Physics 30

Released Items

2011 Released Assessment Materials

Government of Alberta

Alberta

Freedom To Create. Spirit To Achieve.

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The Alberta Education website is found at education.alberta.ca.

Contents

Performance Expectations

The performance expectations for Physics 30 are published in the Physics information bulletin. The graphic below is taken from the *2011 Physics 30 Information Bulletin* available at education.alberta.ca, via this pathway: Administrators > Provincial Testing > Diploma Examinations > Information Bulletins. It shows how different verbs correspond to different cognitive tasks. Here, the verbs are grouped into four categories—knowledge (K), comprehension and application (C/A), higher mental activities (HMA) and attitudes and skills.

Cognitive Expectations		
Knowledge	**Comprehension and Application**	**Higher Mental Activities**
Choose, classify, define, describe, identify, list, label, match, name, outline, predict*, recall, select, state, what, when, who Use memorized or algorithmic methods to solve problems	Apply, analyze, calculate, change, compare*, contrast, determine, estimate (interpolate or extrapolate), explain*, generalize, interpret*, infer, relate, translate, solve Design a procedure for a known experiment	Assess, compare*, differentiate, compile, compose, conclude, create, defend, evaluate, explain*, interpret*, judge, justify, organize, plan, summarize Transfer methods from one area to another Use generalized methods to solve problems Design a new procedure for an unfamiliar experiment
Attitudes and Skills Appreciate, collect, conduct, develop, gather, measure, observe, plot, work collaboratively		

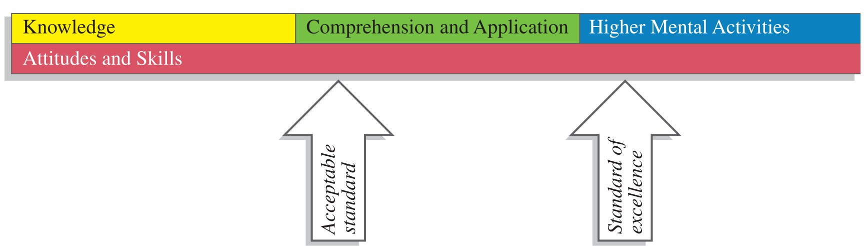
*These verbs are ambiguous because they have multiple connotations. The cognitive expectation is communicated by the context. If it is a very familiar context, the expectation is knowledge or comprehension and application; if it is unfamiliar, the expectation is comprehension and application or higher mental activity.

Acceptable Standard

Students who achieve the acceptable standard in Physics 30 will receive a final course mark of 50% or higher. Students achieving the acceptable standard have gained **new skills** and **knowledge** in physics but may encounter difficulties if they choose to enroll in post-secondary physics courses. These students are able to **define** basic physics terms: for example, scalar, vector, momentum, force, field, charging by conduction or by induction, refraction, diffraction, interference, the photoelectric effect, the Compton effect, matter-energy equivalence, nucleons, nucleus, decay, half-life, and stable energy states. These students are able to **state** and **use formulas as they appear** on the equation sheet: for example, momentum of a single object, linear momentum analysis, electric force, electric field, magnetic deflecting force, motor force, angle of refraction, index of refraction, focal length, magnification, photon energy, work function, mass (activity or percentage) remaining of a radioactive nuclide, photon energy, and energy change associated with photon emission or absorption. They can do this in situations where they need to sort through a **limited amount of information**. Their laboratory skills are limited to **following explicit directions** and to **using** laboratory data to **verify known physics** information. They are able to **identify** manipulated and responding variables, but not relevant controlled variables. These students are able to **relate graph shape** to **memorized** relationships, but their **analysis** of graphs is **limited to linear data**. These students tend to use **item-specific methods** in their problem solving and rarely apply the major principles of physics in their solutions: for example, conservation laws, balanced or unbalanced forces, and type of motion. When explaining the connections between science, technology, and society, these students tend to use **examples provided** from textbooks. These students have difficulty connecting physics to real-life scenarios beyond the classroom.

Standard of Excellence

Students who achieve the standard of excellence in Physics 30 receive a final course mark of 80% or higher. They have demonstrated their **ability** and **interest** in both mathematics and physics, and **feel confident** about their scientific abilities. These students should encounter little difficulty in post-secondary physics programs and should be encouraged to pursue careers in which they will utilize their talents in physics. Students who achieve the standard of excellence show **flexibility** and **creativity** when solving problems, and minor changes in problem format do not cause them major difficulties. These students are capable of **analyzing** situations that involve two-dimensional vectors, charge motion initially perpendicular to an external electric field, charge motion perpendicular to an external magnetic field, and energy-level values above or below given values based on photon characteristics, etc. They seek **general methods** to solve problems and are **not afraid** to **use physics principles** as a framework for their solutions. In the laboratory, students who achieve the standard of excellence can deal with **data that are less than perfect** or with **instructions that are incomplete**. These students are able to explicitly **relate** graph shape to **mathematical models** and to **physics equations**. They **transfer** knowledge from one area of physics to another and can express their answers in **clear** and **concise** terms. These students are able to **apply** cause-and-effect logic in a **variety of situations**: algebraically, experimentally, etc. In addition, these students can **connect** their understanding of physics to real-world situations that include technological applications and implications **beyond the classroom setting**.



Conclusion: Students who are functioning most of the time at only a **knowledge level** will not achieve the acceptable standard (50%) in either Physics 20 or Physics 30. Students who are functioning only at a **comprehension and application** level will not achieve the standard of excellence (80%). One of the purposes of these released items is to help students and teachers understand the level of functioning that a student is demonstrating, and to help students move to a higher level if the student wants to.

For examples of machine-scored items illustrating the different standards, refer to the 2011 *Physics 30 Information Bulletin.*

Released Machine-Scored Items

The Assessment Sector has released many machine-scored items that assess the Physics 30 portion of the Physics 20–30 Program of Studies, 2007, on the QuestA+ platform at https://questaplus.alberta.ca/ in the practice tests area.

