VicPhys

2018 Physics Teachers' Conference

Discussion Group Activity

Teaching strategies and exam techniques for poorly done exam questions

This Package has:

- for the topics of i) Projectile Motion, ii) Connected Bodies, iii) Energy & Energy Transfer and iv) PE Effect has information on
  - Key Principles,
  - Misconceptions,
  - Exam question that was poorly done,
  - Teaching strategies,
  - Exam Techniques and
  - Discussion questions, as well as
- A Response Sheet

Your Table's Task is to:

- Work in groups of 2 or 3,
- Each group to select a different topic,
- Each group to do the discussion questions and complete a Response Sheet, then
- Share their thoughts with others at the table.

This document and the responses will be http://www.vicphysics.org/conf2018.html

Vicphysics Teachers' Network

Projectile Motion

Contexts: Objects (for example golf balls) moving in a parabolic path under the action of gravity. Air resistance is to be considered as negligible in quantitative questions involving calculations, but may need to be included in qualitative questions.

Key questions:
- What is the maximum height reached by the projectile?
- What is the time taken for the projectile to land?
- What is the velocity of the projectile at different points of its flight?
- How far does the projectile travel?

Principles:
- If air resistance is negligible, then the total energy is constant.
- Objects that are projected from, and land on the same horizontal surface will have a vertically symmetrical path.
- In the vertical direction, a projectile accelerates due to the force of gravity (9.8 m/s^2 downwards). Assuming air resistance is ignored, in the horizontal direction a projectile has a uniform velocity component as no forces are acting.

Common misconceptions and mistakes
- Incorrectly using or copying formulas (including the Range Formula) from student notes.
- Not clearly setting out working when solving multi-step problems.
- Using the approach of finding the time to the top of flight and then doubling it to find the total time, but forgetting to double it
- Incorrectly assuming that the kinetic energy is zero at the top of the flight/at the midpoint
- Neglecting the vector nature of the quantities omitting negative signs
- Confusing the vertical component of the velocity with the total velocity
- Misusing range formula when launch and target are at different levels.

Students use a catapult to investigate projectile motion. In their first experiment, a ball of mass 0.10 kg is fired from the catapult at an angle of 30° to the horizontal. Ignore air resistance. In this first experiment, the ball leaves the catapult at ground level with a speed of 20 m s^{-1}.

However, instead of reaching the ground, the ball strikes a wall 26 m from the launching point, as shown in Figure 8a. Figure 8b shows an enlarged view of the catapult.

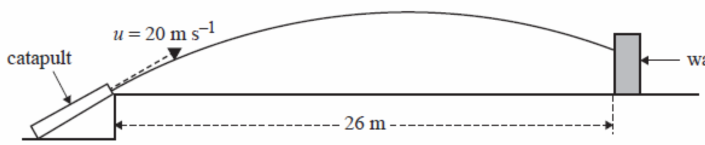


Figure 8a

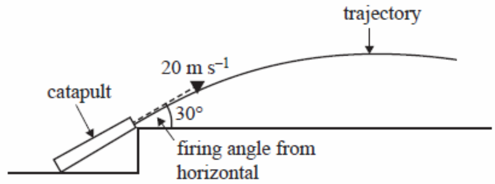


Figure 8b

a. Calculate the height of the ball above the ground when it strikes the wall. Show your working. 3 marks

2017 Q'n 9a: Average: 1.4 out of 3, only 40% got 3 marks

Teaching Strategy:

- Review free falling objects dropped from a height
- Discuss what the path of a projectile launched horizontally looks like, the forces acting on the object etc
- Compare the free falling object with the projectile launched horizontally. Analyse the motion by resolving into the horizontal and vertical component
- Discuss inclined projectiles
- Demo: While walking across the classroom with an object in the palm of your hand, and looking ahead the whole time, project the object vertically upwards, continue walking. Ask the students how close the object came back to your hand. It takes some practice

Resources

- *Predict Observe Explain* activity dropping a ball horizontally and vertically from the same height (https://www.youtube.com/watch?v=zMF4CD7i3hg)
- Demonstration with a Ballistics cart – (https://www.youtube.com/watch?v=2kCNjqpckMk)
- Prac Task with marble projectile launcher
- PHET Projectile Motion Simulation - https://phet.colorado.edu/en/simulation/projectile-motion
- Model projectile motion in Excel
- Roll a ball down a ramp and determine the ball's velocity with a pair of photogates. Get students to predict where the ball will land

Extension

- Air Resistance. Conceptual Understanding. VCAA 2007 Exam 1 Qu 16- 17 only 16% of students achieved full marks.

