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| **Subject:** | **Physics** | **Time: 1h 15 min** |
| **Level:** | A-Level |
| **Worksheet Title:** | **P06 – Falling Magnet through a Solenoid – Virtual Laboratory** |

**Apparatus List**

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| 01 × laptop | 01 × pre-activity worksheet |

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| 1. In this practical, electromagnetic ideas will be induced in your brains using the easy Java simulation ejs\_FallingMagnet08.jar. ☺
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| 1. Predict outcomes of various scenarios.
2. Explain your reasoning. (This is so that, in the unlikely event you are wrong, you can trace the wrong thinking and weed it out.)
3. Run the simulation to verify your prediction.
4. Are your predicted outcome and the simulated outcome identical? If they are not, what is the difference and what could have caused this difference? (We have to learn to check for own flaws in thinking.)
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| Before we start, one clarification between magnet falling down through a copper tube versus magnet falling down through a solenoid of copper wire – the induced current in the solenoid is constrained to flow along the copper wire.  |

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| **Scenario A – Setting the Baseline – Teacher go through** |
| Default Settings

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| **Parameter / unit** | **Magnitude** |
| Magnet\_Z / m | 0.500 |
| L / m (in **red** for magnet) | 0.100 |
| B / T | 2.470 |
| v / m/s (in **red** for magnet) | 0.000 |
| Solenoid\_Z / m | –0.500 |
| L / m (in **orange** for solenoid) | 0.000 **🡺 0.500** |
| 30/L  | ∞ 🡺 60.0 |
| v / m/s (in **orange** for solenoid) | 0.000 |

1. **Change solenoid length to 0.500 m.**
2. **Must press Enter key. Please note that 30/L becomes 60.0 automatically.**
3. **Click on emf vs t (bottom right).**
4. **Click on Coil (bottom right above v).**
5. **Click**  **to run the simulation.**
 | *t****E*** |
| Explanation:………………………………………………………………………………………………………………………2nd peak higher than 1st and 2nd curve thinner than 1st curve because increase in velocity due to acceleration of free fall, hence higher rate of change of flux for magnet leaving solenoid compared to entering solenoid. Area under the two peaks are same because area under E-t graph represents change in flux linkage and it would be the same change in flux linkage for the same magnet approaching and leaving. |
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| **Scenario B – Reversing Polarity (Will the new graph be any different from A? Why?)** |
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| **Parameter / unit** | **Magnitude** |
| Magnet\_Z / m | 0.500 |
| L / m (in **red** for magnet) | 0.100 |
| B / T | 2.470 |
| v / m/s (in **red** for magnet) | 0.000 |
| Solenoid\_Z / m | –0.500 |
| L / m (in **orange** for solenoid) | **0.500** |
| 30/L  | 60.0 |
| v / m/s (in **orange** for solenoid) | 0.000 |

1. **Sketch and explain your expected *E – t* graph in blue/black.**
2. **Click Reset** **.**
3. **Reverse the polarity of the magnet so that South is down.**
4. **Click**  **to run the simulation.**
5. **Copy the simulated graph onto the same axes in red.**
6. **Explain the shape of the graph.**
 | **Predicted Graph in Blue/Black*****t******E*** |
| Explanation:………………………………………………………………………………………………………………………Previously, N-pole approaches so induced \*\*current flows such that induced effect is N. Now S-pole approaches so induced current flows such that induced effect is S. Same for magnet leaving solenoid. So the graph is flipped horizontally.\*\*may or may not have induced current |
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| **Scenario C – Varying Strength of Magnet (What will this affect?)** |
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| **Parameter / unit** | **Magnitude** |
| Magnet\_Z / m | 0.500 |
| L / m (in **red** for magnet) | 0.100 |
| B / T | 2.470 **🡺 5** |
| v / m/s (in **red** for magnet) | 0.000 |
| Solenoid\_Z / m | –0.500 |
| L / m (in **orange** for solenoid) | **0.500** |
| 30/L  | 60.0 |
| v / m/s (in **orange** for solenoid) | 0.000 |

