INVOCAB CURRICULUM SUPPORT MANUAL

PHYSICS

Contents

INVOCAB

Curriculum Support Manual

Rationale

Problem Areas

The INVOCAB Baseline Questionnaires: Analysis of Data broadly summarizes the five most problematic areas in the study of Physics at the secondary school level in Trinidad and Tobago. This forms the basis for the choice of problem areas that will be addressed in the implementation of the INVOCAB project.

The Caribbean Secondary Education Certificate (CSEC) reports (2010, 2011, 2013) state that there is a greater thrust in science and technology in the Caribbean, hence the need for more innovation to 'drive future development of Caribbean countries'. To fulfil this mandate, educational goals should shift from an examination focus to one of innovation to help stimulate life-long learners with a true interest in scientific fields and endeavours. Classes should be designed to pique students' interests while engendering a wonder and care for the universe beyond the subject area, furthered by the intrinsic motivation to apply their scientific knowledge to solve real world problems.

The ideal Caribbean person should aim for success academically, professionally and personally. Education serves as a critical tool that can address the social problems in present society, especially poverty. The Caribbean Community Secretariat (1996) proposes that effective education is the key to counteract evidence of repetition in works, drop-outs of students, absenteeism and truancy. This is evidenced by the fact that twelve percent (12%) of CXC candidates obtain five (5) or more subjects at the CSEC level with thirty – six (36) passing no subjects at all (Caribbean Community Secretariat, 1996).

Wang (2005) recognizes that the "world is changing" and teaching strategies must change in order to maintain students' interest in the subject.

Topics

GRAPHS

1.3 use graphs of experimental data from simple pendulum;

1.4 draw a line of 'best fit' for a set of plotted values;

1.5 determine the gradient of the straight line graph;

REFLECTION OF LIGHT

4.5 apply the laws of reflection

4.6 describe the formation of images in a plane mirror

REFRACTION OF LIGHT

4.8 describe the refraction of light rays;

4.10 apply Snell's Law;

MAGNETISM – TRANSFORMERS

7.13 explain the principle of operation of a transformer

7.14 state the advantages of using a.c. for transferring electrical energy;

7.15 apply the ideal transformer formula $P_{out} = P_{in}$.

HEAT TRANSFER

4.1 explain the transfer of thermal energy by conduction

4.2 explain the transfer of thermal energy by convection

4.3 explain the transfer of thermal energy by radiation

4.4 conduct experiments to investigate the factors on which absorption and emission of radiation depend;

4.5 recall that good absorbers are good emitters

Problem Area 1: Graphs

SECTION A – MECHANICS

SPECIFIC OBJECTIVES	CONTENT/ EXPLANATORY NOTES	SUGGESTED PRACTICAL ACTIVITIES
Students should be able to:		
1.3 use graphs of experimental data from simple pendulum;	*Use ⊙ or ⍰ to denote plotted points.*	*Allow students to plot T vs. L and T_2 vs. L.*
1.4 draw a line of 'best fit' for a set of plotted values;	*Reasons why 'best fit' line is the 'best' average of the data.*	
1.5 the gradient of the straight line graph;	*Use a triangle that covers at least half of the 'best fit' line.* *Include the derivation of the unit of the gradient.*	*Use gradient to determine g.*

Common Issues

There is a need for adequate practice in the use of graphs to counterattack the problems of

- *Poor selection for the choice of points in determining the gradient.*

It has been observed that students usually choose points obtained from the table as opposed to the reading-off of values from the best-fit line drawn.

- *Unsuitable size of triangle used for determining gradient*.

For finding the slope, it is best to select points that cover at least three-quarters the length of the line of best-fit.

- *Incorrect determination of the unit when calculating the gradient.*

The formula for calculating gradient must be used in the right context. Additionally, derived quantities for Section A Specific Objective 3.4 should be connected to the value of a gradient having both a numeral part and a unit. A properly drawn line of best fit must firstly be constructed to determine the gradient.

While it is expected that students will be familiar with graphs at the lower school level and should be studying the CSEC Mathematics syllabus or some equivalent in tandem, interdisciplinary support is lacking. Therefore, educators are required to teach graphs to students without support, which can be challenging.

Background Information

For examination purposes, graphs are selected from a variety of content areas. Hence, in the teaching of graphs, using a variety of examples that covers various scales should provide sufficient practice for learners.

Suggested Teaching Strategies and Activities

Activity 1

- Students should be reminded about derived quantities (Sect. A S.O. 4.3) to aid in connecting the syllabus especially in the area of determining units for the gradient of the graph.

A table of possible graphs can be given to students which allows them to determine the units of the gradient of the graph using S.I. units.

For example,

GRAPH OF	Y – AXIS (dependent variable)		X – AXIS (independent variable)		UNIT OF GRADIENT
	Quantity	Unit	Quantity	Unit	
Displacement versus time					
Force versus extension					
Sin r versus sin i					
Height of image versus height of object					
Voltage versus current					
Pressure versus temperature					
Temperature versus time					

From the exercise, it can be drawn to students' attention of the possibility of a gradient being dimensionless, that is, having no units. Additionally, it enables students to recall fundamental units. Modifications and/or other inclusion will assist learners in manipulation of units.

Activity 2

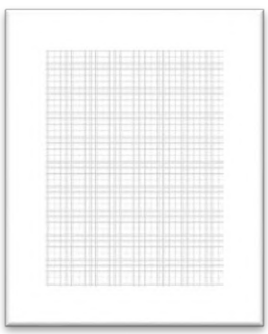
Teaching students to draw graphs with the use of an example will allow them to apply general ideas to individual graphs.

Example

Plot the following graph of Period^2, T^2 / s^2 versus Length, l / cm.

Length, l / cm	*30*	*40*	*45*	*50*	*60*	*70*
Period^2, T^2 / s^2	*1.70*	*2.45*	*2.97*	*3.89*	*4.58*	*5.73*

1. Arrange graph page in portrait orientation as shown below.



2. Using two centi-metre mark on the page, count the number of blocks obtained length-wise and width-wise on the page.

On the graph page shown, there are

twelve (12) 2 – cm spaces on the y – axis, and

nine (9) 2 – cm spaces on the x – axis

for the portrait orientation of the page.

3. Look for the largest value in each variable to be plotted.

For the table above,

Largest length value = 80 cm

Largest T^2 value = 6.56 s^2

Where there are negative values in the set of readings, subtract the smallest value from the largest to obtain the range of each set of values to be plotted.

4. To determine the scale to be used, divide the largest value by the number of block obtained on the graph on the axis to be plotted. Round the value obtained so that the ratio of the scale is a multiple or sub-multiple of 1, 2, 5, 10.

For example, on the Y – axis where T^2 will be plotted 5.73/12 = 0.4775. This will be rounded to 0.50 per graduation mark on the graph page.