Exam Technique

- Draw a fully labelled diagram.
- If the initial velocity is given, draw a vector and diagram and resolve it into the horizontal and vertical components
- Treat the horizontal and vertical component separately by dividing the working area down the middle. Using clear headings or a table can assist students with setting out work. List the known and unknown values (label the direction + or -, if ↑ is positive, then a is -).
- For vertical component use the equations of motion. For horizontal component use $v = d/t$
- The time of flight is the link between the horizontal and vertical component

Discussion Questions

1. Working out in multi-step problems has been identified as an area of concern. Do you suggest other ways that students should set out their work?
2. What mistakes do your students make?
3. How would you modify the exam technique?
4. Should students avoid the range formula, etc and instead use first principles?

Connected Bodies

Contexts: Cars and trailers, trains and carriages, pulleys, hot air balloons, abseiling. These are examples of the two body problem where two objects interact with each other. 'Connected bodies' is a basic model.

Key question: What is the tension in the connector and will it hold?

Principles:

- Newton's 2nd Law applies to each mass separately, and also to the system as a whole,
- Forces within the connector are an example of Newton's 3rd Law and
- The two connected bodies have the same acceleration.

Common misconceptions and mistakes

- Ignore the tension in the connector and assume the only force acting is the weight force
- Assume tension only acts on the mass being pulled and not on the mass doing the pulling
- Assume acceleration = g

Exam results

Two physics students are conducting an experiment in which a block, m_1, of mass 0.40 kg is being pulled by a string across a frictionless surface. The string is attached over a frictionless pulley to another mass, m_2, of 0.10 kg. The second mass, m_2, is free to fall vertically. This is shown in Figure 1.

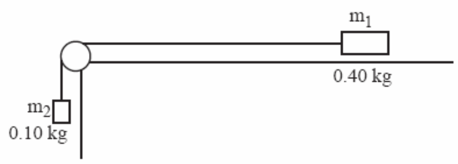


Figure 1

Q'n 3
Average: 0.7 out of 2 (35%),
Only 10% got 2 marks

The block is released from rest.

Question 3

What is the acceleration of the block m_1?

Teaching Strategy:

- Identify the various contexts as examples of broader category of the two body problem and view the exam style scenarios as a simplified version.
- Set up a scenario on an air track with a falling mass connected by string to glider.
- Illustrate that the mass and the glider will have the same displacement, same speed and same acceleration.
- Draw labelled diagram of the scenario with mass values and force vectors for weight and tension, with two vectors for tension, one acting on each mass.
- Emphasise the 3rd law for the connector and that the tension is an internal force within the system.
- Identify the force(s) acting on the system as a whole.
- Use Newton's 2nd Law to develop expressions for each mass and for the system as a whole.
- Solve for the acceleration and for the tension in the connector
- Practice the analysis as a class exercise using the air track with different masses and photogates to measure the acceleration of the glider. Do several examples with different combinations of masses.

Extension

- Introduce frictional forces

Exam Technique

- Draw on the diagram vectors for all the forces including the tension acting on both masses.
- Determine what is being asked and decide whether to apply Newton's 2nd Law to the falling mass, the sliding mass or the whole system.
- Apply 2nd law and solve for unknown.

Discussion Questions

1. Suggest some scenarios of two body problems and connected bodies.
2. What mistakes do your students make?
3. How would you modify the strategy and also the exam technique.