1. **Sketch and explain your expected *E – t* graph in blue/black.**
2. **Click Reset** **.**
3. **Change magnet strength to 5 T.**
4. **Press Enter key.**
5. **Click**  **to run the simulation.**
6. **Copy the simulated graph onto the same axes in red.**
7. **Explain the shape of the graph.**
 | **Predicted Graph in Blue/Black*****t******E*** |
| Explanation:………………………………………………………………………………………………………………………Peak has double the height/depth. Previously, E = –dΦ/dt but with 2B and same rate, E’ = –d(2Φ)/dt = 2E |
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| **Scenario D – Loooong solenoid (What happens while the magnet is falling inside the solenoid?)** |
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| **Parameter / unit** | **Magnitude** |
| Magnet\_Z / m | 0.500 |
| L / m (in **red** for magnet) | 0.100 |
| B / T | 2.470 |
| v / m/s (in **red** for magnet) | 0.000 |
| Solenoid\_Z / m | –0.500 |
| L / m (in **orange** for solenoid) | 0.500 **🡺 1.000** |
| 30/L  | 60.0 🡺 30.0 |
| v / m/s (in **orange** for solenoid) | 0.000 |

1. **Sketch and explain your expected *E – t* graph in blue/black.**
2. **Click Reset** **.**
3. **Change solenoid length to 1.000 m.Please note that 30/L becomes 30.0 automatically.**
4. **Press Enter key.**
5. **Click**  **to run the simulation.**
6. **Copy the simulated graph onto the same axes in red.**
7. **Explain the shape of the graph.**
 | **Predicted Graph in Blue/Black*****t******E*** |
| Explanation:……………………………………………………………………………………………………………………… |
| E = 0 in between the 2 peaks! No change in flux while the magnet is falling inside the solenoid.……………………………………………………………………………………………………………………… |
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**Please take 15 minutes to complete an online survey.**

**https://docs.google.com/a/moe.edu.sg/spreadsheet/viewform?hl=en&key=0AiAkAg4FK9\_xdENMUDlTdXFadUU2d2o5TzkxQ2U3X1E (shortcut on desktop)**

**OR http://tinyurl.com/magfallQ**

The survey serves as a means for us to solicit your feedback
on the effectiveness of the applet/worksheet/lesson.

Your feedback and comments will be used to improve future lessons/applets.

If you have any other feedback to improve the design of the applet,
you can email weelookang@gmail.com.

Thank you for taking the time and effort to complete this questionnaire. ☺ 🖒 ♥

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| **Check Point for Understanding 🗹**  |

An *E*-*t* graph is obtained by dropping a magnet through a solenoid connected to the voltage sensor of a data-logger.

***E***



***t***

Answer the following questions.

1. Explain why the curve slopes upwards from A to B.

As magnet falls towards or approaches the solenoid, there is an increase in magnetic flux linkage. This change induces an **increasing** e.m.f. in the solenoid in a direction such that it may oppose the increase in flux linkage.

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1. Explain why the induced e.m.f. shown at B has a smaller magnitude than the e.m.f. shown at D.

As the magnet is falling freely, it undergoes acceleration *g* and its velocity upon leaving the solenoid is larger than entering the solenoid. Thus the rate of change of magnetic flux linkage is higher when the magnet leaves the solenoid, resulting in a larger induced emf at D compared to B. (Faraday’s Law)

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1. Explain why the graph has a positive and a negative section.

As magnet approaches the solenoid, there is an increase in magnetic flux linkage. This increase induces an e.m.f. in the solenoid in a direction such that it may oppose the increase in flux linkage. When the magnet leaves the solenoid, there is now a decrease in magnetic flux linkage. This decrease induces an e.m.f. in a direction opposite to the previous case such that it may oppose the decrease in flux linkage.

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1. The areas under the two segments of the curve are the same. Explain why this is so.

Area under the two peaks are same because area under E-t graph represents change in flux linkage and it would be the same change in flux linkage for the same magnet approaching and leaving.

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