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Introduction

These items are the complete Physics 30 June 2009 Diploma Examination.

For details about these items including provincial difficulties, Program of Studies classifications, and item descriptions, please refer to the Physics 30 Diploma Examination Jurisdiction or School Report June 2009.

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+](https://questaplus.alberta.ca/) platform at <https://questaplus.alberta.ca/> in the practice tests area.

Additional Documents

Learner Assessment supports the instruction of Physics 30 in classrooms with the following documents available online at www.education.alberta.ca.

[Physics 20–30 Classroom-Based Performance Standards](#)

This document provides a detailed but not prescriptive or exhaustive list of student behaviours observable in the classroom and links those behaviours to the acceptable standard or the standard of excellence.

[Physics 30 Information Bulletin](#)

This document provides a description of the diploma examination design and blueprint, written-response sample questions, generic scoring guides, and descriptions of trends in student performance on the physics diploma examinations. In addition, this year's bulletin contains the June 2009 Part A, sample solutions, and illustrative responses with scoring rationale.

Physics 30 June 2009 Diploma Examination Key

Multiple-Choice and Numerical-Response Keys

Multiple Choice

- | | | | |
|-----|---|-----|---|
| 1. | B | 21. | D |
| 2. | D | 22. | A |
| 3. | D | 23. | C |
| 4. | C | 24. | C |
| 5. | D | 25. | B |
| 6. | D | 26. | D |
| 7. | D | 27. | C |
| 8. | A | 28. | A |
| 9. | B | 29. | A |
| 10. | B | 30. | B |
| 11. | C | 31. | D |
| 12. | B | 32. | C |
| 13. | C | 33. | A |
| 14. | A | 34. | A |
| 15. | C | 35. | D |
| 16. | D | 36. | D |
| 17. | B | 37. | B |
| 18. | C | 38. | A |
| 19. | D | 39. | B |
| 20. | A | 40. | A |

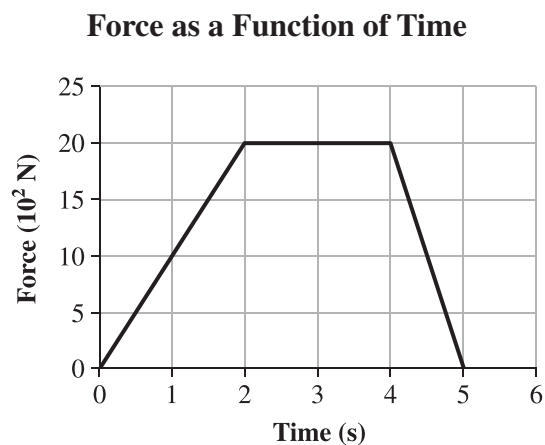
Numerical Response

- | | | | |
|----|------|-----|------------------------|
| 1. | 1.33 | 6. | 2567 |
| 2. | 8282 | 7. | 1324, 3124, 1342, 3142 |
| 3. | 4175 | 8. | 4211, 2221 |
| 4. | 1343 | 9. | 6010 |
| 5. | 23.5 | 10. | 1432 |

Physics 30 June 2009 Diploma Examination Machine-Scoreable Released Questions

Use the following information to answer the first question.

The graph below represents the force applied on a car during a period of time.

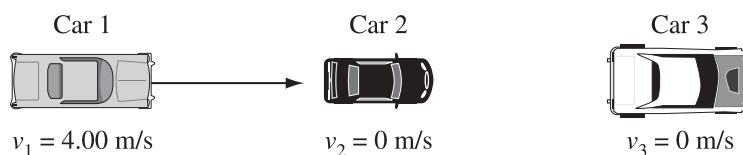


1. The impulse experienced by the car from $t = 2.0$ s to $t = 5.0$ s is
- A. 4.0×10^3 kg·m/s
 - B. 5.0×10^3 kg·m/s
 - C. 6.0×10^3 kg·m/s
 - D. 1.0×10^4 kg·m/s

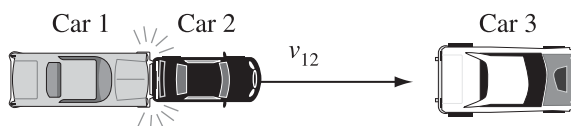
Use the following information to answer the next question.

Car 1 has a mass of 1.50×10^3 kg and is moving at a constant speed of 4.00 m/s. It strikes Car 2, which is at rest and has a mass of 1.20×10^3 kg. The cars lock together and continue to roll forward. They then collide and lock together with Car 3, which is at rest and has a mass of 1.80×10^3 kg.

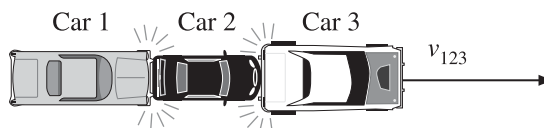
Before First Collision



Immediately After First Collision



Immediately After Second Collision



Note: Vector arrows are **not** drawn to scale.

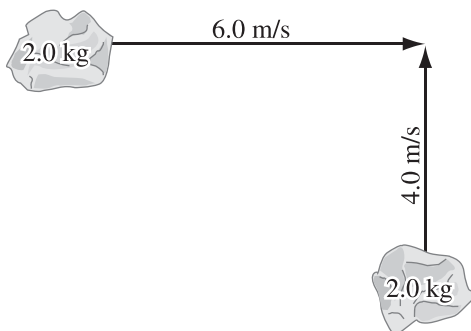
Numerical Response

1. The maximum speed of this three-car system, v_{123} , immediately after the second collision is _____ m/s.

(Record your **three-digit answer** in the numerical-response section on the answer sheet.)

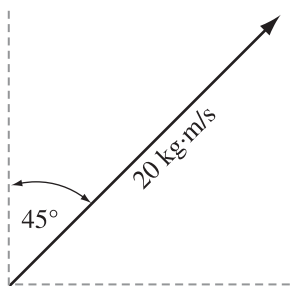
Use the following information to answer the next question.

A 2.0 kg lump of clay moving north at 4.0 m/s collides with another 2.0 kg lump of clay moving east at 6.0 m/s, as shown below.

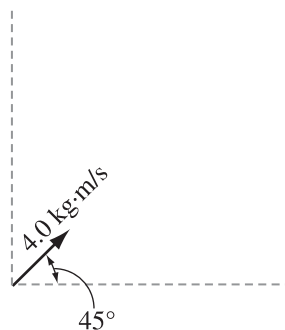


2. Which of the following diagrams shows the momentum of the system immediately after the collision?

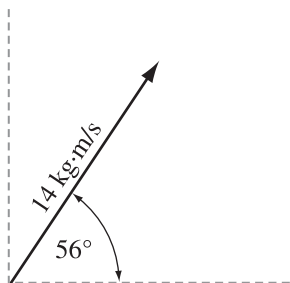
A.



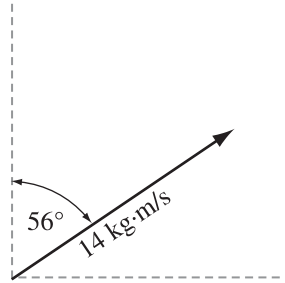
B.



C.



D.



Use the following information to answer the next eight questions.

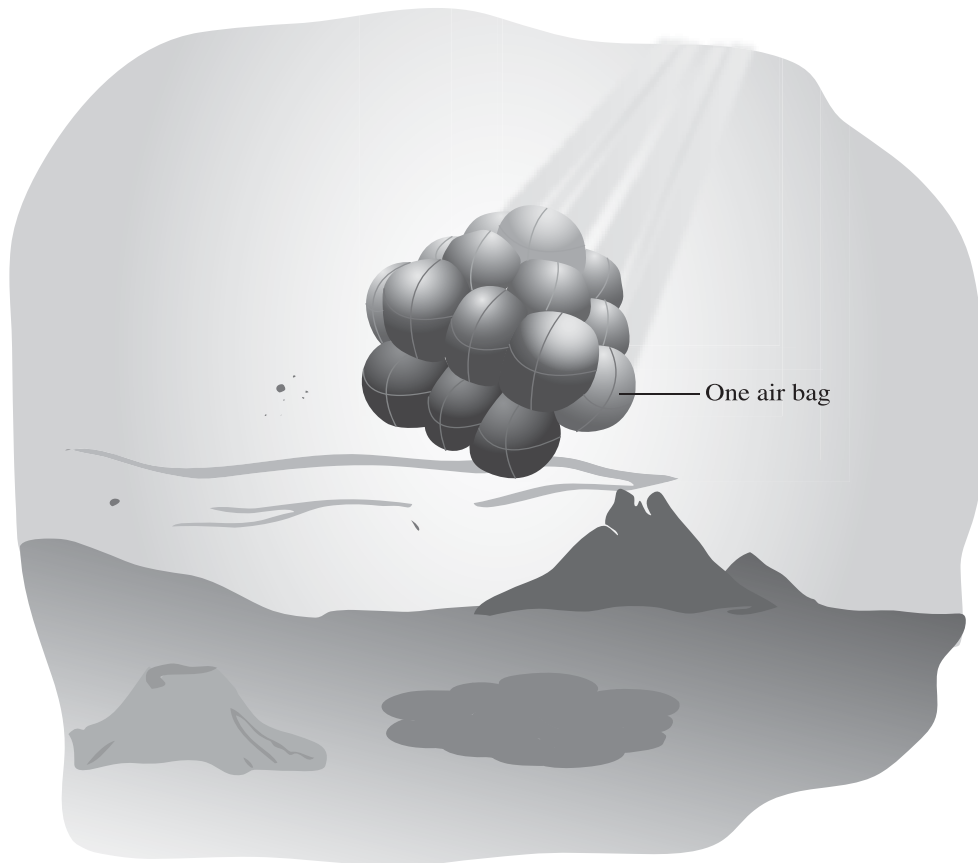
Exploration of the planet Mars uses robotic probes because the conditions involved in such a mission are dangerous to humans.

One mission to Mars used parachutes and airbags to bring a landing unit safely to rest on the planet's surface. The parachutes slowed the landing unit's speed while it was falling through the atmosphere; the airbags were required when the landing unit reached the planet's surface.

After a series of bounces, the landing unit came to rest and released a robotic probe, which explored the planet's surface.

Specifications for the Mission

Mass of landing unit	3.60×10^2 kg
Speed of landing unit as it entered the atmosphere	6.00×10^2 m/s
Velocity of landing unit just before it hit the surface, the first time	18 m/s, down
Velocity of landing unit just after it rebounded from the surface, the first time	11 m/s, up



3. The magnitude of the momentum of the landing unit as it entered the Martian atmosphere was
- A. $3.96 \times 10^3 \text{ kg}\cdot\text{m/s}$
 - B. $6.48 \times 10^3 \text{ kg}\cdot\text{m/s}$
 - C. $1.04 \times 10^4 \text{ kg}\cdot\text{m/s}$
 - D. $2.16 \times 10^5 \text{ kg}\cdot\text{m/s}$
4. The airbags protected the landing unit by
- A. increasing the impulse experienced by the landing unit
 - B. decreasing the impulse experienced by the landing unit
 - C. increasing the time of contact with the surface experienced by the landing unit
 - D. decreasing the time of contact with the surface experienced by the landing unit
5. The magnitude of the impulse experienced by the landing unit during its first collision with the surface of Mars was
- A. $2.5 \times 10^3 \text{ N}\cdot\text{s}$
 - B. $4.0 \times 10^3 \text{ N}\cdot\text{s}$
 - C. $6.5 \times 10^3 \text{ N}\cdot\text{s}$
 - D. $1.0 \times 10^4 \text{ N}\cdot\text{s}$
6. *The collision of the landing unit with the surface of Mars is classified as an i collision because ii conserved.*

The statement above is completed by the information in row

Row	<i>i</i>	<i>ii</i>
A.	elastic	momentum is
B.	elastic	kinetic energy is
C.	inelastic	momentum is not
D.	inelastic	kinetic energy is not

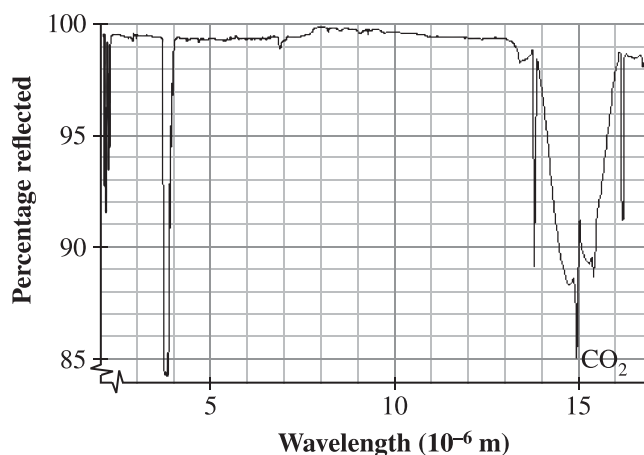
Use the following additional information to answer the next three questions.

The robotic probe had a variety of instruments, including a device that used ground-penetrating radar and a spectral photometer (SPM), that were used to investigate the planet Mars.

Ground-penetrating radar can be used to examine subsurface structures and search for evidence of specific rock formations that would indicate the previous presence of water. This device has an antenna that has a length of 1.00 m, which is half the wavelength of the radar's electromagnetic radiation (EMR).

An SPM can be used to identify the presence of particular substances. The SPM emits EMR over a broad range of the electromagnetic spectrum and detects those wavelengths that are reflected from the sample being examined. The photons that are not reflected cause electron transitions within the sample. The graph below shows SPM data for a particular sample and the deep dip, labelled CO_2 , indicates that carbon dioxide is present.

Percentage of EMR Reflected as a Function of Wavelength



7. The region of the EMR spectrum in which the ground-penetrating radar is classified is
- A. infrared
 - B. gamma
 - C. visible
 - D. radio

8. As a result of a collision between a photon and a carbon dioxide molecule in the sample, the molecule underwent a transition to a *i* energy state, and the photon was *ii* .

The statement above is completed by the information in row

Row	<i>i</i>	<i>ii</i>
A.	higher	absorbed
B.	higher	emitted
C.	lower	absorbed
D.	lower	emitted

Numerical Response

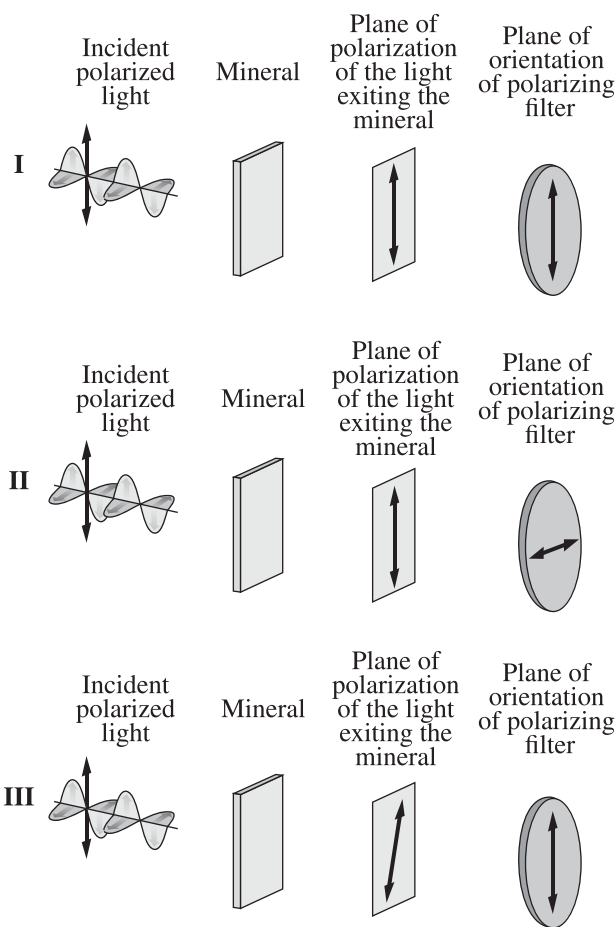
2. The difference in the energy levels of a CO₂ molecule associated with the deep dip in the SPM data, expressed in units of electron volts and in scientific notation, is $a.bc \times 10^{-d}$ eV. The values of *a*, *b*, *c*, and *d* are _____, _____, _____, and _____.

(Record all **four digits** of your answer in the numerical-response section on the answer sheet.)

Use the following additional information to answer the next question.

The probe was also equipped with a microscope that uses polarized light. This light passed through a mineral sample being analyzed. Certain minerals can cause the plane of polarization of the light to change. The light was then passed through a polarizing filter and a signal was detected.

Three arrangements of polarized light, mineral, and polarizing filter are shown below.



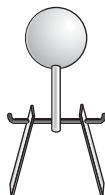
9. The order of the arrangements, as numbered above, from the one that would produce the **strongest** signal to the one that would produce the **weakest** signal is

- A. I, II, and III
- B. I, III, and II
- C. II, III, and I
- D. III, II, and I

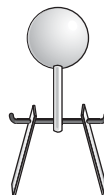
Use the following information to answer the next question.

Two identically charged electroscopes are shown below.

Electroscope I



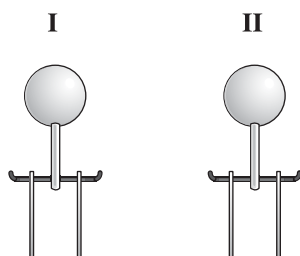
Electroscope II



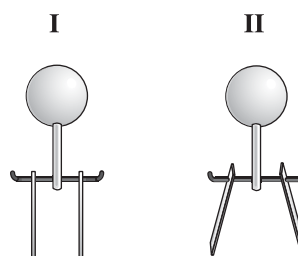
A student touches Electroscopes I with a neutral metal rod. The student touches Electroscopes II with a neutral glass rod.

10. Which of the following diagrams **best** shows the leaves of the electroscopes after the electroscopes are touched with the rods?

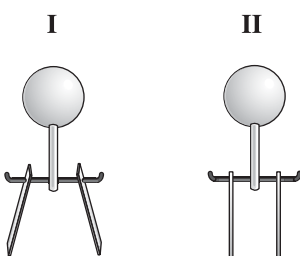
A.



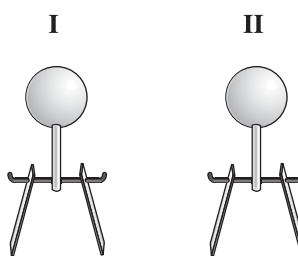
B.



C.



D.

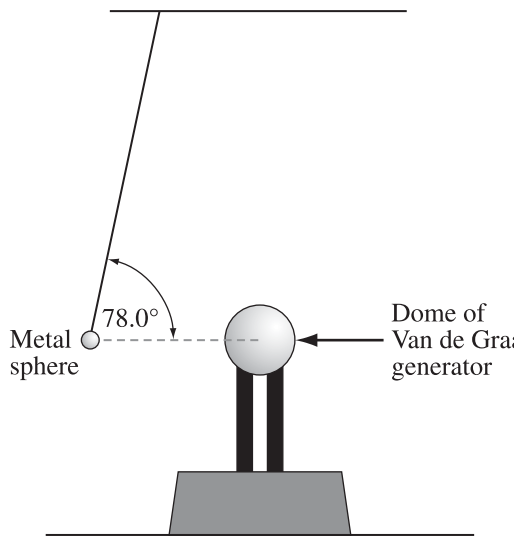


Use the following information to answer the next two questions.

An experiment is performed using an initially neutral metal sphere and the positively charged dome on a Van de Graaff generator. The metal sphere, which hangs on a thread, touches the dome of the generator and is then repelled. The mass of the metal sphere is 2.00×10^{-5} kg.

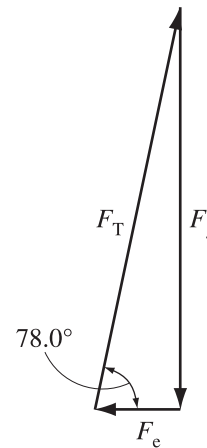
Observations

The diagram below illustrates the metal sphere in equilibrium some distance from the centre of the dome of the Van de Graaff generator.



Analysis

Three forces act on the metal sphere to produce equilibrium: the tension force, F_T , the gravitational force, F_g , and the electric force, F_e . When vectors representing the forces are added, the vector addition diagram given below results.



11. When it touches the generator, the metal sphere becomes *i* charged as a result of the transfer of *ii* .

The statement above is completed by the information in row

Row	<i>i</i>	<i>ii</i>
A.	negatively	electrons
B.	negatively	protons
C.	positively	electrons
D.	positively	protons

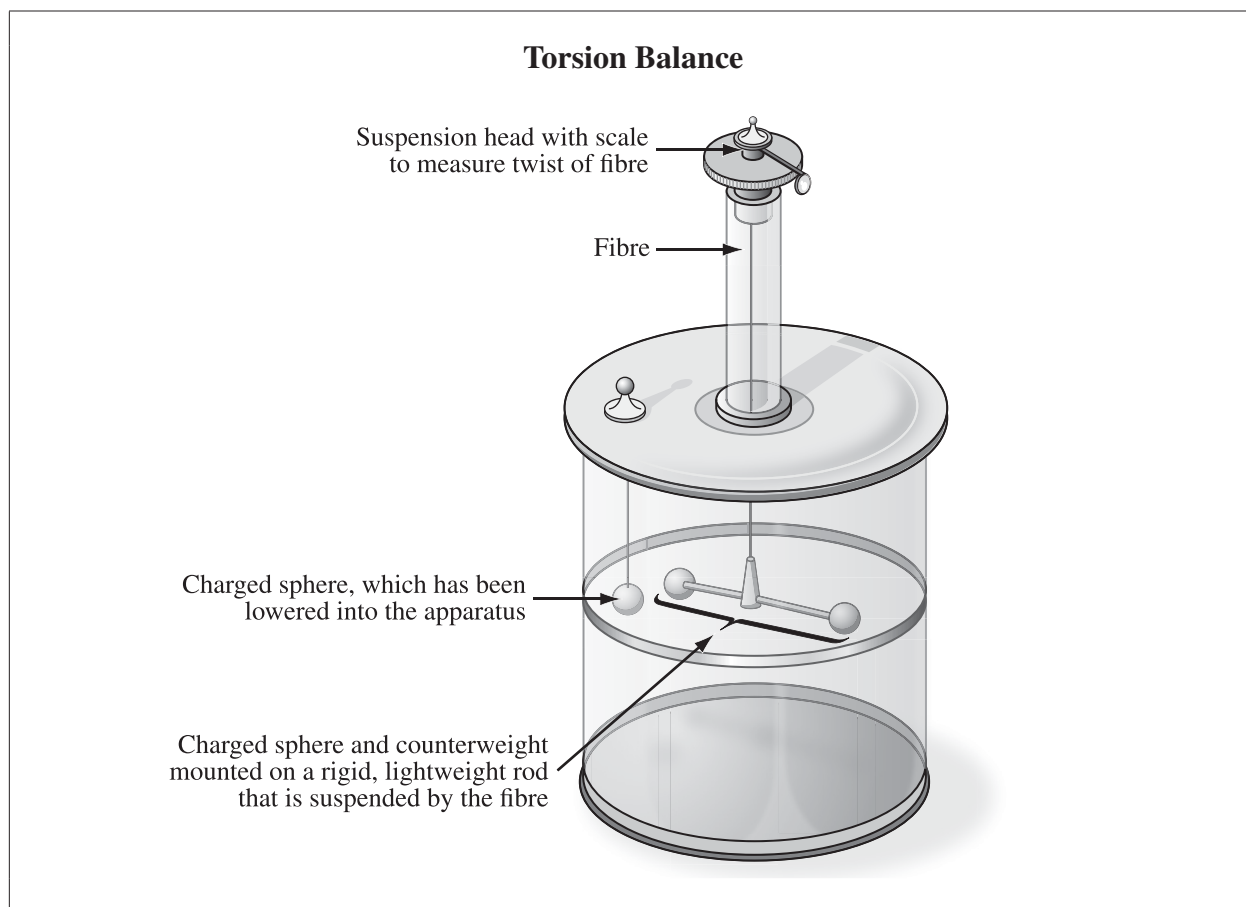
Numerical Response

3. The magnitude of the electric force, F_e , expressed in scientific notation, is $a.bc \times 10^{-d}$ N. The values of a , b , c , and d are _____, _____, _____, and _____.

(Record all **four digits** of your answer in the numerical-response section on the answer sheet.)

12. One charged object exerts a force, F , on a second charged object. If the distance between the two charged objects is doubled, and the charge on one of the objects is doubled, then the electric force that one charge exerts on the other is
- A. $\frac{1}{4}F$
- B. $\frac{1}{2}F$
- C. F
- D. $2F$

Use the following information to answer the next question.



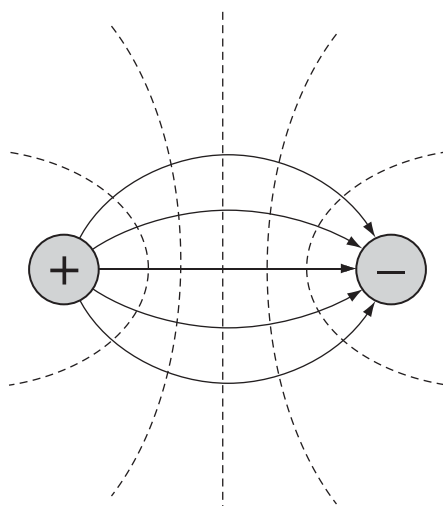
13. The angle of the twist of the fibre is a measure of *i* , which is directly proportional to *ii* .