Energy and Energy Transfer

Contexts: Motion of masses connected to springs, motion of cars and trains on roller coasters, motion of particles in fields

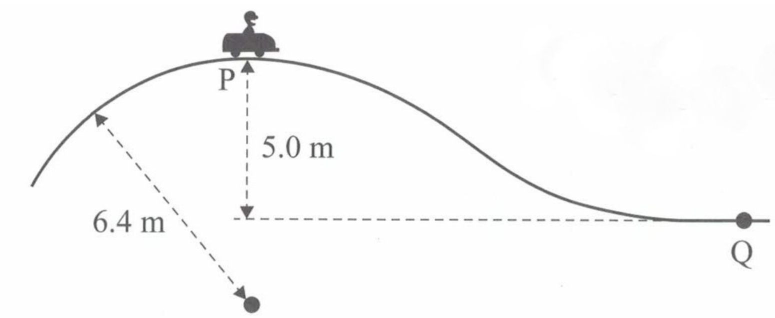
Key question: How does the energy of a moving particle change as it moves?

Principles:
- For a closed system, the total energy is conserved. Within the system, energy can be transferred from one form to another.
- Energy can be transferred into or out of a system by doing work, heating or radiation.

Misconceptions:
A major difficulty for students is to fully identify the system of objects that they are considering, eg if there is gravitational potential energy, then there must be masses interacting, if there is spring potential energy, then there must be a spring in the system, if there is motion of any components, there must be kinetic energy. They tend to focus on a particle and not know how to include the interactions that the particle is having with its system that are result in energy being transferred between different components of the system.

Sometimes students try to analyse motion using forces, and are unsuccessful because they don't realise that the net forces on moving particles in situations such as those shown below are not constant.

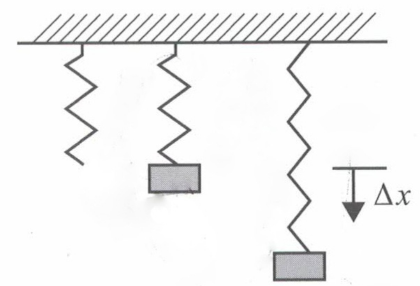
Exam results:
2017 Q8b
A roller-coaster is arranged so that the normal reaction force on a rider in a car at the top of the circular arc at point P, shown below, is briefly zero. The section of track at point P has a radius of 6.4 m.



Average 0.75 out of 2 (38%)
The most common error was to ignore the initial KE and simply convert the GPE into final KE

b. The car is faulty and only achieves a speed of 4.0 m s^{-1} at the top of the arc at point P. Calculate how fast this car would be moving when it reaches the bottom at point Q 5.0 m below point P. Assume that there is no friction and no driving force on the car. 2 marks

2017 Q13a
Pat and Robin hang a mass of 2.00 kg on the end of a spring with a spring constant k = 20.0 N m^{-1}. They hold the mass at the unstretched length and release it, allowing to fall, as below.



Average 0.85 marks out of 3 (32%).
The most common error was to use mg = kx.

a) Determine how far the spring stretches until the mass momentarily comes to rest. Show your working 3 marks

Teaching Strategies:

- As a class, consider Feynman's block accounting analogy for conservation of energy in a system http://www.feynmanlectures.caltech.edu/I_04.html.
- When teaching problem solving, give priority to taking time to define the system and the energies stored in the system.
- Use energy pie charts to illustrate the different distribution of energy in the system as time evolves. Best for closed systems where there is no friction.
- Use energy bar graphs to illustrate the different distribution of energy in the system as time evolves. Able to be extended to cases of systems where energy is transferred in or out.
- Explore the PheT Pendulum Lab or Skate Park Lab (both updated to HTML 5)
- Set up a spring system like the one in Q 13 and film it using Tracker, or measure motion of mass with a data logger, and graph the kinetic energy of the mass, the gravitational potential energy of the mass and the spring potential energy versus time.
- Investigate the motion of a vertically bouncing ball and graph the kinetic energy of the ball and gravitational potential energy of the ball over time.

<u>Extension:</u> Consider energy transfer in and out of the system, due to work done, absorption/emission of heat, or absorption/emission of radiation.

Exam Technique:

- List all the elements in the system with kinetic energy. (Note assumptions given in the question such as, for example, that the mass of a spring can be neglected.)
- List all the elements in the system that are interacting, as a result of which there is potential energy in the system.
- Calculate values of the above where possible at an initial time.
- Calculate values of the above where possible at a later time.
- Apply conservation of energy to determine unknown energy values.

