Physics 30 | Released Items

2015 Released Diploma Examination Items

Alberta Government

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

Contents

Introduction

These four items have been chosen to help classroom teachers develop high-quality student assessments.

When the *Physics 20-30 Program of Studies 2007* (Updated 2014) was implemented, styles of written-response items and their corresponding scoring criteria were developed by Alberta teachers from across the province. These items reflect those discussions.

For additional written-response items that are designed for the *Physics 20-30 Program of Studies 2007* (Updated 2014), see the *Physics 30 Written-Response Archive* on the Alberta Education website.

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* (Updated 2014), on the QuestA+ platform at https://questaplus.alberta.ca/ in the Practice Tests area.

Mathematics and Science Directing Words

Discuss	The word "discuss" will not be used as a directing word on math and science diploma examinations because it is not used consistently to mean a single activity.

The following words are specific in meaning.

Algebraically	Using mathematical procedures that involve letters or symbols to represent numbers
Analyze	To make a mathematical, chemical, or methodical examination of parts to determine the nature, proportion, function, interrelationship, etc. of the whole
Compare	Examine the character or qualities of two things by providing characteristics of both that point out their similarities and differences
Conclude	State a logical end based on reasoning and/or evidence
Contrast/Distinguish	Point out the differences between two things that have similar or comparable natures
Criticize	Point out the demerits of an item or issue
Define	Provide the essential qualities or meaning of a word or concept; make distinct and clear by marking out the limits
Describe	Give a written account or represent the characteristics of something by a figure, model, or picture
Design/Plan	Construct a plan; i.e, a detailed sequence of actions for a specific purpose
Determine	Find a solution, to a specified degree of accuracy, to a problem by showing appropriate formulas, procedures, and calculations
Enumerate	Specify one by one or list in concise form and according to some order
Evaluate	Give the significance or worth of something by identifying the good and bad points or the advantages and disadvantages
Explain	Make clear what is not immediately obvious or entirely known; give the cause of or reason for; make known in detail
Graphically	Using a drawing that is produced electronically or by hand and that shows a relation between certain sets of numbers

How	Show in what manner or way, with what meaning
Hypothesize	Form a tentative proposition intended as a possible explanation for an observed phenomenon; i.e., a possible cause for a specific effect. The proposition should be testable logically and/or empirically
Identify	Recognize and select as having the characteristics of something
Illustrate	Make clear by giving an example. The form of the example must be specified in the question; i.e., word description, sketch, or diagram
Infer	Form a generalization from sample data; arrive at a conclusion by reasoning from evidence
Interpret	Tell the meaning of something; present information in a new form that adds meaning to the original data
Justify/Show How	Show reasons for or give facts that support a position
Model	Find a model (in mathematics, a model of a situation is a pattern that is supposed to represent or set a standard for a real situation) that does a good job of representing a situation
Outline	Give, in an organized fashion, the essential parts of something. The form of the outline must be specified in the question; i.e., list, flow chart, concept map
Predict	Tell in advance on the basis of empirical evidence and/or logic
Prove	Establish the truth or validity of a statement for the general case by giving factual evidence or logical argument
Relate	Show logical or causal connection between things
Sketch	Provide a drawing that represents the key features of an object or graph
Solve	Give a solution for a problem; i.e., explanation in words and/or numbers
Summarize	Give a brief account of the main points
Trace	Give a step-by-step description of the development
Verify	Establish, by substitution for a particular case or by geometric comparison, the truth of a statement
Why	Show the cause, reason, or purpose

Additional Documents

The Provincial Assessment Sector supports the instruction of Physics 30 in classrooms with the following documents, which are available online at www.education.alberta.ca.

Physics 20–30 Student-Based Performance Standards
This document provides a detailed but not prescriptive or exhaustive list of observable student behaviours and links those behaviours to the acceptable standard or the standard of excellence.

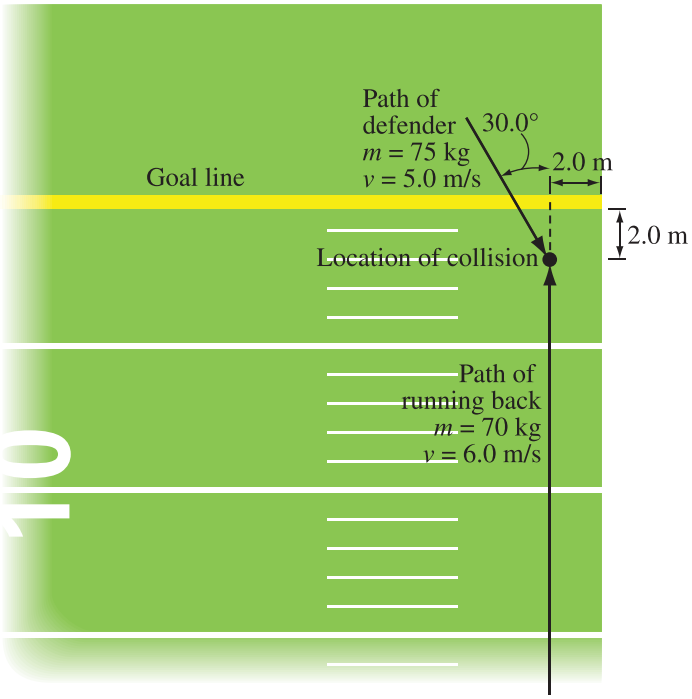
Physics 30 Information Bulletin
This document provides descriptions of the diploma examination design and blueprint and descriptions of trends in student performance on the physics diploma examinations.

Summative Assessment Items

Two-dimensional Vector Skills Written Response

Use the following information to answer this two-dimensional vector-skills question.

In a high school championship football game, a running back is carrying the football north, running 2 m from the sidelines toward the end zone. The defending team's safety sees the running back coming in and runs toward him. The velocities and masses of the two players are shown in the diagram below.



Written Response—10 marks

1. **Determine** if the running back scores a touchdown by crossing the goal line or if the defender knocks him out of bounds before crossing the goal line. In your response, **sketch** an arrow showing the expected path of the two players immediately after the collision, **explain** how you determined the direction, **sketch** a vector addition diagram consistent with the vector analysis method you choose, and state all necessary physics principles and formulas.

Marks will be awarded based on your vector diagrams, the physics that you use, and on the mathematical treatment that you provide.

Scoring Guide for Two-dimensional Vector Questions – Vector Diagrams

Score	Description
5	• The physics logic that provides the direction of the vectors is explicitly communicated* • A diagram showing the directions of the significant vectors is given (e.g., for a question dealing with forces, this is the free-body diagram; for a conservation of momentum question, this is a situational diagram) • A vector-addition diagram is given • All vector conventions are followed** • The solution is presented in an organized manner **Note:** One minor error may be present***
4	• The vector diagrams are present but have two minor errors. However, enough of the vector-addition diagram is present and correct to complete the analysis **or** • The situational diagram may be missing from an otherwise complete response **or** • A solution using components is given, but the relationship between the components and one of the vectors is missing
3	• The vector-addition diagram is given as a triangle (i.e., lines instead of arrows), but labels are present (i.e., the problem is solvable from the diagram given)
2	• A complete diagram showing the directions of the significant vectors is present (e.g., free body diagram or a situational diagram) or • The vector addition diagram is given as a triangle with more than one label present or • Some vector addition is shown but not enough for the problem to be solved (e.g., the net vector is absent or labels are missing)
1	• There is a valid start present (e.g., a labelled situational diagram drawn as lines with some labels present)
0	• Nothing valid to vector addition is provided
NR	• No response to the vector diagram component of the question is provided

***Directional logic: where appropriate, the following (or equivalent) is required:**

- A compass rosette is drawn and labelled
- Coordinate axes are drawn and labelled
- Like charges repel or unlike charges attract
- The direction of an electric field is the direction of the electrostatic force on a positive test charge
- The direction of a magnetic field is the direction of the magnetic force on the N-pole of a test magnet

**Vector conventions include
- Vectors are drawn as arrows pointing in the direction of the vector
- Arrows are labelled with the magnitude or name of the vector
- Angles are labelled at the vector's tail
- Scaling of vectors in the situational diagram or in the vector-addition diagram is not required

***Minor errors include
- Missing one arrowhead
- Missing one label

Scoring Guide for Two-dimensional Vector Questions – Mathematical Treatment

Score	Description
5	• The physics principle related to the solution, if necessary, is explicitly communicated (e.g., conservation of momentum, work done equals change in energy, equilibrium means F_{net} = zero) • All formulas are present • All substitutions are shown • The final answer is stated with appropriate significant digits and appropriate units. Unit analysis is explicitly provided, if required **Note:** One minor error may be present*
4	• A complete solution is present, but it contains two minor errors or one major error or omission**
3	• A valid method is begun and contains no errors **or** • The solution is complete, but there are significant errors or omissions
2	• A valid method is begun **or** • A linear analysis is present***
1	• A valid start is present. This may be one valid calculation
0	• Only inappropriate mathematical treatment is present
NR	• No response to the mathematical treatment is provided

*Minor errors include
- Stating the final answer with incorrect (but still respectful) units
- Stating the final answer with incorrect (but still respectful) significant digits
- Missing one formula

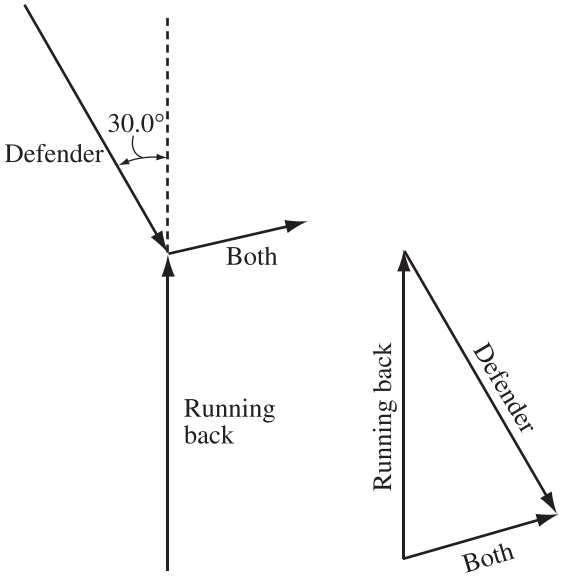
**Major omissions include
- Missing the physics principle
- Missing more than one formula
- Missing several substitutions
- Substituting a calculated value from one formula into another formula without explaining why this substitution is valid

***Linear Analysis**
A response that contains a linear mathematical treatment of a two-dimensional situation could receive a maximum score of 2 for mathematical treatment if the Physics principle is stated, all formulas are shown, all substitutions are shown, and the answer is stated with appropriate significant digits and units.

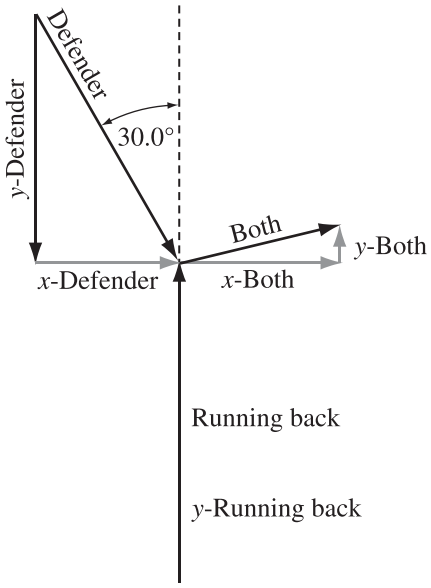
Note: A student response calculated using a calculator in radian mode is valid until a numerical value does not make physics sense.

Sample Response

The path of both players after the collision will have some *x*-component because momentum is conserved and the defender has *x*-momentum.



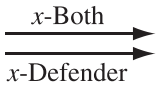
Drawing the components on the diagram gives



$\vec{p} = m\vec{v}$ **or** $p = mv$
$p_{\text{Defender}} = (75\text{ kg})(5.0\text{ m/s})$
$p_{\text{Defender}} = 375\text{ kg·m/s}$

$p_{\text{RunningBack}} = (70\text{ kg})(65.0\text{ m/s})$
$p_{\text{RunningBack}} = 420\text{ kg·m/s}$

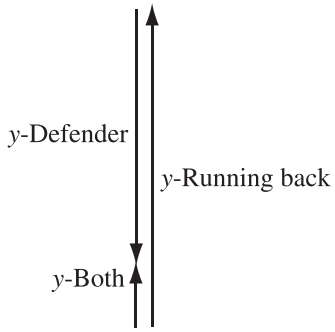
Looking at the *x*-components:



$p_{\text{Defender}_x} = p_{\text{Defender}} \sin\theta$ (Sine is used because the angle is measured to the *y*-axis.)
$p_{\text{Defender}_x} = (375\text{ kg·m/s})(\sin 30°)$
$p_{\text{Defender}_x} = +187.5\text{ kg·m/s}$ (The positive value means motion is in the direction of the positive *x*-axis.)

There is no *x*-component of the running back.

Since momentum is conserved, then
$p_{\text{Defender}_{xi}} = p_{\text{Both}_{xf}}$
$p_{\text{Both}_{xf}} = +187.5\text{ kg·m/s}$



Looking at the *y*-components:

$$p_{\text{Defender}_y} = p_{\text{Defender}} \cos\theta$$
$$p_{\text{Defender}_y} = (375 \text{ kg·m/s})(\cos 30°)$$
$$p_{\text{Defender}_y} = -324.7595 \text{ kg·m/s}$$

The running back has only positive *y*-direction.

Momentum is conserved in the *y*-direction.

$$p_{y_i} = p_{y_f}$$
$$p_{\text{Defender}_{yi}} + p_{\text{RunningBack}_{yf}} = p_{\text{Both}_{yf}}$$
$$-324.7595 \text{ kg·m/s} + {}^{+}420 \text{ kg·m/s} = p_{\text{Both}_{yf}}$$
$$p_{\text{Both}_{xf}} = +95.24 \text{ kg·m/s}$$

Adding the two components after the collision:

You only need to look at the angle. If it is greater than 45° from the *y*-axis, there is no touchdown. If it is less than 45°, there is a touchdown.

Qualitatively, the *x*-component is greater than the *y*-component, so there is no touchdown!

$$\tan\theta = \left(\frac{p_{\text{Both}_{xf}}}{p_{\text{Both}_{yf}}}\right)$$
$$\theta = \tan^{-1}\left(\frac{187.7}{95.24}\right)$$
$$\theta = 63.1^\circ > 45^\circ$$

therefore, there is no touchdown.

Holistic Written Response

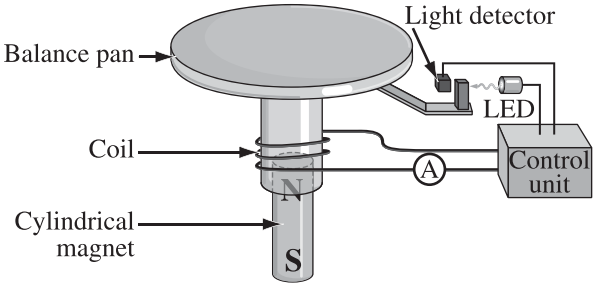
Use the following information to answer this holistic question.

An electronic scale uses the magnetic force on a current-carrying conductor (the motor effect) to determine the mass of an object.

The control unit in the scale is activated when the light from a light emitting diode (LED) is incident on the light detector, which is a photocell. The control unit supplies current to a coil that sits below the pan. Current in the coil produces a motor effect that is strong enough to lift the pan. The coil and scale pan move up or down relative to a strong permanent magnet.

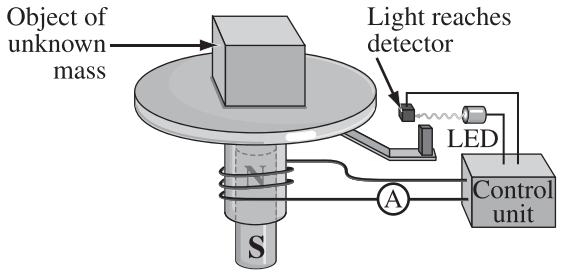
Description of the Operation of an Electronic Scale

Diagram I: No object on the scale pan



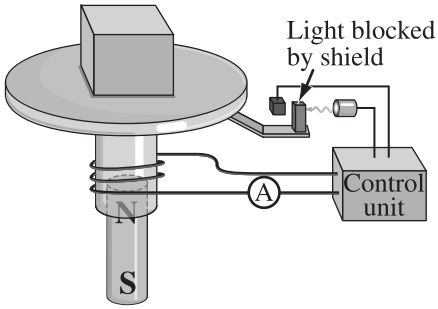
A shield blocks light from the LED, preventing it from reaching the light detector. The control unit does not supply current to the coil.

Diagram II: An object is placed on the scale pan



The weight of the object moves the pan downward. As a result, the shield moves down and light from the LED reaches the light detector. The presence of light on the light detector signals the control unit to supply current to the coil.

Diagram III: Measurement of current to determine mass



The current in the coil induces a magnetic field. The interaction of this field with that of the permanent magnet forces the pan upward. The control unit increases the current until the shield is high enough to block the light from the LED. The control unit then determines the current required to keep the pan at this fixed height. The measurement of this current is used to determine the mass of the object.

Written Response—5 marks

2. Using the principles of free-body diagrams, the photoelectric effect, and magnetic field theory, **analyze** the operation of the electronic scale described on the previous page. In your response,

- **draw** and **label** the free-body diagram of the two significant forces that are acting on the object of unknown mass, as illustrated in Diagram II. **Explain** how you estimated the relative lengths of the two arrows
- **identify** one characteristic of the electromagnetic radiation emitted by the LED that is necessary to activate the light detector
- **determine** the direction of the electron flow in the ammeter in Diagram III that causes the balance pan to return to its original position. **Explain** how you determined the direction of electron flow.

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

Scoring Guide for Holistic Question

Major Concepts: Free-body diagram; photoelectric effect; hand rule

Knowledge Expectations:
- The force of gravity acts downward, the force of the pan acts upward.
- The incident frequency is greater than the threshold frequency.
- A hand rule is used to determine the direction of electron flow.

Application Expectations:
- The lengths of the arrows in the free-body diagram should match the description of which force is greater in magnitude consistent with the situation the student has chosen.
- An explanation of why a north pole is induced at the bottom of the coil and a description of the orientation of the fingers and thumb to determine the direction of electron flow should be provided.

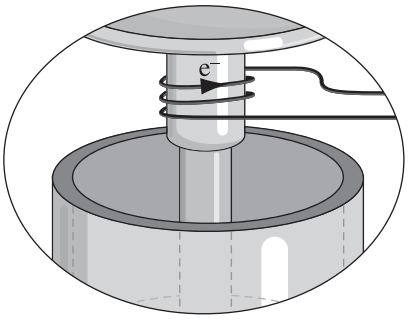
Score	Description
5	• The response addresses, with appropriate knowledge, all the major concepts in the question • The student applies major physics principles in the response • The relationships between ideas contained in the response are explicit • The reader has no difficulty in following the strategy 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	• 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	• The response addresses, with some appropriate knowledge, more than half of the full scope of the question **or** The response addresses more than half of the full scope of the question with a mixture of knowledge and application • 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	• The response addresses, with some appropriate knowledge, two of the five expectations in the question
1	• The response addresses, with some appropriate knowledge, one of the five expectations in the question
0	• The student provides a solution that is invalid for the question
NR	• There is no response to the question

Sample Response

When the mass is first placed on the pan of the balance, the gravitational force down will be greater than the force exerted upward by the pan. The sum of the forces will give a net force down. (NOTE: The student may also respond that the force of the pan upward is equal to the force of gravity down when the pan is at the bottom or the top—Diagram III if the student's discussion is consistent with the location and diagram. The student might also respond that the force of the pan upward is greater than the force of gravity downward because once the current flows, the pan will be pushing up with a force greater than gravity.)

In order for the control unit to be activated, the light must have a frequency higher than the threshold frequency required by the detector or energy greater than the work function or a wavelength shorter than the threshold wavelength.

The induced magnetic field must produce a north pole at the bottom to repel the north pole of the cylindrical magnet because like poles repel. Using the left-hand grasp rule, because electron flow uses the left hand, the thumb points toward the bottom of the coil, the direction of the induced north pole, and the fingers curl around from left to right across the face. Therefore, the direction of the electron flow is from left to right across the face of the coil and from left to right through the ammeter.



Graphing Skills Written Response

Use the following information to answer this graphing-skills question.

A group of students performs a double-slit experiment that produces an interference pattern on a screen. They use a laser that emits light that has a wavelength of 632.8 nm. They measure the distance from the double-slit to the screen and the distance from the central maximum to the first maximum. The students then increase the distance from the double-slit to the screen by increments of 20.0 cm. Their observations are given in the table below.

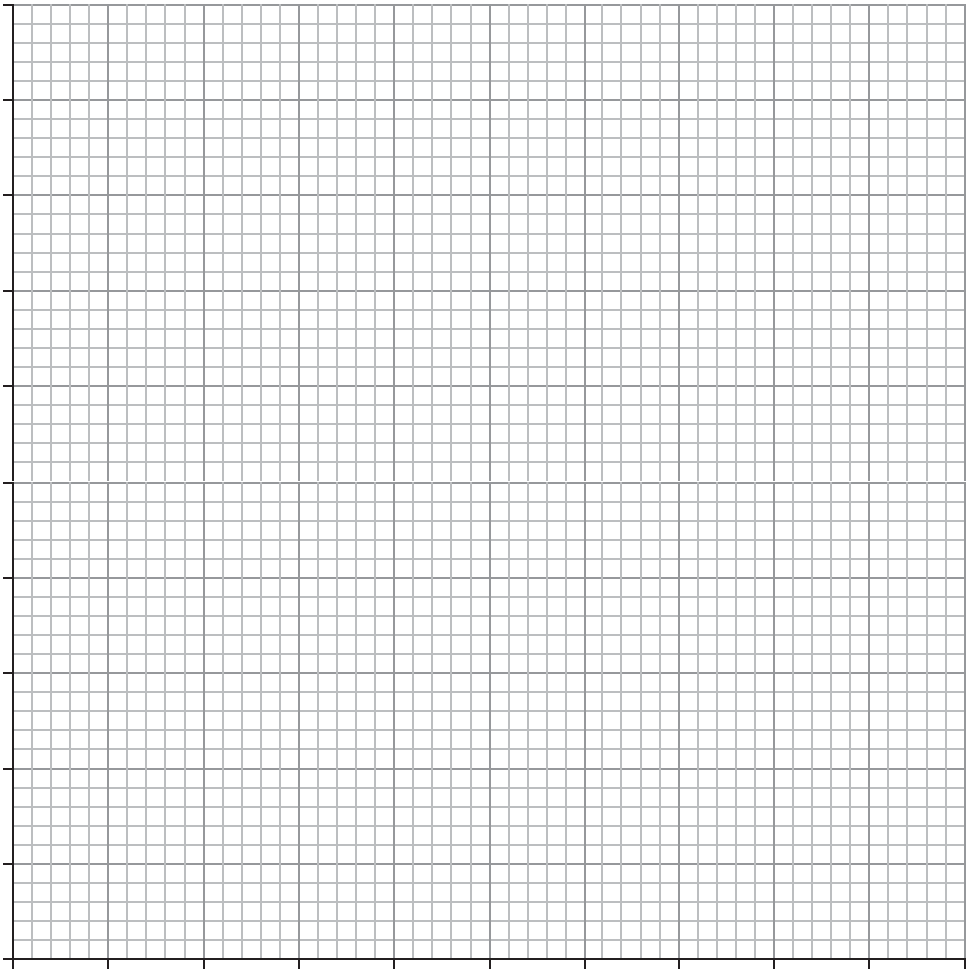
Distance to Screen (m)	Distance to First Maximum (m)
0.200	0.025
0.400	0.060
0.600	0.080
0.800	0.115
1.000	0.135

Written Response—10 marks

3. Using graphical analysis, **determine** the slit separation. In your response, **provide** a graph of the distance to the first maximum as a function of the distance to the screen, **determine** the slope of the graph, and **relate** the slope algebraically to a physics equation. **State** all necessary physics concepts and formulas.

Marks will be awarded for your graph, the physics that you use, and the mathematical treatment that you provide.

(Title)



(Label)

(Label)

Scoring Guide for Graphing-skills Questions – Graph

Score	Description
5	All conventions for title, labels, scales, plotting of data, and line of best fit are followed* **Note:** One minor error may be present**
4	Two minor errors may be present **or** Four graphing conventions are present but enough of the graph is present and correct that the analysis could be done
3	Three of the conventions are present **or** A major error is present***
2	Two of the conventions are present
1	One of the conventions is present
0	The graph was started but nothing valid is present
NR	No response to the graphing portion of the question is present

*Graphing Conventions

Graphing conventions are as follows. Descriptions within [ ] denote calculator active response equivalents.

- The title is in the form "responding variable as a function of manipulated variable"
- The axes are labelled with the variable, including powers of 10 if required, and units [how the data are entered into the calculator is clearly communicated, including powers of 10 and units]
- The scales are such that the data, when plotted, cover a majority of the graph and interpolation or extrapolation of points based on the line of best fit is convenient [window settings are provided]
- All the data points are plotted [the sketch of the calculator window shows the locations of the data points relative to the line of best fit determined by the appropriate regression]
- The line of best fit, either a line or a curve, provides the best approximation of the trend of the data given the context of the data (i.e., students should be able to predict the shape of a graph based on physics knowledge and mathematical graphing) [The quality of the line of best fit is provided by stating the validity of the regression used based on the physics and logic of the situation or by comparing r-squared values for several different regression models]

**Minor Errors

- A data point that has been plotted incorrectly by a margin of more than one-half of a grid box
- Missing one set of units on one of the axes
- Reversing the order of the variables in the title
- The line of best fit is an appropriate trend but is not the best line of best fit

***Major Errors

- Reversed axes
- Dot-to-dot line of best fit
- Missing line of best fit
- Plotting inappropriate data

Scoring Guide for Graphing-skills Questions – Mathematical Treatment

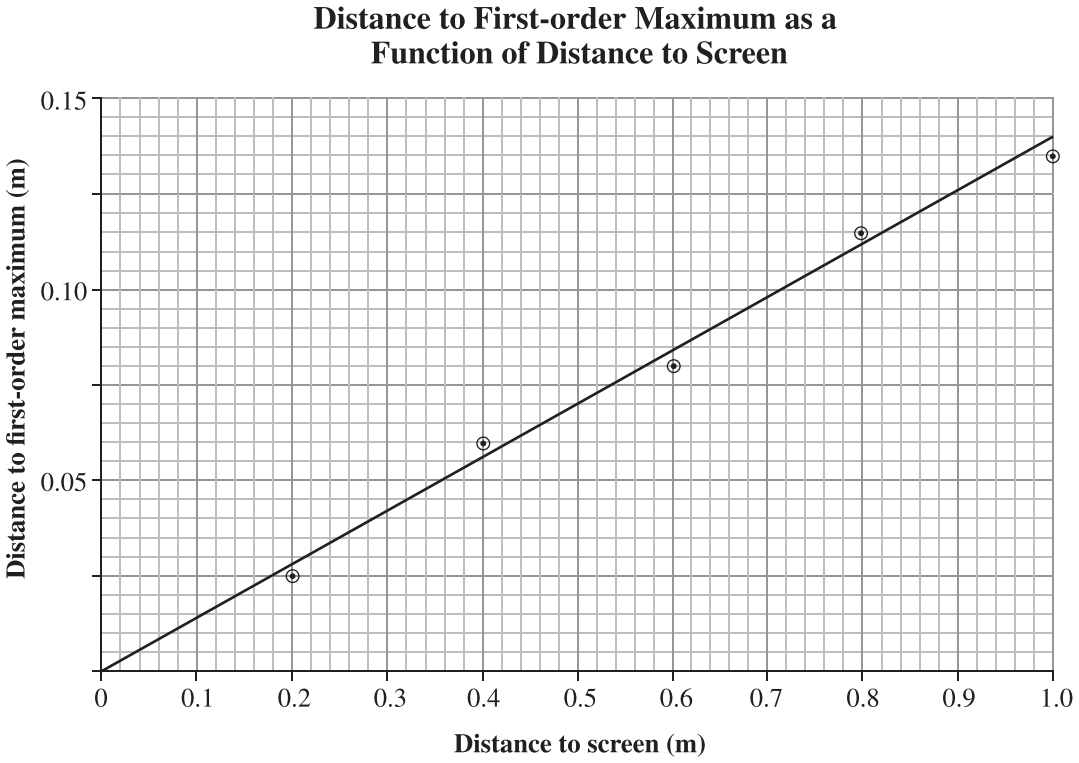
Score	Description
5	• All formulas are present • All substitutions are given and are consistent with the graphed data • The algebraic relationship between the slope, area, or intercept and the appropriate physics equation is explicitly communicated • The final answer is stated • Unit analysis is explicitly provided, if required **Note:** One minor error may be present*
4	• The response contains implicit treatment** **or** • The response contains explicit treatment with up to three minor errors or one major error***
3	• The response is incomplete but contains some valid progress toward answering the question (e.g., coordinates of relevant points are read correctly, including powers of 10 and units, and a valid substitution is shown)
2	• The coordinates of one relevant point are read • The reason a point is needed is addressed
1	• A valid start is present
0	• Only inappropriate mathematical treatment is present
NR	• No mathematical treatment is provided

***Implicit treatment means*
- Substituting appropriate values into a formula from the data sheets without stating the formula
- Starting with memorized, derived formulas not given on the equations sheet
- Substituting the value from one calculation into a second formula without communicating that the physics quantity in the two formulas is the same

*Minor Errors
- Misreading a data value by a margin of up to one-half of a grid while interpolating or extrapolating
- Stating the final answer with incorrect (but still respectful) units
- Stating the final answer with incorrect (but still respectful) significant digits
- Missing one of several different formulas

***Major Errors
- Using off-line points (most often, this is calculating the slope using data points that are not on a linear line of best fit)
- Using a single data point ratio as the slope
- Missing powers of 10 in interpolating or extrapolating

Sample Response

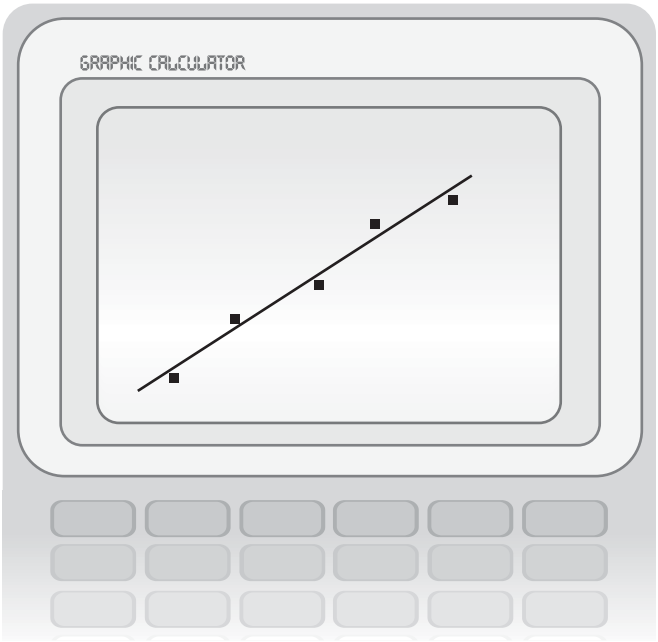


$$\text{Slope} = \frac{\text{rise}}{\text{run}}$$

$$= \frac{0.140\ \text{m} - 0.070\ \text{m}}{1.00\ \text{m} - 0.50\ \text{m}}$$

$$= 0.104$$

Calculator Active Solution



Store the distance to the screen in L1 in units of m.
Store the distance to the first maxima in L2 in units of m.

Window Setting
$\{x \mid 0.12, 1.08\}$
$\{y \mid 0.0063, 0.1537\}$

Linear Regression
Perform the linear regression of
$y = ax + b$ on L1, L2.

$a = 0.1375$
$b = 5 \times 10^{-4}$

slope = 0.1375 no units

Determine the slit separation using graphical analysis.

The variable plotted on the *y*-axis is the distance to the first maxima (x).
The variable plotted on the *x*-axis is the distance to the screen (l).

The physics equation is $\lambda = \frac{xd}{nl}$.

$$x = \left(\frac{n\lambda}{d}\right) l + 0$$
$$y = mx + b$$

Therefore, slope $= \frac{n\lambda}{d}$, which gives

$$d = \frac{n\lambda}{\text{slope}} = \frac{(1)(632.8\text{ nm})}{0.140} = 4.5 \times 10^{-6}\text{ m (2 S.D.s as per data chart)}$$

Or using the calculator active slope:

$$d = \frac{n\lambda}{\text{slope}} = \frac{(1)(632.8\text{ nm})}{0.1375} = 4.6 \times 10^{-6}\text{ m (2 S.D.s as per data chart)}$$

Anaholistic Written Response

Use the following information to answer this anaholistic question.

James Chadwick is credited with the discovery of the neutron. He used a radioactive source that contained polonium-210 to produce a stream of high-energy alpha particles ($v = 1.59 \times 10^7$ m/s). In the experiment, the alpha particles were directed at a beryllium target. Occasionally, an alpha particle would hit a beryllium nucleus and knock a high-energy particle free.

The system created by the radioactive decay of a nucleus of polonium-210 includes the alpha particle and the daughter nucleus ($m = 3.42 \times 10^{-25}$ kg) and can be modelled as an isolated system. This permits an analysis in which the increase in kinetic energy of the system results from a loss in measurable mass in the system.

Written Response—10 marks

4. **Determine** the mass defect of a polonium-210 nucleus.

Marks will be awarded based on the relationships among the two physics principles* that you state, the formulas that you state, the substitutions that you show, and your final answer.

*** The physics principles are given on the data sheet.**

Analytic Scoring Guide

Physics Principles

Score	Description
NOTE: Extraneous principles not required to answer the question *may* result in a score reduction	
4	• Both relevant physics principles are stated and both are clearly related to the response. Physics principles for questions involving linear vector addition require explicit communication of vector nature; e.g., a situational diagram or a free-body diagram (FBD) for forces and a vector-addition diagram
3	• Both relevant physics principles are stated, but only one is clearly related to the response
2	• Both relevant physics principles are stated but neither is clearly related to the response **or** • One relevant physics principle is stated and is clearly related to the response
1	• One relevant physics principle is stated
0	• Only an unrelated physics principle is stated
NR	• No physics principle is stated

Substitutions

Score	Description
1	• Substitutions are shown • Significant digits are not required in intermediate steps • A response with at most one implicit unit conversion may receive this score • An incomplete or incorrect response may receive this score if all the values substituted are appropriate; e.g., length measurements into length variables or energy measurements into energy variables
0	• Substitutions are missing **or** • The response contains one invalid substitution; e.g., electric field strength for energy, speed for electric potential difference
NR	• No substitutions are shown

Formulas

Score	Description
NOTE: Extraneous formulas not required to answer the question *may* result in a score reduction	
3	• All relevant formulas required for the complete solution are present and have been written as they appear on the equations sheet or in the information given with the question
2	• Most relevant formulas are stated **or** • Derived formulas are used as starting points
1	• One relevant formula is stated
0	• Only formulas not relevant to the solution are stated
NR	• No formulas are stated

Final Answer

Score	Description
2	• The final answer to the complete problem is stated with the appropriate number of significant digits and with appropriate units • A response in which an inappropriate substitution has been made may receive this score if the incorrect units are consistently carried forward
1	• The value of the final answer is stated, but units or significant digits are incorrect **or** • The response is incomplete (i.e., one of the physics principles is completely addressed or two parts (one part from each principle) are completed), but an intermediate value is stated with appropriate units (significant digits not required)
0	• The response is too incomplete **or** • The answer stated is unrelated to the solution shown
NR	• No answer to any part of the solution is given

Sample Response

The physics principles that are necessary to this determination are conservation of momentum, which is valid because the system is isolated, and conservation of mass-energy because the text box gives us this information.

$$^{210}_{84}\text{Po} \rightarrow {}^{208}_{82}\text{Pb} + {}^{4}_{2}\alpha$$

By conservation of momentum, $\vec{p}_i = \vec{p}_f$. The frame of reference can be defined such that the polonium-210 nucleus is at rest, so $\vec{p}_i = 0$. That means $\vec{p}_f = \vec{p}_\alpha + \vec{p}_{Pb} = 0$.

$$|\vec{p}_\alpha| = |\vec{p}_{Pb}|$$

$$m_\alpha v_\alpha = m_{Pb} v_{Pb}$$

$$v_{Pb} = \frac{(6.65 \times 10^{-27}\ \text{kg})(1.59 \times 10^{7}\ \text{m/s})}{3.42 \times 10^{-25}\ \text{kg}}$$

$$v_{Pb} = 3.091\,66 \times 10^{5}\ \text{m/s}$$

To find the mass defect
$\sum E_i = \sum E_f$

Since the system is defined such that the initial momentum is zero, the initial kinetic energy is also zero. However, there is still the energy associated with the mass defect. The final energy is the kinetic energy of the alpha particle and the lead nucleus.

$$E_{\text{mass defect}} = \triangle E_{\text{k of system}} = E_{k_\alpha} + E_{k_{Pb}}$$

$$\triangle mc^2 = \frac{1}{2} m_\alpha (v_\alpha)^2 + \frac{1}{2} m_{Pb} (v_{Pb})^2$$

$$\triangle m = \frac{(6.65 \times 10^{-27}\ \text{kg})(1.59 \times 10^{7}\ \text{m/s})^2 + (3.42 \times 10^{-25}\ \text{kg})(3.091\,66 \times 10^{5}\ \text{m/s})^2}{2(3.00 \times 10^{8}\ \text{m/s})^2}$$

$$\triangle m = 9.52 \times 10^{-30}\ \text{kg}$$