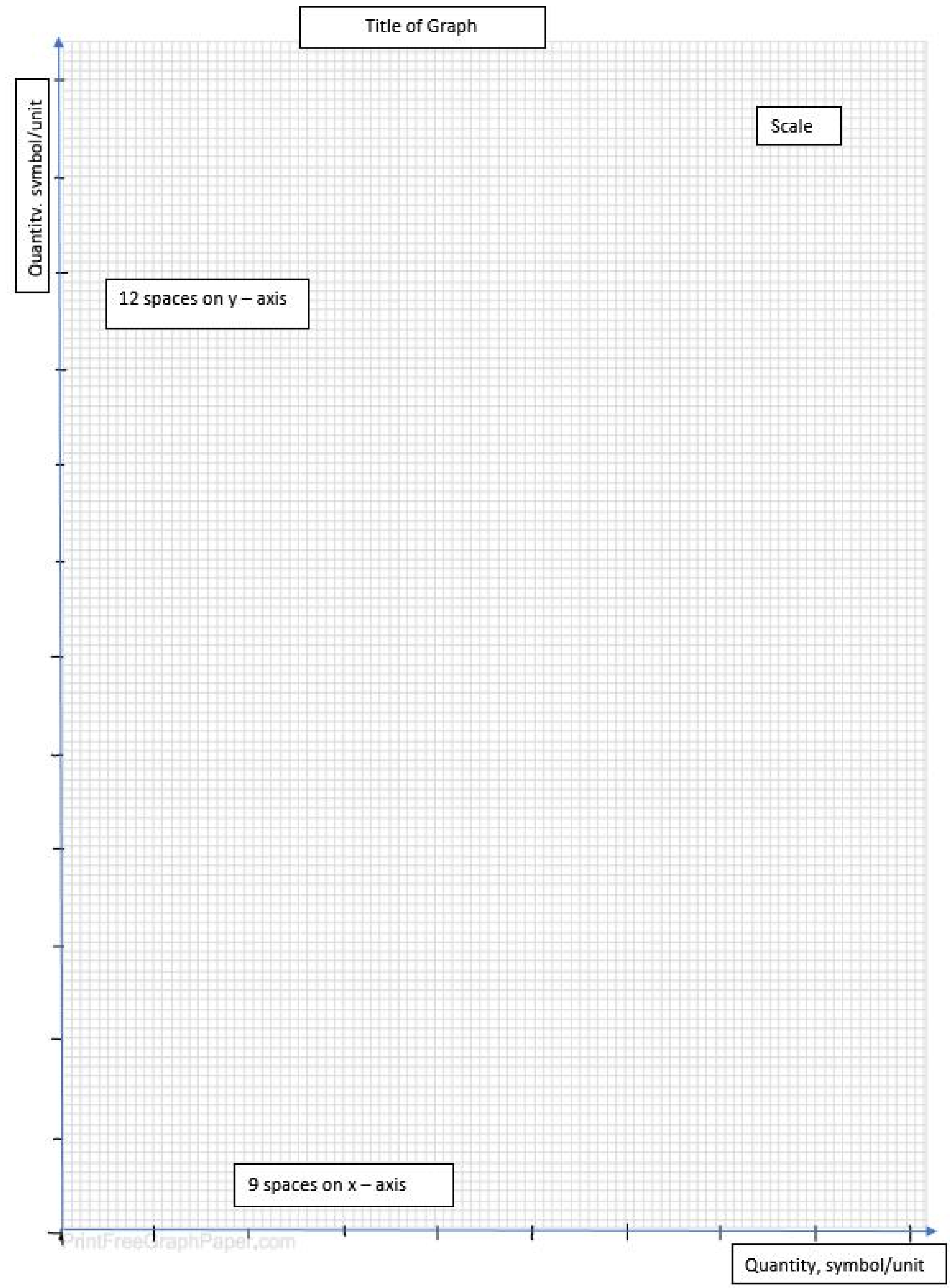
Similarly, on the X – axis where L will be plotted 70 / 9 = 7.77. Therefore, this will be rounded to 10 cm per graduation mark on the axis.

Therefore,

on the X – axis, a ratio of 1: 0.5 will be used.

on the Y – axis a ratio of 1: 10 will be used.

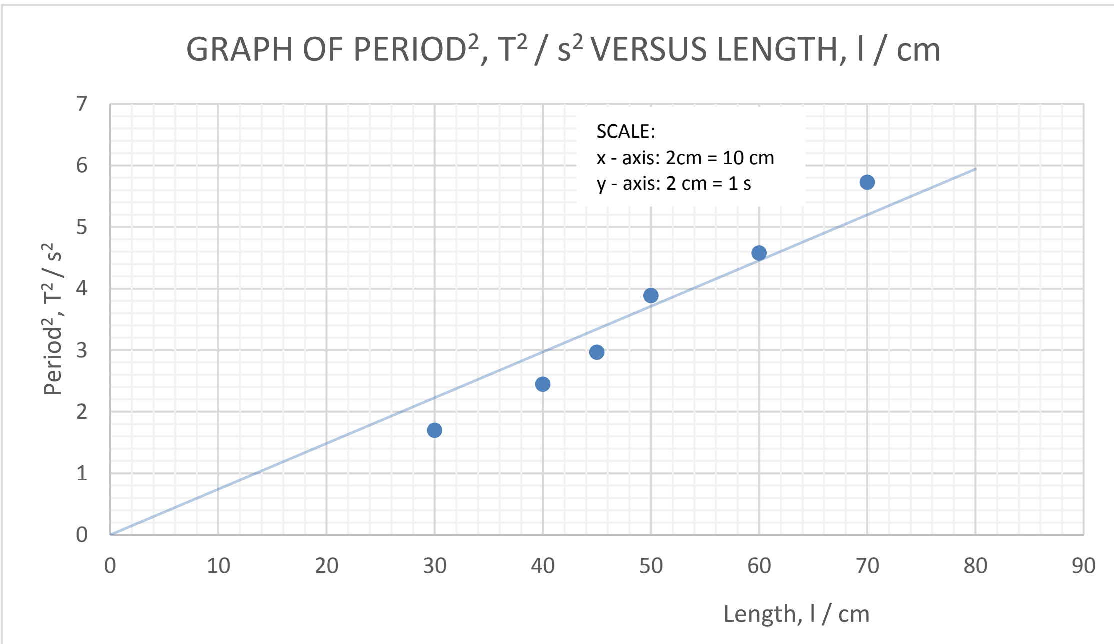
5. Complete labelling of axes ensuring consistency in the spacings of the marks on each axis as well as correct starting point, ending point and correct numbering.



GENERAL FORMAT FOR LABELLING A GRAPH

6. Plot co-ordinates, using ⊙ or *x* by locating x-axis value followed by y-axis value.

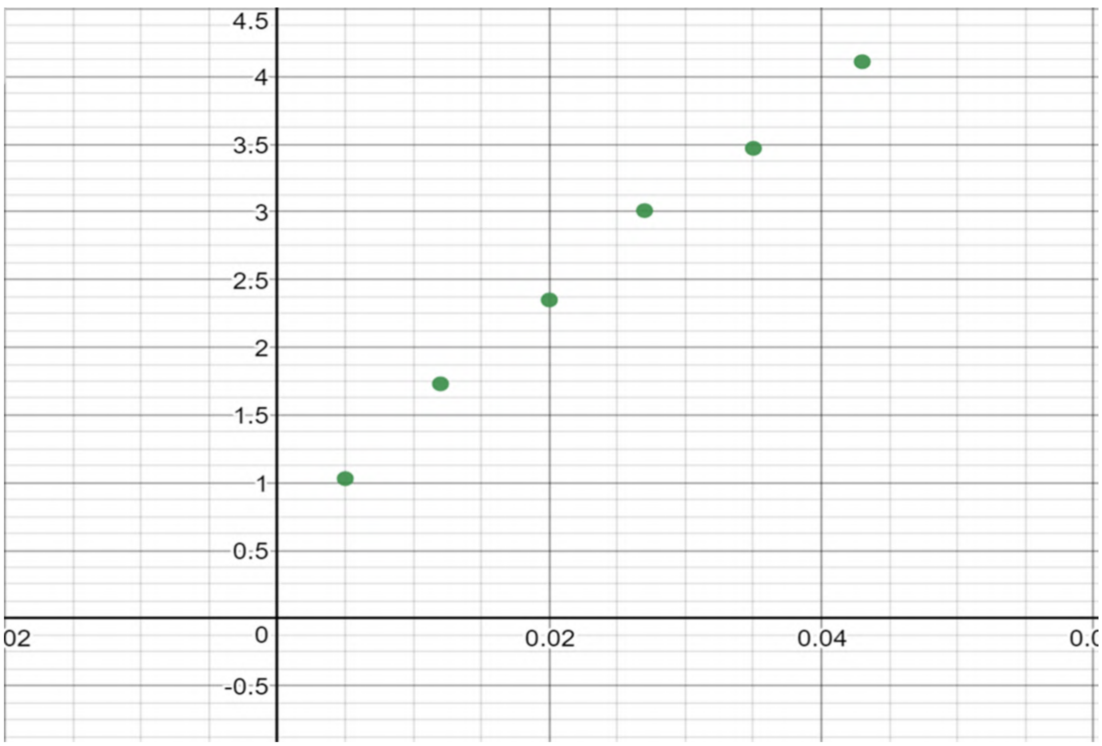
7. Draw line of best fit or a smooth curve to complete the graph.

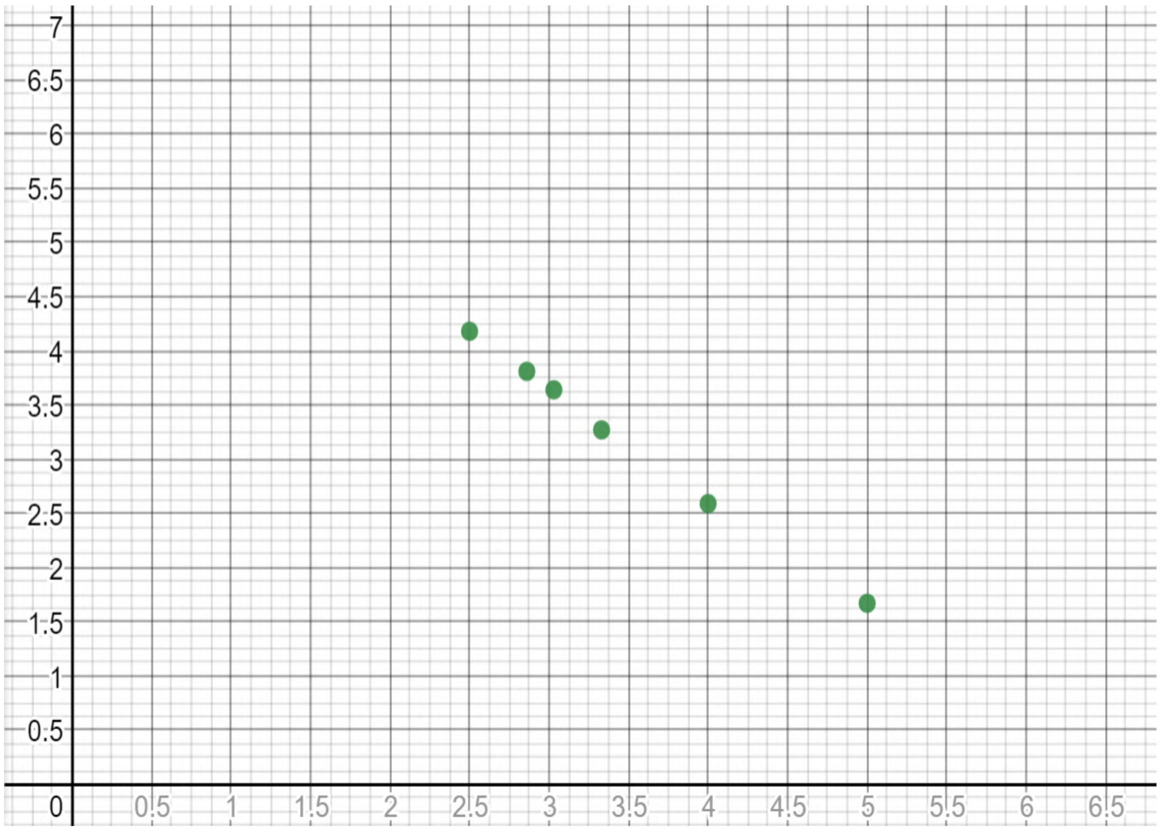


Activity 3

- Subject teacher should assist students in drawing the line of best fit in a variety of cases. Further, examples should include sufficient variety to distinguish curves from straight line graphs.

Using a graphing simulation, a variety of graphs with plotted points can be supplied to students to draw in line of best fit with the teacher's guidance.




7
6.5
6
5.5
5
4.5
4
3.5
3
2.5
2
1.5
1
0.5
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0.5
1
1.5
2
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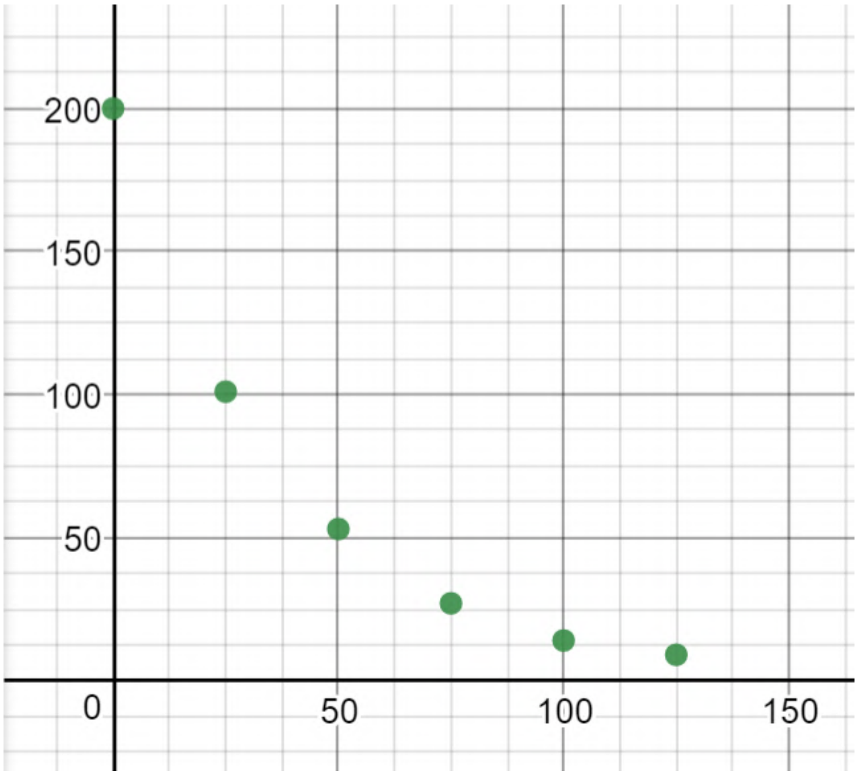
6
6.5



Activity 4

- A list of values should be given to students to draw graphs.

For example, for an analysis of results to determine the resistance per unit length of constantan wire, the following values can be utilized.

Length, l / cm	15	20	25	30	40	50
Resistance, R / Ω	1.67	2.59	3.27	3.64	3.81	4.18

After plotting of points and drawing line of best fit, students can be advised on suitable points for determining gradient. It must be strongly highlighted that

- plotted points not be used for determining gradient
- choice of points should form a large triangle.

The calculated gradient should then be used to determine the resistance per unit length of the wire.

Similarly, for radioactive decay simulation, the following values can be used to introduce students to the difference between linear graphs and curves.

Time, t / s	**Activity, A / Bq**
0	200
25	100
50	53
75	27
100	14
125	8

Students should be encouraged to draw a smooth curve through the plotted points for a graph of Activity versus time.

Resources

- Grapher Board
- Use of Android simulation app such as Desmos
- Use of online graphing simulations such as symbolab.com, mathway.com

Further Reading

- Cheung, L. and Chew, C. (2001), *Practical physics a course for 'O' Level volume 1*, Singapore, Federal.

Expected Outcomes

The students' understanding of graphs should deepen. In order to develop the necessary skill of interpreting graphs, to qualitatively describe the relationship between quantities, educators, through the use of the activities, can enrich the subject's content.

Students should be able to use graphs in the Analysis/Interpretation as well as the Planning and Design skills of the CSEC Physics Syllabus to demonstrate their development as independent learners.

Problem Area 2: Reflection of Light

SECTION C - WAVES AND OPTICS

Reflection

SPECIFIC OBJECTIVES Students should be able to:	CONTENT/ EXPLANATORY NOTES	SUGGESTED PRACTICAL ACTIVITIES
4.5 apply the laws of reflection	Perform experiments to show the angle of incidence and the angle of reflection are equal.	
4.6 describe the formation of images in a plane mirror	Object and image distances are equal. The image is virtual and the object size is equal to the image size.	Locate virtual image using: (a) ray plotting; (b) no parallax method. Construct diagrams to show the formation of virtual images.

Common Issues

Students were able to fairly describe the image formed in a plane mirror. However, to obtain said image by ray plotting has presented itself as a challenge for learners. The main challenges stem from the improper use of mathematical instruments such as the protractor and the ruler. There is misunderstanding on the students' part about the formation of real and virtual images. Educators need to ensure that this concept is clarified for learners. The adoption of a more hands-on approach to the teaching of the topic at both the lower and upper school level will greatly assist.

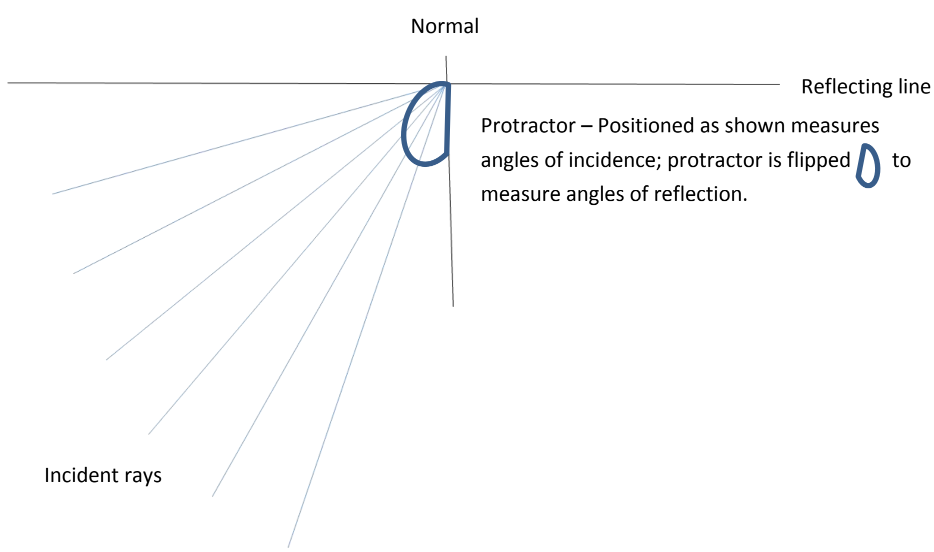
Background Information

Adequate knowledge of measuring angles would greatly assist in the delivery of the content. The use of a worksheet to gauge students' knowledge is essential to determine their level of readiness and to define a starting point.

Suggested Teaching Strategies and Activities

<u>Activity 1</u>

Students can be allowed to experimentally determine the laws of reflection using a ray box.



METHOD:

1. On a blank sheet of paper in landscape orientation taped to a soft board, draw a horizontal line across the page to represent the mirror line.
2. In the middle of the mirror line, draw a normal at 90° to the line.
3. Draw incident rays to the normal ranging from 10° to 80°.
4. Position mirror along the mirror line.
5. Using a ray box, position the light ray along the first ray.
6. Mark with at least two (2) X's the position of the reflected ray.
7. Remove the mirror and draw the reflected ray.
8. Measure and record the angle of reflection for the corresponding angle of incidence.
9. Repeat the procedure for the other rays.

Allow students to form conclusions by comparing corresponding angles of incidence and angles of reflection. Students should formulate a generalized statement on their findings.

Table of results:

Angle of incidence, i / º	Angle of reflection, r / º

Activity 2

Students should be allowed to describe the image formed in a plane mirror by answering the following questions.

- Is it real or virtual?
- How does it compare in size to the object?
- Is it inverted in any way?
- Where is it?

Students should be allowed to perform the practical activity of locating an image in a mirror prior to answering the questions. The differences between real and virtual images should be discussed preceding this activity.

Locating image in a plane mirror

METHOD:

1. On a blank sheet of paper stuck to a soft board, draw a line across the middle of the page to represent the mirror line.
2. Place a dot 5 cm from the line at any position to the left of the line. Label this 'O' to represent the object.
3. Draw two (2) lines, which represent incident rays, at different angles from the dot until they touch the mirror line.
4. For each line, draw in the normal to the mirror line.
5. Measure and record the angles of incidence.
6. For each line representing an incident ray, measure and mark the position of the corresponding angle of reflection.
7. Draw a line from the normal through the mark to represent the reflected ray.
8. Repeat steps 6 and 7 for the other incident ray.

9. Extrapolate the reflected rays behind the mirror line until they meet.
10. Mark the intersection with a dot. Label this ‘I’ to represent the image formed.
11. Measure and record, as OX, the perpendicular distance between the object and the mirror line.
12. Measure and record, as IX, the perpendicular distance between the image and the mirror line.

A modification can be made to this exercise (Steps 6 to 8) by allowing students to use the ray box to locate the reflected rays; then measure and record the angles of incidence.

Teachers should also demonstrate lateral inversion by:

- Writing words in reverse on the board and have students use mirrors to read them. For example:

- Additionally, allow students to face each other as if in a mirror. One student acts as the mirror image and mimics the other person’s movements. This can be used as an informal assessment of students’ understanding of the concept.

Activity 3

Allow students to research items that use reflection of light in its operation such as a kaleidoscope or periscope. Students should be allowed to build a model of the item if possible, and prepare a report explaining its operation. This may be done individually or as a group. To develop teamwork, and communication skills, group work should feature a small presentation to the class.

Strategy 1

As an assessment, students can be asked to draw a reflection of the word 'MIRROR' or 'INSTANTANEOUS'. Student responses can be compared and the suggestions offered to explain the different appearance of the images.

Resources

- Ray box
- Optical Kit
- Kaleidoscope toy
- Laser pointer

Further Reading

- Farley, A., & Trotz, C. (2014). *Physics for CSEC examinations* (3rd ed.). Port of Spain, Trinidad and Tobago: Macmillian.
- Johnson, K. (2001). *Physics for you*. Cheltenham, United Kingdom: Nelson Thornes.
- Avison, J., Petheram, L., Henry, D., & Neeranjan, D. (2014). *Physics for CSEC* (2nd ed.). Cheltenham, United Kingdom: Nelson Thornes Ltd.
- www.neilatkin.com/2014/04/10-cool-ideas-for-teaching-reflection-of-light
- http://www.schoolphysics.co.uk/age16-19/Optics/Reflection/text/Reflection_/index.html

Expected Outcomes

Common misconceptions that students would have acquired in early learning should be clarified. Learners should be able to offer simple scientific explanations of the visual world around them. Through meaningful collaboration with their peers, students should develop a deeper appreciation of the material as well as the value of scientific discourse.

Problem Area 3: Refraction of Light

SECTION C - WAVES AND OPTICS

Refraction

SPECIFIC OBJECTIVES	CONTENT/ EXPLANATORY NOTES	SUGGESTED PRACTICAL ACTIVITIES
Students should be able to:		
4.8 describe the refraction of light rays;	Recall that the passage of a ray of light through a rectangular block may results in lateral displacement of that ray.	Passage of light rays through: (a) rectangular blocks; (b) triangular prisms Draw diagram(s)
4.10 apply Snell's Law	Definition of refractive index.	Perform an experiment to test Snell's Law

Common Issues

Manipulation of the equation $n = \frac{\sin i}{\sin r}$ is one of the major challenges experienced by students in the topic of refraction. The principle of reversibility of light appears to not be adequately taught to students; this hamper understanding of the topic.

Background Information

Observable everyday phenomena such as the formation of rainbows and multiple images formed from the refraction of light through skyline windows in homes should be referenced to incorporate students' background knowledge of refraction in their environment. The use of the equation of Snell's Law in the form $n_1 \sin\theta_1 = n_2 \sin\theta_2$, along with suitable explanation of the meaning of the symbols, may aid in an easier manipulation of the equation for students.

Suggested Teaching Strategies and Activities

<u>Activity 1</u>

Teachers can demonstrate the phenomenon by using a jar with a coin.

Figure 1

Shallow crucible with 5g mass

Allow students to stand back from a dish and to guess its content.

Figure 2
Crucible with unseen 5g mass

Teacher can then pour water into the dish so that the object becomes visible.

Figure 3
5g mass visible when water is poured into crucible

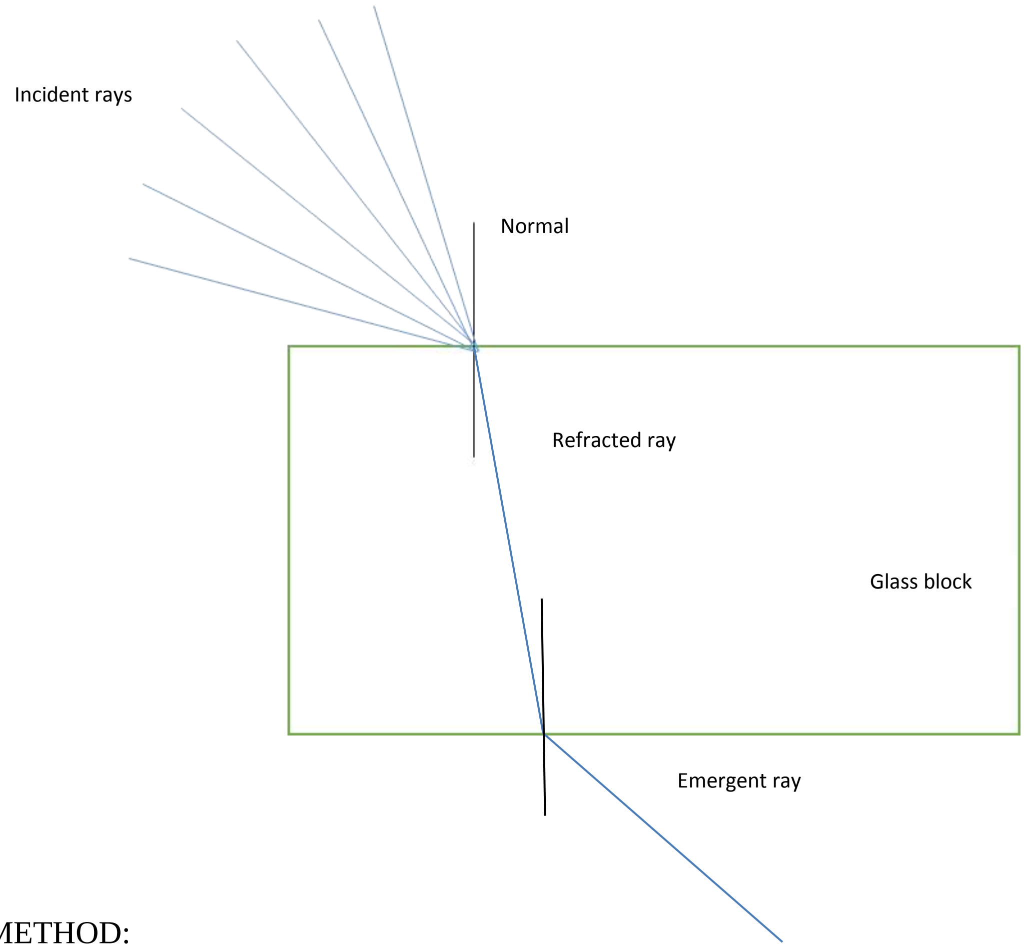
Students' explanations can be used as an introduction to the lesson. They may be able to explain what is happening without using the appropriate technical jargon.

Activity 2

Using sheets consisting of two differently textured surfaces, a smooth bar can be rolled at an angle that allows for change in speed of the movement of the rod. Let students observe. If possible, markings can be made at the angles at which the rod is released.

Activity 3

Students can be allowed to experimentally examine Snell's Law using a ray box.



METHOD:

1. On a blank sheet of paper taped to a soft board, draw the outline of a glass block.
2. Towards the upper left side of the top of the outline, draw a normal.
3. Draw incident rays to the normal ranging from 10° to 80°.
4. Re – position the glass block inside the traced outline.
5. Using a ray box, position the light ray along the first ray.
6. Mark with X's the position of the emergent ray.

7. Draw a line through the X's until it touches the underside of the outline of the glass block. (This represents the emergent ray.)
8. Remove the glass block and draw the refracted ray by connecting the edges of the outline at the normal of the emergent ray to the normal of the incident ray.
9. Measure and record the angle of refraction for the corresponding angle of incidence.
10. Repeat the procedure for the other rays.

Allow students to form conclusions by comparing corresponding angles of incidence and angles of refraction.

Measurements can be recorded in a table format as shown below.

Angles of incidence, i / º	Angle of refraction, r / º	sin i	sin r

To further aid the students' understanding, *sin i versus sin r* or alternatively *sin r versus sin i* can be graphed as well as the gradient of the graph calculated to determine the refractive index of the material.

<u>Activity 4</u>

To assist with the development of the students' mathematical skill, the learners should be given adequate examples to manipulate the Snell's Law equation in order to calculate angles of incidences, angles of refraction and refractive indices.

Worksheets, as in the example below, can be prepared to facilitates the students' understanding of the topic.

Using Snell's Law, complete the table by calculating the missing values.

Angles of incidence, i / o	Angle of refraction, r / o	sin i	sin r	Refractive index, n
18	10			
	17			1.33
30				1.50
		0.637	0.421	
	22	0.833		

The table below shows the expected results.

Using Snell's Law, complete the table by calculating the missing values.

Angles of incidence, i / o	Angle of refraction, r / o	sin i	sin r	Refractive index, n
18.0	10.0	0.309	0.174	1.78
22.9	17.0	0.389	0.292	1.33
30.0	19.5	0.500	0.333	1.50
39.6	24.9	0.637	0.421	1.51
56.4	22.0	0.833	0.375	2.20

Resources

- Ray box
- Optical Kit
- Protractor

Further Reading

- Farley, A., & Trotz, C. (2014). *Physics for CSEC examinations* (3rd ed.). Port of Spain, Trinidad and Tobago: Macmillian.
- Johnson, K. (2001). *Physics for you*. Cheltenham, United Kingdom: Nelson Thornes.
- Avison, J., Petheram, L., Henry, D., & Neeranjan, D. (2014). *Physics for CSEC* (2nd ed.). Cheltenham, United Kingdom: Nelson Thornes Ltd.
- Yoo, J. H., Cho, B. H., Kim, D. K., & Park, S. H. (2009, June). A new technique to teach basic concepts of refraction and reflection of light. In Education and Training in Optics and Photonics (p. EP1). Optical Society of America.
- http://sciencelearn.org.nz/Contexts/Light-and-Sight/Science-Ideas-and-Concepts/Refraction-of-light.

Expected Outcomes

Mathematical and scientific concepts are closely linked through the use of and participation in the described activities. The exercises should introduce learning as a fun activity. Students should be able to demonstrate their understanding of refraction. Additionally, learners should be able to apply the knowledge gained to satisfactorily explain situations that involve refraction outside the classroom setting. Educators are encouraged to use these activities that serve to minimize classroom boredom as well as move towards inquiry based learning.

Problem Area 4: Magnetism: Transformers

SECTION D - ELECTRICITY AND MAGNETISM

Transformers

SPECIFIC OBJECTIVES	CONTENT/ EXPLANATORY NOTES	SUGGESTED PRACTICAL ACTIVITIES
Students should be able to:		
7.13 explain the principle of operation of a transformer;	Diagram of a simple transformer.	Construct a simple transformer.
7.15 apply the ideal transformer formula: $P_{out} = P_{in}$.	Transformer formulae to solve problems	Perform activities to show that for an ideal transformer

Common Issues

While students generally display a good understanding of the structure of a transformer, they also demonstrate a lack of awareness of the advantages of using a transformer. Additionally, the transposing of formulas pose challenges when answering questions related to transformers.

Background Information

Teachers should allow students to develop the understanding of the operations of transformers through the principle of electromagnetism to classify the voltages as step – up or step – down.

Suggested Teaching Strategies and Activities

Strategy 1

- Interdisciplinary teaching with the CSEC Mathematics educator to include the equations when teaching transposition of formulas Section 7 Specific Objective 13 of the CSEC Mathematics Syllabus.

Some common physics formulae, as stated below, can be used in a transposition lesson in a mathematics class.

$$Density, \rho = \frac{Mass, m}{Volume, V}$$

$$Kinetic\ Energy, E_k = {}^{1}\!/_{2}\, mv^2$$

$$Heat\ Energy, E_H = mc\Delta T$$

$$Period\ of\ a\ pendulum, T = 2\pi\sqrt{\frac{l}{g}}$$

Activity 1

Demonstration of wire moving in a magnetic field to show the generation of a voltage/inducing a current.

Figure 4
Wire being moved in a magnetic field

Activity 2

- A teacher led demonstration can be done using the construction of a simple transformer using two hollow coils placed side by side. This can be followed by placing an iron core through the coils.

Figure 5
Hollow coils with iron core

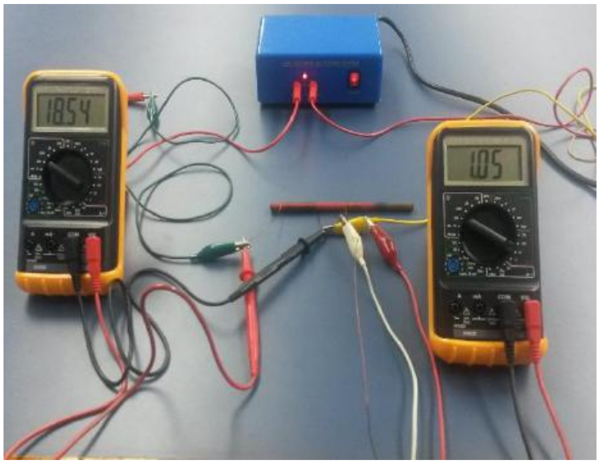


Figure 6
Coils with multimeter connected

- Alternatively, commercial demonstration transformers can be used.

Figure 7
Commercial transformers

Activity 4

- A worksheet can be done on the use of the equation.

TRANSFORMER WORKSHEET

Use your knowledge of transformers as well as the equation $\frac{N_s}{N_p} = \frac{V_s}{V_p} = \frac{I_p}{I_s}$ to complete the worksheet below. For each transformer, determine its type as a step-up or step down.

TRANSFORMER	**N_p**	**N_s**	**V_p /V**	**V_s /V**	**I_p /A**	**I_s /A**	**Type**
A	20	100	50			0.5	
B		440	11	110	5		
C	180		13.5		3	15	
D		1750	2000	15	13.3		
E	6		12	20000	45		
F		143		125	5.0×10^{-3}	35	
G	2000	80000		150000		700	

TRANSFORMER WORKSHEET

Answer Sheet

Use your knowledge of transformers as well as the equation $\frac{N_s}{N_p} = \frac{V_s}{V_p} = \frac{I_p}{I_s}$ to complete the worksheet below. For each transformer, determine its type as a step-up or step down.

TRANSFORMER	**N_p**	**N_s**	**V_p /V**	**V_s /V**	**I_p /A**	**I_s /A**	**Type**
A	20	100	50	250	2.5	0.5	Step-up
B	44	440	11	110	5	0.5	Step-up
C	180	36	13.5	2.7	3	15	Step-down
D	233333	1750	2000	15	13.3	1773	Step-down
E	6	10000	12	20000	45	0.027	Step-up
F	1001000	143	875000	125	5.0×10^{-3}	35	Step-down
G	2000	80000	3750	150000	28000	700	Step-up

Resources

- Solenoid, insulated copper wire, sensitive galvanometer, a.c./d.c. supply
- Worksheet

Further Reading

- http://www.practicalphysics.org/explaining-how-transformer-works.html
- http://www.school-for-champions.com/science/ac_transformers.htm#.V13RmrsrLIU
- http://www.cyberphysics.co.uk/topics/magnetsm/electro/Transfromer/trnsfrmr.htm
- http://c21.phas.ubc.ca/article/transformers

Expected Outcomes

As Liu, Li and Gao (2011) imply, teaching should be done to enhance students' ability to analyze and solve problems. Educators and students should be able to link the mathematical concept of transposing formulas to the CSEC Physics syllabus. An integration of the two subjects should be clearly seen, as expressed in the syllabus, as the mathematical need to have or to be studying the CSEC Mathematics syllabus simultaneously. There should be a connection to the qualitative and quantitative aspects of the subject content. Activities should develop higher order thinking skills as learners move beyond recall of information to the application of knowledge.

Problem Area 5: Heat Transfer

SECTION *B* - THERMAL PHYSICS AND KINETIC THEORY

SPECIFIC OBJECTIVES	CONTENT/ EXPLANATORY NOTES	SUGGESTED PRACTICAL ACTIVITIES
Students should be able to:		
4. *TRANSFER OF THERMAL ENERGY*		
4.1 explain the transfer of thermal energy by conduction;	Relate the fact that air is a very poor conductor to the insulation properties of certain materials, for example, expanded polystyrene, hollow blocks.	Perform activity to compare qualitatively the thermal conductivities of different solids.
4.2 explain the transfer of thermal	Relate convection to common phenomena, for	Perform demonstrations to show convection in fluids

energy by convection;	example, land and sea breezes.	
4.3 explain the transfer of thermal energy by radiation;	Recall that radiant energy is electromagnetic (infra-red).	Perform demonstration to show that radiant energy does not need a medium for transmission.
4.4 conduct experiments to investigate the factors on which absorption and emission of radiation depend;	Factors limited to: (a) texture of surface (rough, smooth); (b) nature of surface (shiny, dull); (c) colour of surface (black, white); (d) area of surface.	Perform experiments to investigate such factors.
4.5 recall that good absorbers are good emitters;	Relate the phenomenon of radiation to common practices	

Common Issues

Students are unable to relate the temperature of a body to the kinetic energy and motion of the molecules of the object. Suitable examples that demonstrate the methods of heat transfer appear to be lacking.

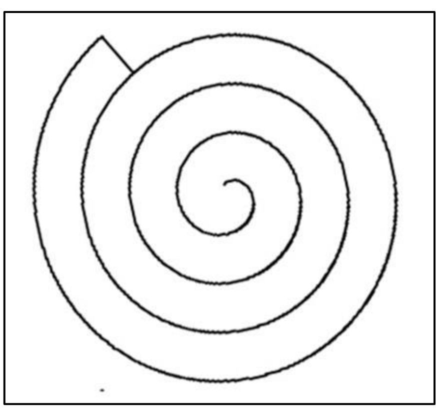
Background Information

The use of silver pots by roadside vendors for the sale of food should be a commonly used example to describe emitters and absorbers of heat energy.

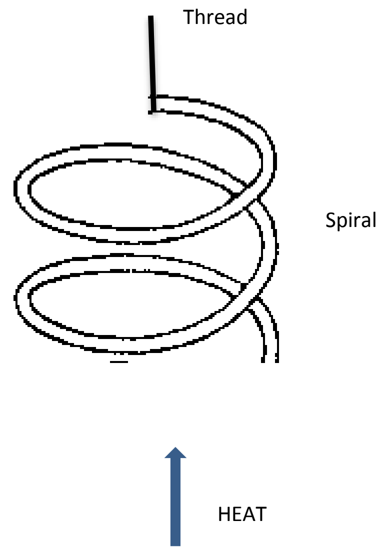
Suggested Teaching Strategies and Activities

Activity 1

Demonstrate convection currents using a spiral paper cut-out over a hot plate or heat source.



Spiral



Students should be questioned as to the causes of the movement of the spiral.

Activity 2

1. Allow students to freeze water in a plastic bottle overnight.

2. Allow students to place bottle in a beaker of water and boil until ice begins to melt.
3. Ask students to predict the temperature of the water in the bottle.
4. Let students carefully remove the bottle from the beaker and measure as well as feel the temperature of the water.

Ask students for suggestions on the reason for the temperature of the water in the bottle.

This activity can be modeled for use as a home activity or can be used as an introduction to a following lesson on heat transfer.

<u>*Activity 3*</u>

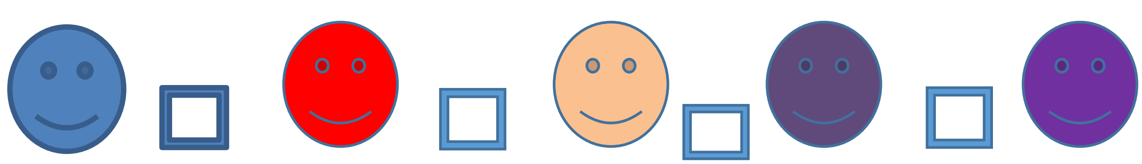
With the use of a soft toy or book, ask students to form a line along the front of the classroom or laboratory area.

Demonstrate:

a) Conduction by allowing students to pass the book/toy from one individual to the next individual.

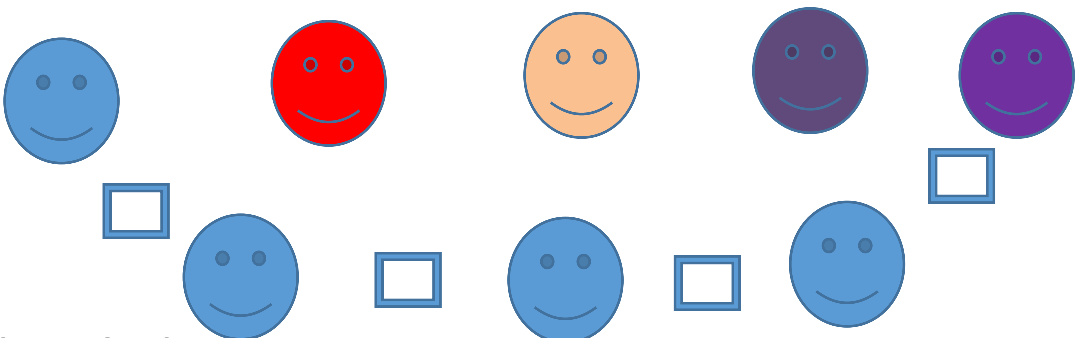
b) Convection by having the first person in the line walk with the book/toy and give it to the individual at the end of the line.

c) Radiation by asking the first student in the line to toss the book/toy to the learner at the end of the line.



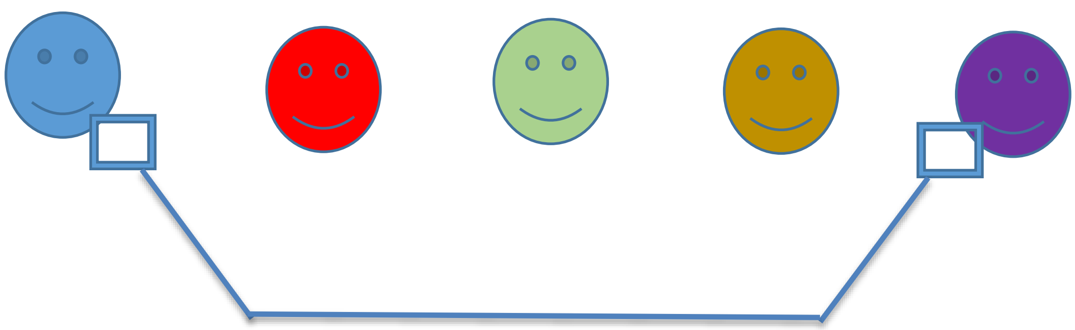
CONDUCTION

Object being passed from person to person.



CONVECTION

First person walks along the line to deliver the object to the last person.



RADIATION

First person throws object to person at the end of the line.

<u>Activity 4</u>

1. Allow students to hold an iron rod about 5 cm away from different surfaces such as ‘rough versus smooth’; ‘shiny versus dull’; ‘black versus white’ and ‘small versus large’.
2. Check the temperature of the object every minute for ten minutes for each surface. Use the recorded results to determine good emitters and absorbers of heat.

Alternatively,

1. Using two 50-ml beaker, wrap one in black plastic paper and the other in aluminum foil paper.
2. Place on a common non-flammable surface.
3. Add 25 cm^3 of boiling water to each beaker.
4. Measure and record the initial temperature of the water in each beaker.
5. Quickly cover each beaker.
6. After a minute, remove the cover and measure and record the temperature.
7. Replace the cover.
8. Repeat steps 6 and 7 for ten minutes.

Modification can be made by varying the materials used to cover the beakers.

Table of results.

Time, t / s										
Temperature of black – covered beaker, T_b / °C										
Temperature of silver – covered beaker, T_s / °C										

Students should draw a graph of temperature versus time for each beaker. This should be used to compare the heat loss from each beaker, thereby making a generalized conclusion on the factors affecting the emission of heat.

Strategy 1

Where possible, an interdisciplinary approach should be employed with the institution's Food and Nutrition department where soups or hot food items can be obtained/observed in different types/ textured pots. Students will be asked to describe their experiences, in particular keeping the food at the correct temperature and to account for the challenges they encountered.

Resources

- Hot plate
- Paper
- Soft toy
- Plastic bottles
- Iron rod
- Different textured surfaces

Further Reading

- Energy 2D software
- http://neilatkin.com/2013/12/30/science-teachers-10-ideas-for-heat-transfer-lessons

Expected Outcomes

The activities have been designed for easy classroom implementation, thereby encouraging teachers to use more non-traditional methods of teaching. Modification of the activities can be done to encourage students to replicate them in the home environment so that further inquiry can take place outside of the formal learning setting. Thus, students should develop an increased desire for learning about the topic and hence be able to clarify any misconceptions.

Additional Resources

These activities have been used as part of the INVOCAB STEM Summer Camps.

PHYSICS CHALLENGE 1

Your parents have mentioned that they made their own telephone system using tin pans and string as children. You think that you can improve on their design while being able to include a third person on the call.

Construct a three-way paper telephone system that enable all listeners to hear any conservation equally.

You may make more than one telephone network. Three different types of string are provided.

Describe how the system works.

What type of string produced the best quality of sound?

Paper Cup and String Telephones

INVOCAB

Team: ____

CATEGORY	**4**	**3**	**2**	**1**
Functionality	Structure functions extraordinarily well so that voices are clearly heard.	Structure functions fairly well so that voices are heard.	Structure functions well so that voices are muffled.	Failure in structure so that no voices are heard.
Choice of Strings	Several telephone networks built using different types of strings.	More than one telephone network built using only one type of string per network.	Only one telephone network built using different types of string.	Only one telephone network built using only one type of string.
Design	Position of all strings allows for clear communication.	Position of all strings allows for fair communication.	Position of all strings allows for muffled communication.	Position of all strings provided very muffled or no communication.

PHYSICS CHALLENGE 2

Your friend has challenged you to a race since he thinks that he is faster than you. You inform him that you know an experiment that will allow to determine scientifically who really is faster.

Calculate reaction time.

MATERIALS:

- Stopwatch
- Ruler

METHOD:

1. Have your friend hold a ruler, using two fingers, at the 5cm mark from the top so that it is up and down with the bottom approximately one (1) metre above the floor. Your friend may have to stand on a chair to do this.
2. Hold your fingers opposite the 25cm mark, but do not touch the ruler! Without warning, your friend should let go of the ruler while you try to catch it with your fingers.
3. Notice at what mark your fingers are on when you catch the stick.
   Subtract this number from 25 or subtract 25 from the number to see how many centimetres the ruler fell before you caught it. Repeat several times to see if you get the same answer.
4. Repeat the procedure with you holding the ruler while your friend try to catch.

   Record your results in a table.

   Draw a graph Time versus Distance Fallen.

WHO HAS THE QUICKEST REACTION TIME?

RESULTS:

Distance Dropped, s/cm	**Reaction Time, t/s**

CRITERIA FOR GRAPH:

- *Correct quantity placed on correct axis*
- *Points correctly plotted*
- *Use of gradient/slope of graph to determine fastest person*

PHYSICS CHALLENGE 3

One of your friends told you about the internet video in which eggs were thrown from a ten feet high wall attached to a plastic bag parachute and did not break. You decided to test it to see if it was true. However, you decide to substitute plasticine for the eggs.

MATERIALS:

Scissors

Ruler

Lengths of light string about (30 cm each)

Plastic Bags

Plasticine

METHOD:

1. From lightweight plastic kitchen bags, cut out three squares. Make one square 10cm x 10cm, a second square 20cm x 20cm, and a third square 30cm by 30cm.

2. Make a parachute out of each square by tying a piece of string to each corner of the square, then attaching the other ends of the strings to a plastic sandwich bag.

3. Make pouches of the same size for each parachute to hold the plasticine balls.

4. Make three plasticine balls each of the same size.

5. Place a plasticine ball in each of the pouches.

6. Predict which plasticine ball has the best chance of surviving the drop.

7. Measure a suitable height off ground level from which you can drop the plasticine ball.

8. After each drop, check the plasticine balls for changes and record what was observed.

Questions:

- Did the result match the predictions?
- What factors affected the results?

Plastic Bag Parachute

INVOCAB

Team: ____

CATEGORY	4	3	2	1
Parachute Construction	Great care taken in construction process so that the structure is neat, attractive and follows plans accurately.	Construction was careful and accurate for the most part, but 1-2 details could have been refined for a more attractive product.	Construction accurately followed the plans, but 3-4 details could have been refined for a more attractive product.	Construction appears careless or haphazard. Many details need refinement for a strong or attractive product.
Height	An optimum height was chosen.	A suitable height was chosen.	A fairly suitable height was chosen.	Inappropriate height was chosen.
Modification	Clear evidence of troubleshooting, testing, and refinements based on first trial.	Some evidence of troubleshooting, testing and refinements based on first trial.	Little evidence of troubleshooting, testing and refinements based on first trial.	No evidence of troubleshooting, testing or refinement based on first trial.

PHYSICS CHALLENGE 4

You would like to be an architect. For your school's career day workshop, you aim to introduce your future profession by carrying a model building designed out of paper.

For your model, you must:

Construct a free standing tower using at most two (2) sheets of letter sized printing paper.

You are allowed the use of transparent tape in pieces no longer than thirty (30) cm in length. No more than ten (10) strips of tape should be used. The paper can be rolled, folded or cut in any proportion.

To be deemed successful, your building/tower should be the tallest, the most stable and must be able to remain standing for at least ten (10) seconds without additional support.

Questions :

What aspects of your tower made it successful?

Free Standing Building

INVOCAB

Team: ____________________________ Group: ___________

CATEGORY	**4**	**3**	**2**	**1**
Paper Used	Only one sheet of paper used.	One sheet and/or part of another sheet.	Two sheets of paper used.	More than two sheets of paper used.
Length of Tape Used	< 40 cm	40 - 50 cm	50 cm	>50 cm
Height	h > 20 cm	15 cm ≤ h < 20 cm	10 cm ≤ h < 15 cm	h <10 cm
Stability	Stands for ≥ 10 seconds and remains upright.	Stands for ≥ 10 seconds but is tilted.	Stands for ≤ 10 seconds and remains upright.	Stands for ≤ 10 seconds and is tilled.
Design	Paper was cut, rolled or folded to produce an intricate structure.	Paper was cut, rolled or folded to produce a fairly intricate structure.	Paper was cut, rolled or folded to produce a simple structure.	Paper was not cut, rolled or folded to produce a structure.

PHYSICS CHALLENGE 5

How many coins can a foil boat hold?

Make a ‘boat’ out of a square of aluminum foil measuring 12cm by 12cm. The boat should be able to hold at least five (5) twenty-five cent (25¢) pieces without sinking as well as should remain afloat for at least twenty (20) seconds.

Compare different designs and account for the features in the design that makes the ‘boat’ holds

- the most coins
- stays afloat the longest.

Foil Boat

INVOCAB

Team: ________________________ Group: _______

CATEGORY	**4**	**3**	**2**	**1**
Stability	Remains afloat ≥ 20 secs.	Remains afloat for 15 secs ≤ f ≤ 20 secs.	Remains afloat for 10 secs ≤ f ≤ 15 secs.	Remains afloat for f ≤ 10 secs.
Weight	Structure holds up under ten 25 cent pieces.	Structure holds up under eight 25 cent pieces.	Structure holds up under six 25 cent pieces.	Structure holds up under four 25 cent pieces.
Number of Trials	Only one attempt was needed.	Only two attempts were needed.	Only three attempts were needed.	More than three attempts were made.

PHYSICS CHALLENGE 6

MAKING A PERISCOPE

INTRODUCTION:

Periscopes, invented in 1854, have long been used in submarines to see above water level. It employs the use reflection of light in parallel mirrors or prisms.

CHALLENGE:

You are to design and build a working periscope.

MATERIALS PROVIDED:

- Square plane mirrors
- Craft knife
- Rectangular boxes or cardboard tubes
- Scissors
- Half-metre ruler
- Glue/Scotch tape

Building A Periscope

Team: ______________________________________

CATEGORY	4	3	2	1
Selection of Construction Materials	Appropriate materials were selected and creatively modified in ways that made them even better.	Appropriate materials were selected and there was an attempt at creative modification to make them even better.	Appropriate materials were selected.	Inappropriate materials were selected and contributed to a product that performed poorly.
Care Taken during Construction	Great care taken in construction process so that the periscope is neat, attractive.	Construction was careful and accurate for the most part, but 1-2 details could have been refined for a more attractive periscope.	Construction was fairly accurate, but 3-4 details could have been refined for a more attractive periscope.	Construction appears careless or haphazard. Periscope is not attractive.
Function	Periscope functions extraordinarily well, with mirrors at 45 degree angles.	Periscope functions well, with mirrors not exactly at 45 degree angles.	Periscope functions pretty well, but mirrors not at 45 degree angles. .	Fatal flaws in function of the periscope with complete failure and mirrors far from 45 degree angles.

PHYSICS CHALLENGE 7

FREEZING OF HOT WATER VERSUS COLD WATER

INTRODUCTION:

Is it possible for hot water to freeze faster than cold water?

CHALLENGE:

You are to test the plausibility of the above question.

MATERIALS:

- Three identical containers
- Thermometer
- Freezer or Styrofoam container filled with ice
- Measuring cylinder
- Markers

EXERCISE:

- Formulate a hypothesis.
- Develop a workable method.
- State the conditions under which the exercise will be conducted.
- State clearly the outcome of the exercise.
- Offer an explanation for your findings.

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