Discussion Questions:

1. How do you approach such questions with your students?
2. Do you have a particular diagrammatic representation that you find successful?
3. How do you teach the concept of work?

Appendix: Some Common Energy Misconceptions in Middle and Senior Science

- Energy is used up or runs out
- Work is always done when an object moves
- Work is always done when a force is applied
- Confusing Work with Power
- An object at rest has no energy
- Something not moving can't have any energy.
- A force acting on an object does work even if the objects does not move.
- Energy is destroyed in transformations from one type to another.
- Energy can be recycled.
- Gravitational potential energy is the only type of potential energy.
- When an object is released to fall, the gravitational potential energy immediately becomes all kinetic energy.
- Energy is not related to Newton's laws.
- Energy is a force.
- Energy is an entity (reinforced by use of "flow" to describe energy)
- Energy associated with living things is not the same as energy in contexts such as heat and light and motion; when the term "energy" is used in Biology (or Chemistry) it is not the same as "energy" when used in Physics
- Confusion between sources of energy and forms of energy (eg petrol is often seen as a source of energy rather than a store of chemical energy)
- Substances can be converted into energy
- The various forms of 'potential energy' are **not** energy but rather situations where there is the potential to gain energy
- The principle of "conservation of energy"– and the need "to conserve energy" use the word 'conserve' in very different ways.

Photoelectric Effect

Context: Photoelectric effect is the emission of electrons from a substance that is illuminated by electromagnetic radiation.

Principles:

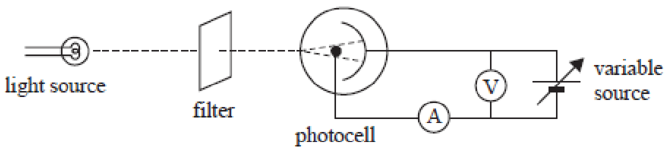
- Understand the experimental set-up – cathode/anode/variable/control and explain how it works
- Graph Interpretation and Prediction
- Understand and Predict the results of the experiment
- Explain with evidence the Particle-like nature of light
- Understand the classical wave model
- Compare wave model and particle model when explaining the nature of light (photon)

Some Common Misconceptions and mistakes:

- Students refer to photon and photo-electron as the same item
- Inability to plot data points and draw line of best fit on $E_{k\ max}$ vs Frequency, thus unable to find the work function from the graph, indicating they do not have a thorough understanding of the graph
- Students tend to read the frequency of the $E_{k\ max}$ vs Frequency without accounting for the multiplier
- Students have difficulty working out the gradient of Plank's Constant from a graph
- Students tend to quote Plank's constant instead of finding Plank's Constant from graph
- Stopping voltage is when electrons almost make it to the other side but then turn back – some students however believe that it is the energy when no electrons escape the metal (difference between stopping voltage and work function)
- Students have difficulty relating the theory of the photoelectric effect to "explain" questions, such as when asked to compare and contrast the particle model and the wave model, or explaining the development of the photon model – often students try and copy from their A4 sheet of notes without addressing the question – this is most evident when the information is correct however irrelevant material is added to the answer.
- Students have difficulty interpreting questions when shown in a different/unfamiliar format, e.g. *From your graph, what is the longest wavelength which would cause a photoelectron to be emitted?*

2016 Exam Question 19 (10 marks)

Emily is conducting an experiment to investigate the photoelectric effect. The apparatus is shown here. It consists of a light source, a filter and a photocell (a metal plate with a collecting electrode in a vacuum tube).



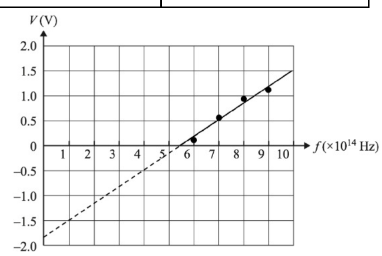
Emily uses various filters to shine a particular wavelength on the photocell. She increases the voltage (V) until the current just goes to zero and records this voltage. Emily repeats this process for different frequencies. Her results are shown in the table below.