Overview of 2011–2012 Physics 30 Released Assessment Materials

In 2010 Alberta Education posted *Physics 30 Formative Released Assessment Materials*. This year, the Physics 30 Assessment Materials contain two versions of a laboratory activity to illustrate an activity set at just the acceptable standard and an activity set at just the standard of excellence. The next set of activities in this package consists of adaptations of two old written-response questions into formative-assessment activities, and then an example of a summative assessment written-response question with a sample response and a holistic scoring guide. This is followed by a stand-alone formative assessment, peer feedback item exploring the evolution of the model of the atom. The final item models how these assessment practices can be applied to Physics 20 outcomes.

Diffraction and Interference Lab

Just-Acceptable Standard

Program of Studies connections

Physics 30 C1.10k	Students will **solve** double-slit and diffraction grating questions using $\lambda = \frac{d \sin\theta}{n}$, $\lambda = \frac{xd}{nl}$
Physics 30 C1.2s	Students will **conduct** investigations into relationships among observable variables and **use** a broad range of tools and techniques to **gather** and **record** data and information
Physics 30 C1.3s	Students will **analyze** data and **apply** mathematical and conceptual models to **develop** and **assess** possible solutions

Purpose

The purpose of this investigation is to verify that the equation $\lambda = \frac{d \sin\theta}{n}$ provides a better prediction for the wavelength of light than does $\lambda = \frac{xd}{nl}$ when the angle θ is greater than 10° or when x is very much greater than l.

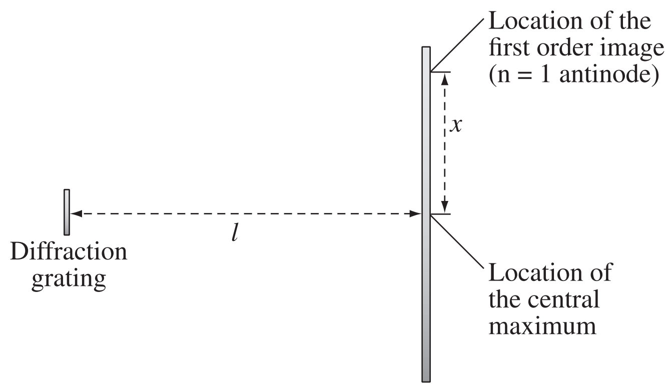
Materials

- 1 laser
- Screen
- Meter stick
- Set of double-slit apparatus with different slit separations
- A portion of a CD with the plastic labels peeled off
- A portion of a DVD with the plastic labels peeled off
- A portion of a blue-ray disk with the plastic labels peeled off

Procedure

1. Record the wavelength of the light emitted by the laser.

2. Arrange the laser and one double-slit apparatus and the screen as shown below.



3. Measure the distance from the double-slit apparatus to the screen and record this value.

4. Record slit separation, *d*.

5. Measure the distance from the central maximum to the first order maximum on either side. Record these values and calculate and record the average of the values.

6. Repeat steps 2 to 4 for several different double-slit apparatus.

7. Repeat steps 2 to 4 for the CD, DVD, and blue-ray disk.

Observations

Wavelength of laser ___________________

Observations					Analysis		
Distance from Double-Slit to Screen, *l* ( )	Slit separation, *d* ( )	Distance from CM to first order maximum, *x*			Angle using average *x* ( )	$\lambda = xd/nl$ ( )	$\lambda = d \sin\theta/n$ ( )
		On the Right ( )	On the Left ( )	Average ( )			
	CD =						
	DVD =						
	Blue-ray =						

Analysis

1. Calculate the angle to the first order maximum for each slit separation.
2. Calculate the wavelength using $\lambda = xd/nl$.
3. Calculate the wavelength using $\lambda = d \sin\theta/n$.

Conclusions

1. Identify the conditions under which each of the equations that model the diffraction and interference of light are good models.
2. Explain why there are two models.

Extensions

1. Design an experiment that allows you to measure θ instead of x. How would this be a better investigation? How would this be a worse investigation?
2. Derive $\lambda = d \sin\theta/n$ from $\lambda = xd/nl$ using trigonometry and interference of waves. Make notes of where you are assuming things are equal even though they are only approximately equal.

Just-Standard of Excellence

Problem

In the "Waves" section on your Physics 30 data sheet there are two equations given that algebraically model the interference pattern that occurs due to the diffraction of light through multiple openings. These equations are as shown below.

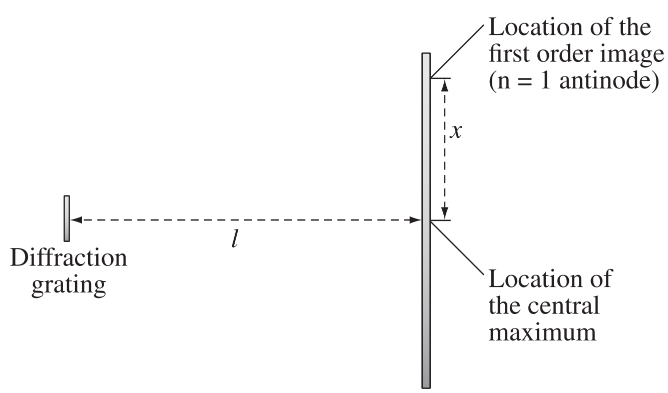
$$\lambda = \frac{xd}{nl} \quad and \quad \lambda = \frac{d\sin\theta}{n}$$

Which of the two equations **best** models the interference pattern created as light passes through a diffraction grating?

Experimental Design

A light source (laser or spectral line) that has a known wavelength value will produce an interference pattern when viewed through a diffraction grating. You will measure the distance between the central antinode and each of the visible antinodes, as well as the distance between the diffraction grating and the "screen" location. Using those measured values you will be able to calculate an experimental value for the spacing between sources on each of the gratings supplied to you. The validity of each of the algebraic models will be determined by comparing the calculated value to the accepted value.

Top View of Experimental Setup



The spacing on a standard lab grating is 1.82×10^{-6} m, on a CD it is 1.5×10^{-6} m, and on a standard DVD it is 7.4×10^{-7} m.

Data and Analysis

Present your data and an analysis of that data in a neat and organized fashion.

Evaluation

Discuss the validity of each of the algebraic models. As part of your response include answers to the following questions.

1. Why is it important to use antinodes on each side of the central maximum when determining an experimental value for the wavelength of the light being observed?

2. Are there any conditions in which it would make little or no difference which of the two algebraic models could be used? Justify your answer.

Suggested Implementation for Peer-Feedback Materials

Day 1 (20 minutes)
Distribute the question and the peer-feedback form at the same time.

For theoretical (i.e., non-skills) questions, have students read the question and talk about the depth of coverage required by the bolded verbs. Have the students then look at the peer-feedback form. In the centre section of the form there are horizontal bars that provide a graphical representation of the depth of coverage expected. Later in this introduction is a quick overview of different verbs and their respective cognitive expectations.

For the skill-based questions, the peer feedback form contains boxes that can be checked by the peer reviewer to indicate the presence, presence with error, or the absence of the required part of the response. This more closely reflects the nature of skill questions: either the responder has the skills or the responder does not. There is much less room for interpretation. Also, it is possible to provide a completely correct solution, so that becomes the expectation.

Day 2 (20 minutes, non-class time)
Students, individually or in groups, develop a response to the question.

Day 3 (20 minutes)
The responses are shared with others in the class, and peer feedback is provided. This feedback consists of completing the peer-feedback form, including comments indicating where the response falls short of the expectation or contains errors. This is the vitally important step: both the peer reviewer and the peer responder get to interact about the content of the course without a mark, score, or judgment about the responder being made.

Students receive their feedback forms from their peers and have an opportunity to describe what changes need to be made to the response. This is a critically important step for students, especially the middle- and lower-performing students, because they likely have not developed the process of using constructive criticism for improvement.

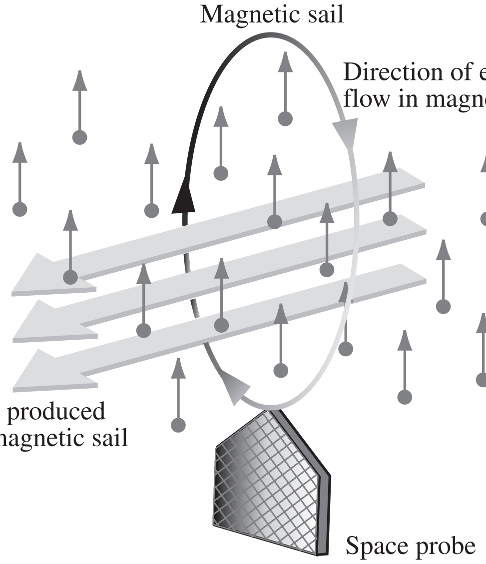
After students have had time to respond to the peer feedback, you can have students submit a final response for scoring or you can build a similar question for individualized assessment that covers similar material. It is good practice to score work done by individual students for the purpose of assigning individual grades; group work and peer feedback are excellent activities for practice, improvement, and learning.

If you decide to provide scores for the students' final responses, remember that a standard of excellence score (80%) requires students to build new connections between ideas and that a response that provides only exactly what the student was told is an acceptable-level response (50%).

Space Exploration Questions

Use the following information to answer the next question.

A magnetic sail is one proposed method of spacecraft propulsion. A magnetic sail consists of a large current-carrying loop made of a superconducting material. A superconductor is a material that has zero electrical resistance.



All stars emit energy in their plasma winds. Some of the energy is in the form of electromagnetic radiation and some of it is in the form of the kinetic energy of high-energy charged particles such as protons and electrons. The current in the magnetic sail induces a magnetic field. This field interacts with the charged particles in the plasma wind. This interaction can be used to produce thrust on the sail.

1. **Analyze** the operation of a magnetic sail. In your response,

- **explain** where the energy in a star's plasma wind comes from
- **determine** the direction of the magnetic deflecting force on a proton in the plasma wind as it passes by the magnetic sail. **Explain** how you determined this direction
- **compare** the thrust provided by a proton in the plasma wind to that provided by an electron in the same wind. **Support** your comparison with appropriate physics and equations and **list** any assumptions you are making
- **determine** the direction of the net force on the magnetic sail. **Explain** how you determined this direction
- **evaluate** this design for space propulsion

Student Name____________________ ***Peer Feedback—Space Exploration—Written Response 1*** Reviewer's Name____________________

Program Links to Tasks in this Question	The horizontal bar indicates the scope required in the response. Place an "x" on the bar to indicate the level demonstrated in the response.	Looking Back
explain where the energy of a star's plasma wind comes from (D3.6k)	Knowledge — Comprehension/Application — Higher Mental Activities **Explain** **Peer Feedback:** I've placed an "x" on the bar to indicate the level of your response. I set the level there because I noticed that…	**Changes that I am going to make** to my response…
determine the direction of the magnetic deflecting force on a proton in the plasma wind as it passes by the magnetic sail. **Explain** how you determined this direction (B3.5k, B3.2s)	Knowledge — Comprehension/Application — Higher Mental Activities **Determine** **Explain** **Peer Feedback:** I've placed an "x" on the bar to indicate the level of your response. I set the level there because I noticed that…	**Changes that I am going to make** to my response…
compare the thrust provided by a proton in the plasma wind to the thrust provided by an electron in the same wind. **Support** your comparison with appropriate physics and equations and **list** any assumptions you are making (A1.2k, A1.2s, B3.5k, B3.2s)	Knowledge — Comprehension/Application — Higher Mental Activities **Compare** **Support** **List** **Peer Feedback:** I've placed an "x" on the bar to indicate the level of your response. I set the level there because I noticed that…	**Changes that I am going to make** to my response…
determine the direction of the net force on the magnetic sail. **Explain** how you determined this direction (B3.2s, B3.3s)	Knowledge — Comprehension/Application — Higher Mental Activities **Determine** **Explain** **Peer Feedback:** I've placed an "x" on the bar to indicate the level of your response. I set the level there because I noticed that…	**Changes that I am going to make** to my response…
evaluate this design for space propulsion (ST 1)	Knowledge — Comprehension/Application — Higher Mental Activities **Evaluate** **Peer Feedback:** I've placed an "x" on the bar to indicate the level of your response. I set the level there because I noticed that…	**Changes that I am going to make** to my response…

Sample Response (and embedded notes to teachers)

Inside a star, smaller nuclei are forced together by very high gravitational pressure. This causes them to fuse together and produce a larger nucleus. The total measureable matter before and after the fusion is not the same—the matter after is less. This matter has been converted into energy as described by the conservation of mass-energy. The energy is carried away from the star as electromagnetic radiation across the full spectrum, with a peak corresponding to the temperature of the star, and high-energy charged particles.

To determine the direction of the force on a proton, I use my right hand (for positive charge), in which my fingers point in the direction of the external magnetic field (left, left and out of the page), my thumb points in the direction of the velocity of the protons, and my palm points in the direction of the deflecting magnetic force. This orientation reveals that the magnetic force on a proton in the solar wind is out of the page.

Note: *The hand rule must be described so that anyone could apply the rule to get the direction of the force. Because of the oblique view in the art, the actual direction of the force may be to the right and out of the page, but only if the magnetic field is described as to the left and out of the page.*

The equation that describes the force is $F_m = Bv_{\perp}q$. Since the electrons and the protons have the same charge and are travelling in the same magnetic field, the force acting on the sail as a reaction to the force acting on the particle depends on the speed of the particle. This information implies the speeds are the same, so the forces have the same magnitude.

To determine the direction of the net force on the solar sail I need to think about all of the forces acting on the sail. The forces acting on the sail are reaction forces, as described by Newton's third law: for every force, there is an equal but opposite-direction reaction force acting on the other object. All of the protons experience a force out of the page. They combine to cause the sail to experience a force into the page. The electrons in the plasma wind also experience a deflecting force. To get the direction I can use the idea that opposite charge will be deflected in the opposite direction, so the electrons are deflected into the page and the force they cause the sail to experience is out of the page.

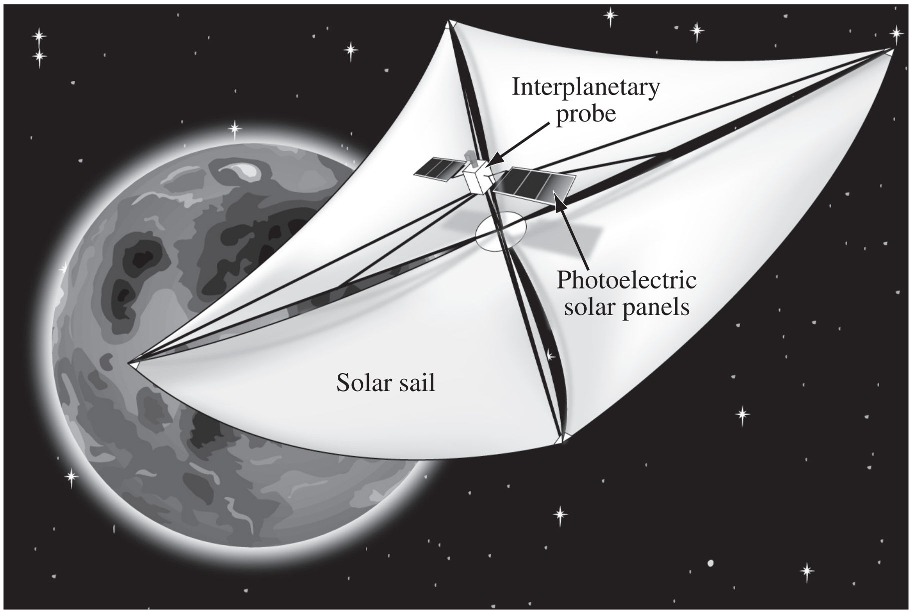
If the abundance of the particles is similar, then the net force acting on the sail is zero.

Evaluation: Based on the assumptions made, this is a poor design—the net force is zero. However, if the protons and the electrons have non-similar speeds, or if the number of electrons and protons is not identical, then there will be some net thrust. More research is required before this design is used.

Note: *An evaluation requires a statement of whether the design is good or poor (a value statement) and some support. The students need to explicitly relate the judgment they have provided to the information that supports that judgment.*

Use the following information to answer the next question.

Stars, such as our sun, emit electromagnetic radiation in all regions of the spectrum. An interplanetary probe can use the energy and the momentum of these emitted photons as a source of electricity and propulsion, respectively.



2. Analyze the use of electromagnetic radiation by a solar probe for thrust and power generation. In your response,

- **compare** the different parts of the solar spectrum for usefulness to provide propulsion and to activate the solar panels to produce electricity. **Justify** your comparison using appropriate formulas
- **predict** the effect of the increasing distance from the Sun on both the electrical potential difference and the current produced by the solar cells of the planetary probe as it moves farther away from the Sun. **Justify** your response
- **evaluate** which solar sail design would provide better propulsion: a shiny sail (highly reflective) or a black sail (highly absorptive)
- **predict** one feature that could be added to the interplanetary probe to protect it from damage caused by exposure to the electromagnetic radiation from the Sun. **Explain** how this feature would protect the probe

Student Name____________________ Reviewer's Name____________________

Peer Feedback—Space Exploration—Written Response 2

Program Links to Tasks in this Question	The horizontal bar indicates the scope required in the response. Place an "x" on the bar to indicate the level demonstrated in the response.	Looking Back
compare the different parts of the solar spectrum for usefulness to provide propulsion and to activate the solar panels to produce electricity. **Justify** your comparison using appropriate formulas (A1.2k, A1.3s, A1.4k, C2.1k, C2.1s, C2.3k, C2.6k)	Knowledge Comprehension/Application Higher Mental Activities **Compare** **Justify** **Peer Feedback:** I've placed an "x" on the bar to indicate the level of your response. I set the level there because I noticed that…	**Changes that I am going to make** to my response…
predict the effect of the increasing distance from the Sun on both the electrical potential difference and the current produced by the solar cells of the planetary probe as it moves farther away from the Sun. **Justify** your response (A1.2k, A1.3s, A1.4k, C2.1s, C2.3k, C2.6k)	Knowledge Comprehension/Application Higher Mental Activities **Predict** **Justify** **Peer Feedback:** I've placed an "x" on the bar to indicate the level of your response. I set the level there because I noticed that…	**Changes that I am going to make** to my response…
evaluate which solar sail design would provide better propulsion: a shiny sail (highly reflective) or a black sail (highly absorptive) (A1.2k, A1.3s, A1.4k)	Knowledge Comprehension/Application Higher Mental Activities **Evaluate** **Peer Feedback:** I've placed an "x" on the bar to indicate the level of your response. I set the level there because I noticed that…	**Changes that I am going to make** to my response…
predict one feature that could be added to the interplanetary probe to protect it from damage caused by exposure to the electromagnetic radiation from the Sun. **Explain** how this feature would protect the probe (C2.3k, ST 1)	Knowledge Comprehension/Application Higher Mental Activities **Predict** **Explain** **Peer Feedback:** I've placed an "x" on the bar to indicate the level of your response. I set the level there because I noticed that…	**Changes that I am going to make** to my response…

Sample Response (and embedded notes to teachers)

Solar panels use photon energy and the photoelectric effect to produce electricity. This requires the photons to carry energy greater than the work function of the solar panel, $E_{photon} > W$ (or frequency greater than the threshold frequency, $f > f_0$). This would be higher frequency visible light, ultraviolet, or maybe X-ray.

Propulsion uses photon momentum, $p = \frac{h}{\lambda}$. Shorter wavelengths (higher frequency) carry more momentum, which means that X-rays or gamma radiation have photons that have high momentum.

When the probe is close to the sun, the intensity is high. Lots of photons hitting the solar panels mean lots of photoelectric electrons being emitted, which means a high current. When the probe moves farther away, the intensity is less so the current is less. However, the frequency is the same close or far away so the potential difference will be the same.

Note: *The ejected electrons do not obey the photoelectric effect in terms of energy because within a photovoltaic device the electrons remain trapped and simply move across the p-n junction energy gap. So the solar panels produce electrical energy as long as* hf_0 *is greater than the gap energy.*

A shiny sail would reflect the photons back the way they came while the black sail would stop the photons. The change in velocity of the protons hitting the shiny sail is roughly twice that of those hitting the black sail.

So, the change in momentum of the photons incident on the shiny sail is greater (twice) and so the thrust force will be greater. $\Delta p = F\Delta t$ (or, the black sail will re-emit the energy in random directions so that there will be less forward thrust from the initial collision and then random thrust from the re-emissions).

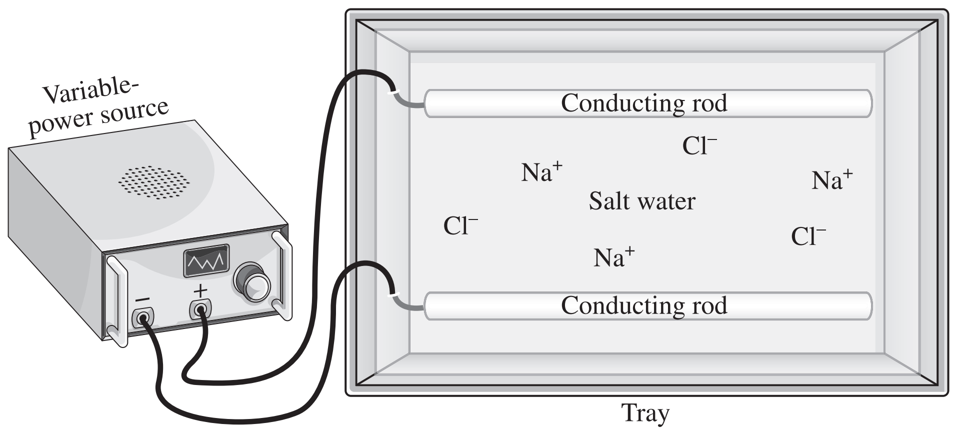
To protect the probe:
- Install a heat insulation shield to keep the probe from being "baked"
- Cover the probe with a high work function surface so that it is less likely to become charged (so that there is no electrical discharging which would damage electrical components)
- Cover the probe with a lead shield to block X-rays

Summative Assessment Question

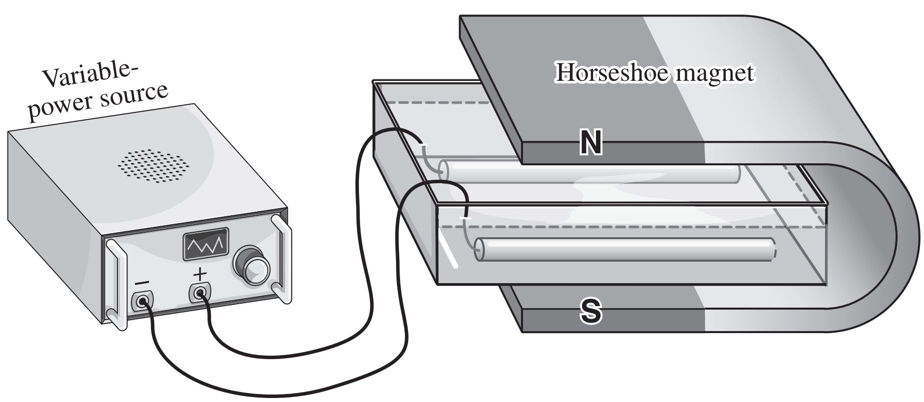
Use the following information to answer the next question.

A group of students observes the effect of electric and magnetic fields on the ions found in salt water.

Two conducting rods are submerged in a glass tray containing salt water, as shown in Diagram I. The salt water contains sodium ions (Na^+) and chloride ions (Cl^-). As a result of the electric forces exerted on the ions, the ions begin to accelerate.



A strong U-shaped magnet is placed around the tray, so that the north pole of the magnet is above the tray and the south pole of the magnet is below the tray, as shown in Diagram II. As a result of this external magnetic field, the motion of the ions in the salt water changes.



Written Response—5 marks

3. Using the concepts of electric fields, the effect of external fields on moving charges, and Newton's laws, **analyze** the students' observations. In your response,

- **draw** and **label** an arrow representing the direction of the electric field between the conducting rods in Diagram I
- for one of the ions of sodium, Na^+, and for one of the chloride ions, Cl^-,
  - — **draw** and **label** an arrow showing the direction of the electrostatic force on that ion, in Diagram I
  - — **identify** the direction of the magnetic force action on that ion, in Diagram II. **Explain** how you determined the direction
- **explain** how this technology could be used to propel an ocean-going ship

Marks will be awarded for the physics used to solve this problem and for the effective communication of your response.

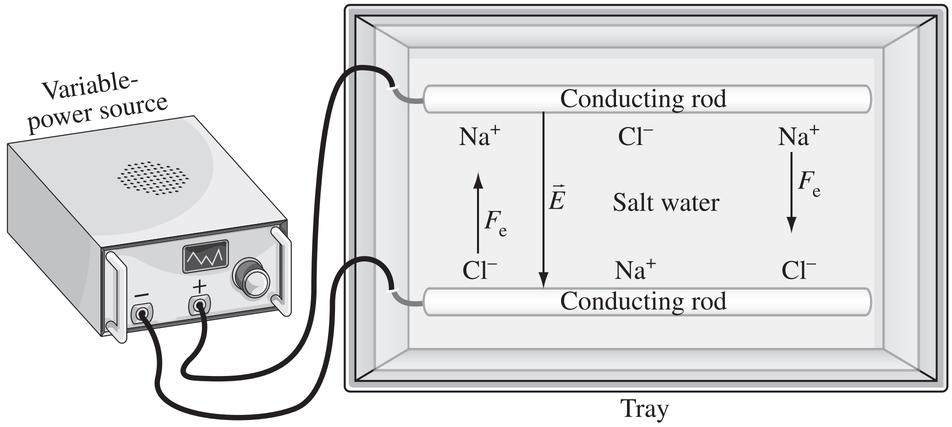
Holistic Scoring Guide

The **knowledge** expectations of this question are
- drawing and labelling the direction of the electric field
- drawing and labelling the direction of the electrostatic forces
- identifying the direction of the magnetic force exerted on the ions

The student shows **application** by
- explaining, in terms of mutually perpendicular vectors, in a manner that can be followed to always produce the same result, how to determine the direction of the magnetic force
- using Newton's laws to explain the propulsion of a ship (Newton's third law to provide propulsion)

Score	Description
5	A response that will receive a score of 5 has the following characteristics: • The response addresses, with appropriate knowledge, all the major concepts in the question • The student applies major physics principles in the response • The relationships between ideas contained in the response are explicit • The reader has no difficulty in following the strategy or solution presented by the student • Statements made in the response are supported explicitly **Note:** the response may contain minor errors or have minor omissions
4	A response that will receive a score of 4 has the following characteristics: • The response addresses, with appropriate knowledge, all the major concepts in the question • The student applies major physics principles in the response • The relationships between the ideas contained in the response are implied • The reader has some difficulty following the strategy or solution presented by the student • Statements made in the response are supported implicitly **Note:** the response may contain errors or have omissions *The response is mostly complete and mostly correct, and contains some application of physics principles*
3	A response that will receive a score of 3 has the following characteristics: • The response addresses, with some appropriate knowledge, all the major concepts in the question • The student does not apply major physics principles in the response • There are no relationships between the ideas contained in the response • The reader may have difficulty following the strategy or solution presented by the student
2	A response that will receive a score of 2 has the following characteristic: The response addresses, with some appropriate knowledge, two of the major concepts in the question
1	A response that will receive a score of 1 has the following characteristic: • The response addresses, with some appropriate knowledge, one of the major concepts in the question
0	The student provides a solution that is invalid for the question

Sample response



A hand rule is used to determine the direction of the magnetic force exerted on an ion. The magnetic field produced by the horseshoe magnet goes from the north pole to the south pole (i.e., from above the tray to below the tray).

Using the left hand for negative charges and the perspective of Diagram II, the thumb indicates the direction of the Cl^- velocity, the fingers indicate the direction of the magnetic field, and the palm indicates the direction of the magnetic force. The direction of the magnetic force is to the right side of the page. Using the right hand for positive charges, the Na^+ will experience a magnetic force in the same direction as that experienced by the Cl^-.

To propel an ocean-going ship, the rods would be attached to the ship but submerged in the sea water. As each ion experiences a magnetic force toward the back of the ship, the ship experiences an equal and opposite force forward as described by Newton's third law. The force exerted on each individual ion is very small, but the accumulated force exerted on many ions results in accumulated reaction forces acting on the ship that are large enough to change the ship's motion.

Evolution of Atomic Models Question

Use the following information to answer the next question.

In 1967, a team of nuclear physicists from the Stanford Linear Accelerator Center (SLAC) and the Massachusetts Institute of Technology (MIT) began investigating the structures of nucleons (protons and neutrons). Some significant aspects of the experiment, now known as the "SLAC-MIT Experiment", are given below.

Prediction: Protons are "soft", meaning that when high-energy electrons are projected at a proton, most of them should pass straight through the proton without changing speed or direction.

Procedure: Electrons were accelerated by a high potential difference, focused into a beam, and projected through liquid hydrogen. Each nucleus in the liquid hydrogen consisted of a single proton. Detectors around the tank of liquid hydrogen were used to determine the locations to which the incident electrons were scattered.

Key Observation: Although many of the highly energetic electrons passed straight through the protons without changing speed or direction, some electrons were deflected at large angles.

4. Using the concepts of the Rutherford alpha particle scattering experiment; the relationship between experiment and theory; and the quark model of matter, **compare** the Rutherford alpha particle scattering experiment and its results to those of the SLAC-MIT experiment. In your response,

- **describe** Rutherford's alpha particle scattering experiment. **Summarize** the conclusions supported by the analysis of the observations from the Rutherford alpha particle scattering experiment
- **compare** the Rutherford alpha particle scattering experiment to the SLAC-MIT experiment in terms of the significant components of the apparatus and procedures
- **predict** one characteristic of the internal structure of a proton. **Justify** your prediction using the key observation from the SLAC-MIT experiment

Student Name____________________

Peer Feedback—Evolution of Atomic Models

Reviewer's Name____________________

Program Links to Tasks in this Question	The horizontal bar indicates the scope required in the response. Place an "x" on the bar to indicate the level demonstrated in the response.	Looking Back
describe Rutherford's alpha particle scattering experiment. **Summarize** the conclusions supported by the analysis of the observations from the Rutherford alpha particle scattering experiment (D1.4k)	Knowledge / Comprehension/Application / Higher Mental Activities **Describe** **Summarize** **Peer Feedback:** I've placed an "x" on the bar to indicate the level of your response. I set the level there because I noticed that…	**Changes that I am going to make** to my response…
compare the Rutherford alpha particle scattering experiment to the SLAC MIT experiment in terms of the significant components of the apparatus and procedures (D1.4k, D4.3k)	Knowledge / Comprehension/Application / Higher Mental Activities **Compare** **Peer Feedback:** I've placed an "x" on the bar to indicate the level of your response. I set the level there because I noticed that…	**Changes that I am going to make** to my response…
predict one characteristic of the internal structure of a proton. **Justify** your prediction using the key observation from the SLAC-MIT experiment (D4.3k)	Knowledge / Comprehension/Application / Higher Mental Activities **Predict** **Justify** **Peer Feedback:** I've placed an "x" on the bar to indicate the level of your response. I set the level there because I noticed that…	**Changes that I am going to make** to my response…

Sample Response

In Rutherford's alpha scattering experiment, a beam of alpha particles was directed at a thin gold foil. The vast majority of alpha particles were detected on the other side of the foil, having passed through the foil without deflection. A few of the alpha particles were detected after having undergone deflections of significant angles, even as much as 180°.

In both experiments, a beam of particles was directed at a stationary target. Detectors around the target were used to determine whether the particles passed straight through the target or were deflected by the target.

In the Rutherford experiment, the beam of particles being directed at a target consisted of alpha particles. In the SLAC-MIT experiment, the particles were electrons. The targets in the Rutherford experiment were the atoms of gold in the metal foil. In the SLAC-MIT experiment, the targets were the hydrogen atoms (i.e., protons).

The quark model of matter describes a proton as consisting of uud quarks. The idea of internal structure is supported by the electron deflection: if protons had uniform density, electrons would pass through the proton without deflection. The electrons were deflected, so there must be some internal structure to the proton that the electrons could collide with and be deflected by. These internal structures must be relatively small when compared to the size of the proton, since most electrons passed through without deflection. The electrons that weren't deflected could pass through the gaps in between the internal structures.

Physics 20 Moon's Orbit Question

Use the following information to answer the next question.

Mass Data

Mass of Moon	7.35×10^{22} kg
Mass of Earth	5.97×10^{24} kg
Mass of the Sun	1.99×10^{30} kg

Orbital Data—Moon around Earth

Perigee	3.63×10^{8} m
Apogee	4.06×10^{8} m
Period	27.7 days

Orbital Data—Earth around the Sun

Mean orbital radius	1.50×10^{11} m

Sputnik I, Earth's first artificial satellite, had an orbital period of 5 760 s and a mean orbital radius of 6.82×10^{6} m.

5. Using the physics models of Kepler's equations, Newton's Laws, Newton's law of universal gravity, and the physics principle of the conservation of energy, **analyze** the Moon's orbit. In your response,

- **determine**, based on the satellite data given above, the mean Moon orbital radius. **List** the assumptions that you made. **Evaluate** your calculated value
- **determine** the average force of gravity Earth exerts on the Moon
- **draw** and **label** a free-body diagram for the Moon. Provide an **explanation** for your diagram, including assumptions that you have made regarding frame of reference, directions and which forces are significant
- in the Moon-Earth system, **compare**, qualitatively, the Moon's change in velocity to Earth's. **Support** your comparison
- assuming that the Moon's orbit is perfectly circular, **determine** the work done by the force of gravity on the moon in a one-month (30-day, 1/12th of a year) time period. **Evaluate** the assumption
- fully **classify** the Moon-Earth system. **Support** your classifications

Student Name____________________

Peer Feedback—Moon's Orbit

Reviewer's Name____________________

Program Links to Tasks in this Question	The horizontal bar indicates the scope required in the response. Place an "x" on the bar to indicate the level demonstrated in the response.	Looking Back
determine, based on the satellite data given above, the mean Moon orbital radius. **List** the assumptions that you made. **Evaluate** your calculated value (P20-C1.7k)	Knowledge — Comprehension/Application — Higher Mental Activities **Determine** **List** **Evaluate** **Peer Feedback:** I've placed an "x" on the bar to indicate the level of your response. I set the level there because I noticed that…	**Changes that I am going to make** to my response…
determine the average force of gravity Earth exerts on the Moon (P20-B2.2k)	Knowledge — Comprehension/Application — Higher Mental Activities **Determine** **Peer Feedback:** I've placed an "x" on the bar to indicate the level of your response. I set the level there because I noticed that…	**Changes that I am going to make** to my response…
draw and **label** a free-body diagram for the Moon. Provide an **explanation** for your diagram, including assumptions that you have made regarding frame of reference, directions and which forces are significant (P20-B2.3s)	Knowledge — Comprehension/Application — Higher Mental Activities **Draw** **Label** **Explain** **Peer Feedback:** I've placed an "x" on the bar to indicate the level of your response. I set the level there because I noticed that…	**Changes that I am going to make** to my response…

continued

Student Name____________________ ***Peer Feedback—Moon's Orbit*** **continued** Reviewer's Name____________________

Program Links to Tasks in this Question	The horizontal bar indicates the scope required in the response. Place an "x" on the bar to indicate the level demonstrated in the response.	**Looking Back**
compare, qualitatively, the Moon's change in velocity to Earth's. **Support** your comparison (P20-B1.1k, B1.3k)	Knowledge — Comprehension/Application — Higher Mental Activities **Compare** **Support** **Peer Feedback:** I've placed an "x" on the bar to indicate the level of your response. I set the level there because I noticed that…	**Changes that I am going to make** to my response…
assuming that the Moon's orbit is perfectly circular, **determine** the work done by the force of gravity on the Moon in a one-month (30-day, 1/12th of a year) time period. **Evaluate** the assumption (P20-C2.4k)	Knowledge — Comprehension/Application — Higher Mental Activities **Determine** **Evaluate** **Peer Feedback:** I've placed an "x" on the bar to indicate the level of your response. I set the level there because I noticed that…	**Changes that I am going to make** to my response…
fully **classify** the Moon-Earth system. **Support** your classifications (P20-C2.6k)	Knowledge — Comprehension/Application — Higher Mental Activities **Classify** **Support** **Peer Feedback:** I've placed an "x" on the bar to indicate the level of your response. I set the level there because I noticed that…	**Changes that I am going to make** to my response…

Sample Response (and embedded notes to Teachers)

$$\frac{T_{\text{Moon}}^2}{r_{\text{Moon}}^3} = \frac{T_{\text{satellite}}^2}{r_{\text{satellite}}^3}$$

$$\frac{(27.7 \text{ days} \times 24 \text{ h/day} \times 3\,600 \text{ s/h})^2}{r_{\text{Moon}}^3} = \frac{(5\,760 \text{ s})^2}{(6.82 \times 10^6 \text{ m})^3}$$

$$r_{\text{Moon}} = 3.80 \times 10^8 \text{ m}$$

The main assumption is that Kepler’s empirical model is appropriate to apply to a satellite and the Moon.

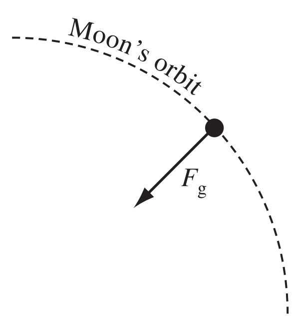
The calculated value is good because it falls between the perigee and the apogee values, which are the largest and the smallest radii of the orbit.

$$F_g = \frac{Gm_{\text{Moon}}m_{\text{Earth}}}{r_{\text{distance between the centres}}^2}$$

$$F_g = \frac{(6.67 \times 10^{-11} \text{ N•m/kg}^2)(7.35 \times 10^{22} \text{ kg})(5.97 \times 10^{24} \text{ kg})}{(3.80 \times 10^8 \text{ m})^2}$$

$$F_g = 2.03 \times 10^{20} \text{ N}$$

Free-body diagram: In Earth’s frame of reference there is only one force acting:



Note 1: *There is only one force acting on the Moon—the gravitational force acting toward the centre of Earth. Students may add a gravitational force from the Sun, but they should be encouraged to check its significance by determining the ratio of Earth’s force to the Sun’s force.*

Note 2: *Some students will draw a second force, and label it F_c. Many students know that they should add another force so that the speed of the Moon remains constant. This misconception is fully explored in this question and students should be encouraged* *to engage with their misunderstanding. There is a second explanation for the second force—in the Moon's frame of reference, it experiences a "centrifugal" force.*

Note 3: *Students may draw the force of gravity caused by the Sun. This force is $F_g = 4.36 \times 10^{20}$ N, which is twice the force caused by Earth. If they include this force, then there is the learning opportunity of exploring significant forces; that is, both Earth and the Moon experience the same gravitational field created by the Sun's mass, so they are in "free fall" around the Sun and the orbit of the Moon around Earth happens inside the Sun's field.*

By Newton's third law, each force causes a reaction force. So, the Moon experiences a force of 2.03×10^{20} N and exerts a force of 2.03×10^{20} N on Earth. Change in velocity is acceleration. By Newton's second law, the acceleration of an object is directly proportional to the force and inversely proportional to the mass. Since the mass of Earth is approximately 100 times larger, the change of the Moon's velocity will be 100 times greater.

The work done by the gravitational force is zero. The force acts perpendicularly to the displacement. This means there is no change in the kinetic energy of the Moon. The assumption of a perfectly circular orbit is fairly good because the apogee radius is less than 7% of the mean value so that a circle is a pretty good model **or** because the perigee and apogee values are not the same as the average radius, the actual orbit isn't circular. The speed of the Moon changes, as it travels quickly at perigee and slowly at apogee. This change in the kinetic energy needs to be caused by a force that does work. Although the gravitational force acts toward the centre of the circle, if the path is elliptical, then there is a component to the force that acts in the same direction as the displacement or in the opposite direction. The component of the force does work causing a change in the system's kinetic energy.

The Moon-Earth system is isolated because the total mechanical energy in the system remains constant **or** the Moon-Earth system is not isolated because the total mechanical energy in the system is decreasing.

Note 4: *There are many, many different ways of classifying systems. Any or all of the possible classifications could be included here, which could be used to increase students' learning by exploring all of the classifications. The program specifies "isolated" and students need to have a fundamental understanding of "isolated" for Physics 30. It is interesting to notice that the term "isolated system" in Physics 20 refers to conservation of mechanical energy and in Physics 30 refers to conservation of momentum. How do we prepare our students to have robust understanding?*

Possible Extensions

How to include the fact the Moon is receding from Earth by 4 cm/year?

Is Earth a “point source” mass? Is Newtonian gravity valid?

Require the students to compare models—is the circular model better than an elliptical one?

What are the effects of gravity on Earth?—Tides (and inertia and setting an introduction to Physics 30)

Why does the Moon always have one face toward Earth?

Qualitatively explore the change in energy–work done in a non-circular orbit system.