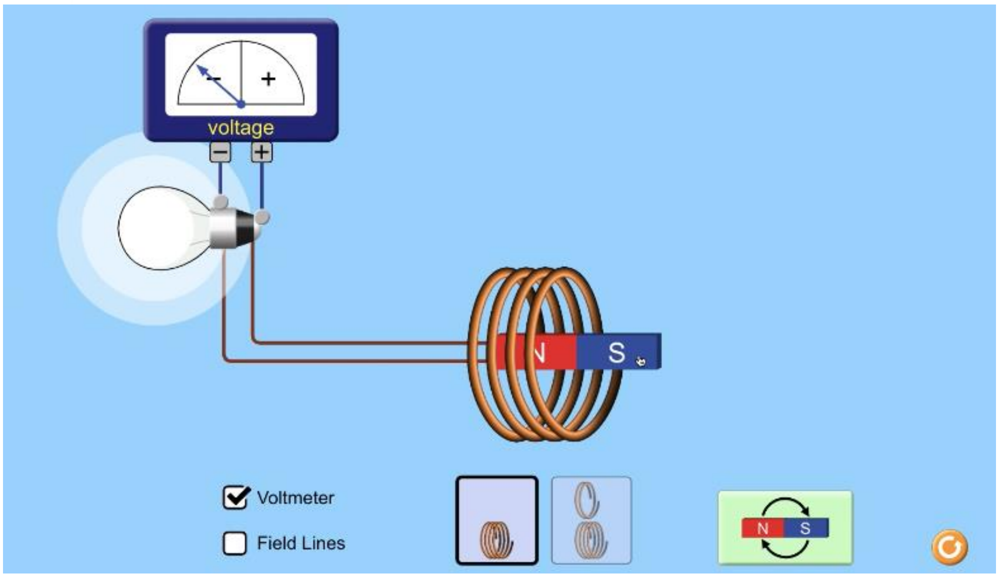


Fig.3.2 The brightness of the bulb and the magnitude and sign of the voltage are higher when the magnet is moving faster

Activity 3. Relationship between the motion of a magnet and the direction of the electric current

- Move the magnet into the coil (from the right side to the left side): Ask students to observe the change of the needle on the Voltmeter
- Move the magnet into the coil (from the left side to the right side): Ask students to observe the change of the needle on the Voltmeter
- Change the poles of the magnet and repeat the steps above.

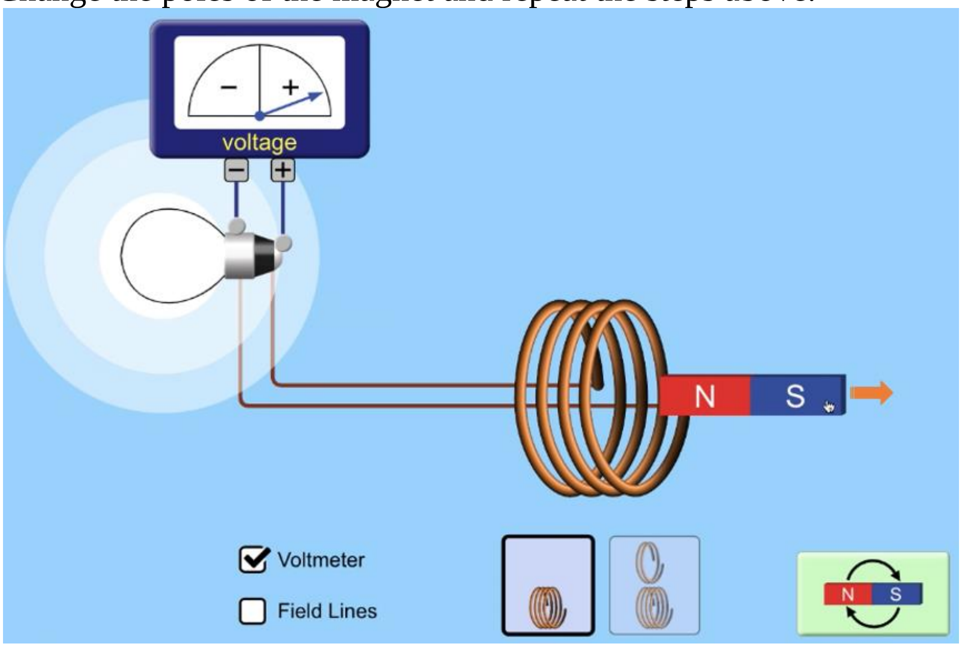


Fig.3.3 The needle shows a positive level when the magnet is moving away the coil

Activity 4. Relationship between the coils (big vs smaller) and the magnitude of the electric current

- Click on the icon of the two coils (bottom of the screen) to present two loops in the experiment

- Move the magnet toward each coil with the same speed: Ask students to observe the brightness of the bulb and the magnitude of the Voltmeter
  + Repeat the step above in different positions and at different speeds.

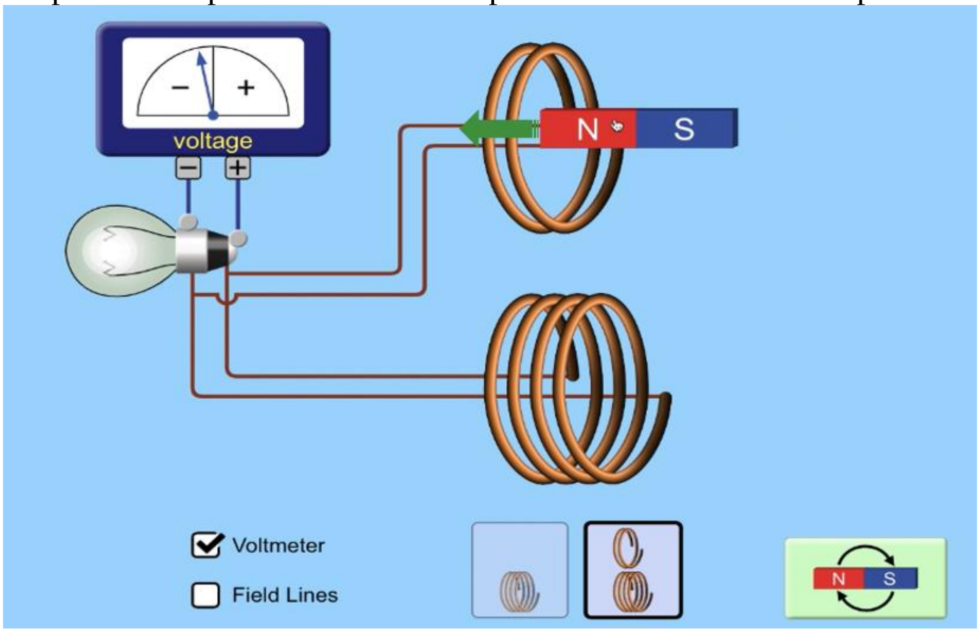


Fig.3.4 Brightness of the bulb and Voltmeter showed a lower level when moving the magnet at the same speed through the coil with a lower number of turns

Activity 5. Explain what happens when a magnet moves through the coil affecting the brightness of the bulb and the magnitude & sign of the voltage

- Click on coils icon (bottom of the screen) to present one loop in the experiment
- Add the magnet field lines by clicking on “Field line”
- Teacher can revise the concept of magnetic flux, Faraday’s law and Lenz’ law
- Move the magnet through the coil: Ask students to explain why a current is created
- Put the magnet inside the coil but don’t move it: Ask student to explain why a current is not created
- Move slowly the magnet through the coil: Ask student to observe the needle in the Voltmeter (direction of the electric current) and to explain.

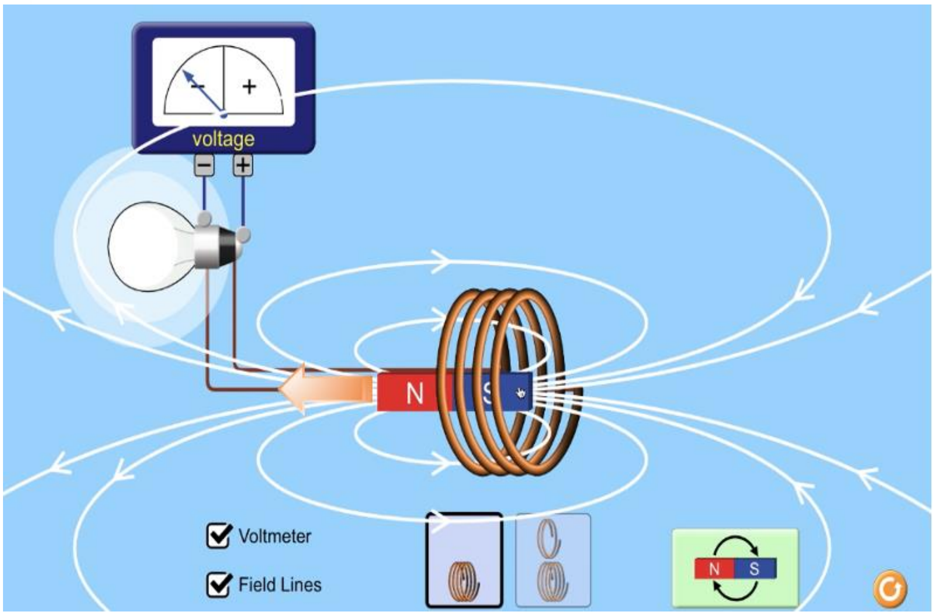


Fig.3.5 The bulb lights up and the needle of the Voltmeter shows a non-zero level when we make multiple time clicks to spin two polar opposites of the magnets.

Student learning sheet

Faraday's Law

Name: ____Class: ___________

Introduction:
Michael Faraday was an English scientist who contributed to the study of electromagnetism. This is the basic principle nowadays for making electric motors. His discovery of electromagnetic induction will be explored by virtual experiment with Interactive Simulation.

Activity and question	Your observation and answer
Activity 1. Conditions to create an electric current - What happens as you move the magnet into the coil? - What happens when you put the magnet near the coil or inside the coil	
Activity 2. Speed of the magnet and magnitude of the electric current - Click on "Voltmeter" to add a Voltmeter that measures the magnitude of voltage. - What happens if you move the magnet into the coil very slowly vs. very quickly? (Focus on the brightness of the bulb and the position of the needle in the Voltmeter) - How does the motion of the magnet relate to the current produced?	
Activity 3. Polar end of magnet and direction of the electric current - What happens to the needle in the Voltmeter as you move the North side of the magnet through the coil? - How does the needle of the Voltmeter change when you move the South side instead of the North?	

	____________ ____________
Activity 4. Number of turns (loops) of the coils and magnitude of the electric current - Click on the two coils icon (bottom of the screen) to present two coils - What happens when you move the magnet into each coil with the same speed? Ask students to observe (the brightness of the bulb and the magnitude detected by the Voltmeter) - Is there a relationship between the number of loops in the coil and the magnitude of the current produced?	____________ ____________ ____________ ____________ ____________ ____________ ____________ ____________
Activity 5. Explain what happens in conditions of the experiments above based on magnetic flux and Faraday's law. - Click on "Field line" to display magnetic field around the magnet - Read carefully the concept of magnetic flux and Faraday's law - Explain what happened by answering: + Why is the current generated when you move the magnet through the coil? + Why does the needle of the Voltmeter change when you move the magnet through the coil? + Is there any way to generate the current when you put the magnet into the coil but not move it?	____________ ____________ ____________ ____________ ____________ ____________ ____________ ____________ ____________ ____________ ____________ ____________ ____________ ____________ ____________

About the Authors

Vo Van De

Dr. Vo Van De is currently a post-doctoral researcher in science education at EPI•STEM - National Centre for STEM Education at the School of Education in the University of Limerick, working on the HEA Performance Fund for developing new on-line CPD resources for secondary school science teachers in Ireland.

Prior to coming to the University of Limerick, Vo worked as a lecturer of Physics Education in the An Giang University, Vietnam National University in Ho Chi Minh City. In 2022, he graduated with a PhD in Educational Studies from the University of Szeged (Hungary). His interests lie at the intersection of science education and assistive technology in education. His studies focus on enhancing the scientific reasoning of young students through activities and thought-provoking challenges in STEM education. Vo is passionate about inspiring science teachers and students in their learning of science in enjoyable and problem-posing environments, particularly through the application of technology and an ICT-enhanced focus to active pedagogies. He is also interested in educational data analysis and programming for educational web applications.

Vo Van De has a number of peer-review papers published in some of the top high-ranked international journals in the field of Science Education and Psychology of Education i.e., International Journal of Science Education, Thinking Skills and Creativity, and the European Journal of Psychology of Education. The papers explore how scientific reasoning skills can be applied to secondary schools science classrooms in new and ground-breaking ways.

In the HEA funded on-line CPD project, underway in EPI•STEM, for science and mathematics teachers in secondary schools in Ireland, Dr. Vo Van De has designed and developed a package of interactive simulations - in the area of linear motion, velocity and acceleration, forces and Faradays Law - in order to encourage ICT-enhanced inquiry-based learning approaches in science at secondary schools. This package aims to offer educational resources to support science teachers and students in a nurturing and digital environment to support the development of SMART classrooms and laboratories in Irish secondary schools.

Geraldine Mooney Simmie

Dr. Geraldine Mooney Simmie is a senior lecturer in the School of Education, the Director of EPI*STEM National Centre for STEM Education and the Principal Investigator for this HEA funded CPD resources project. Geraldine's research interest is in emancipatory teaching and teacher learning - the existential uniqueness of each student, the ethical, social, cultural and political dimensions of education and the outrageously complex nature of teaching and teacher learning in the highly complex, scientific, technological and unequal world of today.

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EPI•STEM Contact Details

Register for on-line CPD resources: https://epistem.ie

EPI•STEM project: Resources

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This on-line CPD project [HEA funded] is an initiative with EPI•STEM for science and mathematics secondary teachers in Ireland. The research-led development team include:

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