Frequency (Hz)	Voltage (V)
6.0×10^{14}	0.16
7.0×10^{14}	0.52
8.0×10^{14}	0.88
9.0×10^{14}	1.20

a. On the axes below, plot Emily's data and draw the graph of voltage versus frequency. 2 marks

Most students were able to correctly plot the points and rule a line of best fit. (Average = 1.8/2)

A number of students did not continue the line below the x-axis, which made it difficult for them to complete Question 19b. Other students simply joined the dots with a jagged line.



b) From the graph, determine the value Emily would have found for each of the following: i) Planck's Constant (eV), ii) the Threshold frequency (Hz) and iii) the Work Function (eV). 3 marks

The most common errors were to simply quote Planck's constant from the data sheet or to read the threshold frequency as 5.5 Hz. (Average = 1.6 / 3)

c) Explain how the recorded voltage measurements give information about the emitted photoelectrons. (2 marks) *(Average - 0.5/2)*

Students were required to indicate that the voltage measurement provides information about the maximum kinetic energy of the photoelectrons. Some students were able to link the voltage to kinetic energy but did not indicate that it was the maximum kinetic energy. Many students wrote about other information regarding the photoelectric effect, but not about the photoelectrons.

d) For each frequency, Emily doubles the intensity of the incident light. Describe the graph Emily will now obtain in comparison with the original graph. Do these two graphs support the wave model or particle model of light? Justify your answer 3 marks *(Average = 1.6/3)*

Students were required to articulate the following:
- *The two graphs would be the same.*
- *The graphs support the particle theory of light.*
- *The energy of the photons depends on their frequency, not the intensity of the light source.*

Most students were able to articulate the first two points but could not articulate the third.

Teaching Strategy:

- Poster of the photoelectric effect experiment labelling all items and explain what each section is/does.
- Sketch and outline the important features of the KE versus Frequency graph e.g. threshold frequency, Ek max, what the slope/gradient represents and show how to calculate it from the graph.
- Explain explicitly that the work function and stopping voltage are different.
- Use of simulation to help visualize the experiment and the results eg PHET - Photoelectric Effect Simulation https://phet.colorado.edu/en/simulation/photoelectric.This allows students to predict the results and then explore their correct and incorrect answers, group discussions, reinforcing concepts.
- Create the photoelectric effect experiment using basic material, to enable a more visual and hands on approach (view: https://www.youtube.com/watch?v=muxRZ1irsrk)
- Use clickers for quizzing students (or e.g. Kahootz) - this provides instant feedback to both teacher and student in relation on what to focus on for improvement
- Quiz students orally shortly after each concept is taught, revisit a week, month, etc. later.
- Discuss as a class (or in groups) the I-V graph e.g. start with a reference light with a particular frequency and intensity, then pose questions as to what occurs when changes are made to the experiment such increase/decrease frequency and or intensity. Once students agree to outcomes, sketch:
  - the reference graph with the comparison graphs when the frequency is increased and decreased
  - the reference graph with the comparison graphs when the intensity is increased and decreased

Extension:

- How does the work function link to where the element is in the periodic table?
- Why is intensity independent of frequency for light but not sound?

Exam Technique:

- When asked to sketch a KE vs frequency graph make sure a line of best fit is created. The gradient of this line is Plank's constant – note: the question may be designed to be close to but not identical to this value. So be careful in sketching and calculating the gradient – show all working out
- Be able to explain the evidence for the particle model by understanding the photoelectric experiment. Read the question to determine what components are required and relevant for the answer instead of just transcribing directly from A4 sheet notes.

Discussion Questions:

1. What is the order in which you structure the content to explain the photoelectric effect?
2. What are the most common misconceptions your students have in relation to the photoelectric effect?
3. What equipment have you used to conduct the photoelectric effect?
4. What apps/simulations have you used to enhance student understanding of the photoelectric effect?

Response Sheet

Group's Response to Discussion Questions

Circle your topic: Projectile Motion Connected Bodies Energy & Energy Transfer PE Effect

Question 1:____

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Question 2:____

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Question 3:____

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Question 4:____

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Other Comments: