Domremy – HSC Physics Module 9.4 From Ideas to Implementation : Student Notes

9.4 From Ideas to Implementation (30 indicative hours)

Contextual Outline

By the beginning of the twentieth century, many of the pieces of the physics puzzle seemed to be falling into place. The wave model of light had successfully explained interference and diffraction, and wavelengths at the extremes of the visible spectrum had been estimated. The invention of a pump that would evacuate tubes to $10^{-4}$ atmospheres allowed the investigation of cathode rays. X-rays would soon be confirmed as electromagnetic radiation and patterns in the Periodic Table appeared to be nearly complete. The nature of cathode rays was resolved with the measurement of the charge on the electron soon to follow. There was a small number of experimental observations still unexplained but this, apparently complete, understanding of the world of the atom was about to be challenged.

The exploration of the atom was well and truly inward bound by this time and, as access to greater amounts of energy became available, the journey of physics moved further and further into the study of subatomic particles. Careful observation, analysis, imagination and creativity throughout the early part of the twentieth century developed a more complete picture of the nature of electromagnetic radiation and matter. The journey taken into the world of the atom has not remained isolated in laboratories. The phenomena discovered by physicists have, with increasing speed, been channelled into technologies, such as computers, to which society has ever-increasing access. These technologies have, in turn, often assisted physicists in their search for further knowledge and understanding of natural phenomena at the subatomic level.

This module increases students’ understanding of the history, nature and practice of physics and the applications and uses of physics, the implications of physics for society and the environment, and the current issues, research and developments in physics.
**Concept Map**

- **Charge**
  - Electric Fields
  - Magnetic Fields
  - Cathode Ray Tubes
  - Thomson’s Experiments

- **Cathode Ray Tubes**
  - Television
  - Cathode Ray Oscilloscopes

- **The Photoelectric Effect**
  - $E = hf$ and $c = f\lambda$
  - Uses of the photoelectric effect
  - Hertz’s Experiments
  - Radio Waves

- **Work of Planck & Einstein**
  - Oscillating Charges

- **Black Body Radiation**
Concept Map

- de Broglie model of electrons in atoms
- Band Structures and electrical resistance in atoms
- Properties of Semi-Conductors
- History of Thermionic & Solid State Electronics
- Miniaturisation
- Integrated Circuits

- Crystal Structure
  - Electrons within crystal lattices
  - Phonon Theory
- Superconductivity
  - Meissner Effect
- Uses of Superconductivity
### From Ideas to Implementation Module Plan

Module Length: 7 weeks

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<tr>
<th>Focus Area</th>
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| 1. Increased understandings of cathode rays led to the development of television | 1    | 1. identify that moving charged particles in a magnetic field experience a force.  
2. explain that cathode ray tubes allowed the manipulation of a stream of charged particles | Contexts II: pp. 219-244                                                                 | 1. (Exp 1) perform an investigation and gather first-hand information to observe the occurrence of different striation patterns for different pressures in discharge tubes |
|                                                                            | 2    | 3. explain why the apparent inconsistent behaviour of cathode rays caused debate as to whether they were charged particles or electromagnetic waves |                                                                                              | 2. (Exp 2) perform an investigation to demonstrate and identify properties of cathode rays using discharge tubes:  
– containing a maltese cross  
– containing electric plates  
– with a fluorescent display screen  
– containing a glass wheel and analyse the information gathered to determine the sign of the charge on cathode rays |
|                                                                            | ½    | 4. identify that charged plates produce an electric field               |                                                                                              |                                                                                                                                            |
|                                                                            | 1    | 5. describe quantitatively the force acting on a charge moving through a magnetic field $F = qvB \sin \theta$ | Humphrey's Set 36 & 47  
Dyett problems 141-145                                                                 | 3. (Act 3) solve problem and analyse information using: $F = qvB \sin \theta$ and $E = \frac{V}{d}$ |
|                                                                            | 1    | 6. discuss qualitatively the electric field strength due to a point charge, positive and negative charges and oppositely charged parallel plates |                                                                                              | 4. (Act 4) gather, analyse and process information on the use of electrically charged plates and point charges in photocopying machines and lightning conductors |
|                                                                            | ½    | 7. describe quantitatively the electric field due to oppositely charged parallel plates |                                                                                              |                                                                                                                                            |
|                                                                            | ½    | 8. outline Thomson’s experiment to measure the charge/mass ratio of an electron |                                                                                              |                                                                                                                                            |
|                                                                            | ½    | 9. outline the role of:  
– electrodes in the electron gun  
– the electric field  
– the fluorescent screen; in the cathode ray tube of conventional TV displays and oscilloscopes. |                                                                                              |                                                                                                                                            |
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<tr>
<td>2. The reconceptualisation of the model of light led to an understanding of the photoelectric effect and black body radiation</td>
<td>1</td>
<td>1. outline qualitatively Hertz’s experiments in measuring the speed of radio waves and how they relate to light waves</td>
<td>Contexts II: pp. 245-260</td>
<td>1. (Exp 5) perform an investigation to demonstrate the production and reception of radio waves</td>
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<td>2</td>
<td>2. describe Hertz’s observation of the effect of a radio wave on a receiver and the photoelectric effect he produced but failed to investigate</td>
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<td>½</td>
<td>3. identify Planck’s hypothesis that radiation emitted and absorbed by the walls of a black body cavity is quantised</td>
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<td>1</td>
<td>4. identify Einstein’s contribution to quantum theory and its relation to black body radiation</td>
<td>2. (Act 6) identify data sources, gather, process and analyse information and use available evidence to assess Einstein’s contribution to quantum theory and its relation to black body radiation</td>
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<td>2</td>
<td>5. explain the particle model of light in terms of photons with particular energy and frequency</td>
<td>3. (Act 7) identify data sources gather, process and present information to summarise the use of the photoelectric effect in photocells.</td>
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<td>1</td>
<td>6. identify the relationships between photon energy, frequency, speed of light and wavelength: ( E = hf ) and ( c = f\lambda )</td>
<td>Humphrey’s Set 61</td>
<td>4. (Act 8) solve problems and analyse information using: ( E = hf ) and ( c = f\lambda )</td>
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<td>5. (Act 9) process information to discuss Einstein and Planck’s differing views about whether science research is removed from social and political forces</td>
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<td>3. Limitations of past technologies and increased research into the structure of the atom resulted in the invention of transistors</td>
<td>½</td>
<td>1. identify that some electrons in solids are shared between atoms and move freely</td>
<td>Contexts II: pp. 290-302</td>
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<td>2</td>
<td>2. describe the difference between conductors, insulators and semiconductors in terms of band structures and relative electrical resistance</td>
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<td>2</td>
<td>3. identify absences of electrons in a nearly full band as holes, and recognise that both electrons and holes help to carry current</td>
<td>1. (^{(\text{Exp 10})}) perform an investigation to model the behaviour of semiconductors, including the creation of a hole or positive charge on the atom that has lost the electron and the movement of electrons and holes in opposite directions when an electric field is applied across the semiconductor</td>
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<td>½</td>
<td>4. compare qualitatively the relative number of free electrons that can drift from atom to atom in conductors, semiconductors and insulators</td>
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<td>½</td>
<td>5. identify that the use of germanium in early transistors is related to lack of ability to produce other materials of suitable purity</td>
<td>2. (^{(\text{Act 11})}) gather, process and present secondary information to discuss how shortcomings in available communication technology lead to an increased knowledge of the properties of materials with particular reference to the invention of the transistor</td>
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<td>½</td>
<td>6. describe how ‘doping’ a semiconductor can change its electrical properties</td>
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<td>7. identify differences in p and n-type semiconductors in terms of the relative number of negative charge carriers and positive holes</td>
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<td>½</td>
<td>8. describe differences between solid state and thermionic devices and discuss why solid state devices replaced thermionic devices</td>
<td>3. (^{(\text{Act 12})}) identify data sources, gather, process, analyse information and use available evidence to assess the impact of the invention of transistors on society with particular reference to their use in microchips and microprocessors</td>
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<td>4. Investigations into the electrical properties of particular metals at different temperatures led to the identification of superconductivity and the exploration of possible applications</td>
<td>1</td>
<td>1. outline the methods used by the Braggs to determine crystal structure.</td>
<td>Contexts II: pp. 271-283</td>
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<td>2½</td>
<td>2. identify that metals possess a crystal lattice structure 3. describe conduction in metals as a free movements of electrons unimpeded by the lattice. 4. identify that resistances in metals is increased by the presence of impurities and scattering of electrons by lattice vibrations.</td>
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<td>½</td>
<td>5. describe the occurrence in superconductors below their critical temperature of a population of electron pairs unaffected by electrical resistance.</td>
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<td>1. (Act 13) process information to identify some of the metals, metal alloys and compounds that have been identified as exhibiting the property of superconductivity and their critical temperatures.</td>
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<td>2</td>
<td>6. discuss the BCS theory.</td>
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<td>2. (Exp 14) perform an investigation to demonstrate magnetic levitation. 3. (Exp 14) analyse information to explain why a magnet is able to hover above a superconducting material that has reached the temperature at which it is superconducting</td>
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<td>1</td>
<td>7. discuss the advantages of using superconductors and identify limitations to their use</td>
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<td>4. (Act 15) gather and process information to describe how superconductors and the effects of magnetic fields have been applied to develop a maglev train 5. (Act 15) process information to discuss possible applications of superconductivity and the effects of those applications on computers, generators and motors and transmission of electricity through power grids</td>
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**HSC Physics C3: From Ideas to Implementation Experiment 1: Discharge Tubes**

**Aim:** To perform an investigation and gather first-hand information to observe the occurrence of different striation patterns for different pressures in discharge tubes

**Materials**
- Discharge tubes
- Induction coil
- Power supply and leads.

**Method**
Your teacher will set up the discharge tubes. Record your observations for each tube.

**Results**
1. Is there a relationship between the striation patterns and the gas pressure? If so, what is it?
2. Why can a perfect vacuum never be achieved?
3. What properties of glass allow it to be stable and resist crushing at high vacuum?

**HSC Physics C3: From Ideas to Implementation Experiment 2: Cathode Ray Tubes**

**Aim:** To perform an investigation and gather first-hand information to demonstrate and identify properties using discharge tubes:
- containing a maltese cross
- containing electric plates
- with a fluorescent display screen
- containing a glass wheel

and analyse the information gathered to determine the charge on the cathode rays.

**Materials**
- Discharge tubes with the above fixtures.
- Induction coil
- Power supply and leads
- Magnet

**Method**
Your teacher will set up the cathode ray tubes. Write down all your observations.
The magnet is used to deflect the cathode rays. Note the direction that the cathode rays move in.

**Discussion**
1. How does the maltese cross experiment show that electrons are particles?
2. How does the paddle wheel experiment show that electrons are particles?
3. How does the deflection of the cathode rays in a magnetic field show it to be negative?
**HSC Physics C3: From Ideas to Implementation Activity 3: Electric Fields & Magnetic Force**

**Aim:** To solve problems and analyse information using \( F = qvB \sin \theta \) and \( E = \frac{V}{d} \)

1. Do Humphrey’s Sets 37 and 47.

3. A velocity filter is a device used to select charged particles of a particular speed. It can be diagrammatically represented as follows:

(a) What is the direction of the force experienced by a positively charged particle due to the electric field?

(b) What is the direction of the force experienced by a positively charged particle due to the magnetic field?

(c) Hence, write an expression for the velocity of a charged particle that passes through the filter undeflected.

(d) What is the speed of a negatively charged particle that passes through a velocity filter undeflected when the spacing between the electric plates is 3 cm with a voltage of 40,000 V and a magnetic field of 2 T?
HSC Physics C3: From Ideas to Implementation Activity 4: Charged Plates

Aim: To gather, analyse and process information on the use of electrically charged plates and point charges in photocopying machines and lightning conductors.

Write a 500 word report on this issue. A bibliography must be included and in-text referencing used.

HSC Physics C3: From Ideas to Implementation Experiment 5: Radio Waves

Aim: To perform an investigation to demonstrate the production and reception of radio waves

Materials
- Induction coil
- Power supply & leads
- Am/FM radio
- (FM transmitter) – kits available from Dick Smith Electronics, Jaycar Electronics, etc.

Method
1. Tune the radio to the AM band and clearly receive a station.
2. Set up the induction coil and turn it on.
3. Listen to the effect of the induction coil on the AM radio.
4. Repeat steps 1 to 3 for a FM station.
5. Use the FM transmitter to broadcast a signal.

Discussion
1. Why isn’t FM affected by the spark gap?
2. How does the FM transmitter work?

HSC Physics C3: From Ideas to Implementation Activity 6: Quantum Einstein

Aim: To identify data sources, gather, process and analyse information and use available evidence to assess Einstein’s contribution to quantum theory and its relation to black body radiation.

Write a 500 word report on this issue. A bibliography must be included and in-text referencing used.
**HSC Physics C3: From Ideas to Implementation Activity 7: Uses of the Photoelectric Effect**

Aim: To identify data sources gather, process and present information to summarise the use of the photoelectric effect in:

- breathalysers
- solar cells
- photocells

Write a 500 word report on this issue.
A bibliography must be included and in-text referencing used.

**HSC Physics C3: From Ideas to Implementation Activity 8: Light Quanta**

Aim: To solve problems and analyse information using \( E = hf \) and \( c = f\lambda \)

1. Do Humphrey’s Set 61

2. Calculate the following given that \( c = 2.9975 \times 10^8 \) m/s:

   (a) The wavelength of light of frequency \( 4.5 \times 10^{14} \) Hz.
   (b) The frequency of yellow light given that its wavelength is 590 nm.
   (c) The length of a mobile phone antenna given that its operating frequency is 900 MHz.
   (d) The period of an ultraviolet laser given that its wavelength is 210 nm.

**HSC Physics C3: From Ideas to Implementation Activity 9: Social Implications**

Aim: To identify data sources, gather and process information to discuss Einstein and Planck’s differing views about whether science research is removed from social and political forces

Write a 400 word report on this issue.
A bibliography must be included and in-text referencing used.
HSC Physics C3: From Ideas to Implementation Experiment 10: Semiconductors

Aim: To perform an investigation to demonstrate a model for explaining the behaviour of semiconductors, including the creation of a hole or positive charge on the atom that has lost the electron and the movement of electrons and holes in opposite directions when an electric field is applied across the semiconductor.

Background
In this experiment, we are going to use the process of gel electrophoresis to simulate the movement of charges in a semiconductor. In gel electrophoresis, an electric field is applied across a gel containing a mixture. Any charged particles in the mixture will be attracted to its oppositely charged plate. In this way the mixture is separated on the basis of its electrical charge (it can also be separated by size since the “stiffness of the agar gel will make it harder for larger molecules to pass).

Materials
PV CD-ROM & computer
Prepared agar gel 10 X 15 X 2 cm
0.1 mol/L potassium permanganate solution (electrons)
0.5 mol/L copper sulfate solution (positive holes)
50 ml beaker.
Aluminium foil
Power supply and leads

Method
1. Pour approximately 5 ml of the copper sulfate solution and 5 ml of the potassium permanganate solution into the 50 ml beaker.
2. Set up the remaining equipment as follows:

3. Apply the mixture along a line in the middle of the agar gel.
4. Turn on the voltage and observe. This may take a while.

Discussion
1. In this model, coloured materials represent the positive holes and electrons. What would the agar gel represent?
2. How does this experiment reconcile with the wave model of electrons?
HSC Physics C3: From Ideas to Implementation Activity 11: Transistors

Aim: To gather, process and present secondary information to discuss how shortcomings in available technology lead to an increased knowledge of the properties of materials with particular reference to the invention of the transistor.

Write a 500 word report on this issue.
A bibliography must be included and in-text referencing used.

HSC Physics C3: From Ideas to Implementation Activity 12: The Impact of Transistors

Aim: To identify data sources, gather, process, analyse information and use available evidence to assess the impact of the invention of transistors on society with particular reference to their use in microchips and microprocessors.

Write a 500 word report on this issue.
A bibliography must be included and in-text referencing used.

HSC Physics C3: From Ideas to Implementation Activity 13: Superconductivity

Aim: To process information to identify some of the metals, metal alloys and compounds that have been identified as exhibiting the property of superconductivity and their critical temperatures.

Read the following articles:
When electrons go with the flow New Scientist 12 Jun 1993
Striptease New Scientist 26 Jun 1999
Superconductors in a twist New Scientist 7 Feb 1998
The heat is on New Scientist 3 May 1997

Based on these articles, write a 500 word report on this issue.
A bibliography must be included and in-text referencing used.
**HSC Physics C3: From Ideas to Implementation Experiment 14: The Meissner Effect**

Aim: To perform an investigation and gather information to demonstrate magnetic levitation.

To analyse information about magnetic levitation to explain why a magnet is able to hover above a superconducting material that has reached the temperature at which it is superconducting

**Materials**
A YBCO superconductor (or similar high temperature superconductor)
Small cylindrical rare earth magnet.
Liquid nitrogen in an open vacuum flask.
*New Scientist* articles from the previous activity.

**Method**
Your teacher may demonstrate a YBCO superconductor in class.

A video of a magnet over a YBCO superconductor is located at http://www.physics.ubc.ca/~outreach/p420_97/bruce/ybco.html

**Discussion**
1. What are some current theories about magnetic field repulsion?
2. What is the Meissner effect?

**HSC Physics C3: From Ideas to Implementation Activity 15: Future of Superconductivity**

Aim: To gather and process information to describe how superconductors and the effects of magnetic fields have been applied to develop the maglev train

To gather and process information to discuss possible applications of superconductivity and the effects of those applications on computers, generators and motors and transmission of electricity through power grids

1. Write a 700 word report on the application of superconductors to maglev trains, computers, generators, motors and the transmission of electricity through power grids. A bibliography must be included and in-text referencing used.