The statement above is completed by the information in row

Row	<i>i</i>	<i>ii</i>
A.	Coulomb's constant	the distance between the charged spheres
B.	Coulomb's constant	the square of the distance between the charged spheres
C.	the force experienced by each charged sphere	the product of the charge on each sphere
D.	the force experienced by each charged sphere	the reciprocal of the product of the charge on each sphere

Use the following information to answer the next question.

The following diagram shows two point sources and selected field lines.



The solid field lines result from determining the direction of the net electric force acting on a test charge placed at a point on the line.

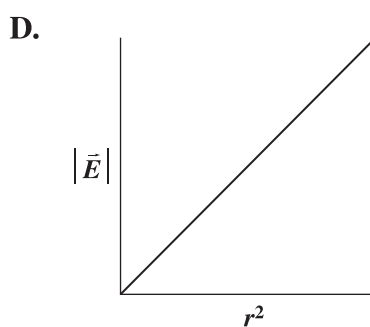
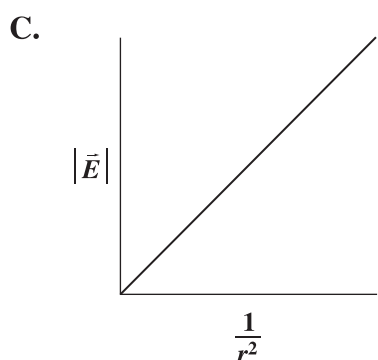
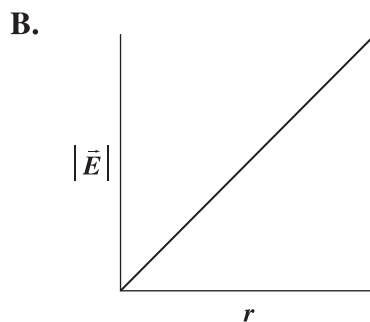
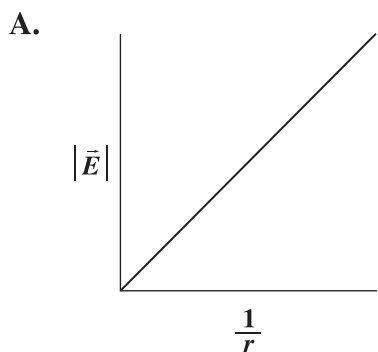
The dashed field lines result from connecting those points on a plane that have the same electric potential when a test charge is placed at that point.

14. The field represented by the solid lines is classified as a *i* field. The field represented by the dashed lines is classified as a *ii* field.

The statements above are completed by the information in row

Row	<i>i</i>	<i>ii</i>
A.	vector	scalar
B.	vector	vector
C.	scalar	scalar
D.	scalar	vector

15. Which of the following graphs **best** shows the relationship between electric field strength and distance from the source charge?



Use the following information to answer the next question.

A pair of parallel plates is separated by a distance of 1 cm and is connected to a 12 V battery. The magnitude of the electric field between the two plates is $|\vec{E}_1|$. A second pair of parallel plates, identical to the first, is separated by a distance of 3 cm and is connected to a 6 V battery.

16. Which of the following equations describes $|\vec{E}_2|$ in terms of $|\vec{E}_1|$?

A. $|\vec{E}_2| = 6|\vec{E}_1|$

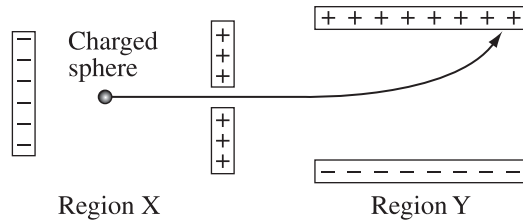
B. $|\vec{E}_2| = 3|\vec{E}_1|$

C. $|\vec{E}_2| = \frac{1}{5}|\vec{E}_1|$

D. $|\vec{E}_2| = \frac{1}{6}|\vec{E}_1|$

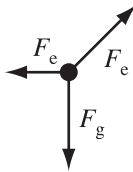
Use the following information to answer the next question.

A negatively charged sphere is accelerated from rest through the electric potential difference in the region labelled X in the diagram below. It then travels into Region Y. The entire apparatus is in a vacuum.



17. Which of the following free-body diagrams, drawn to scale, shows the forces acting on the negatively charged sphere when it is in Region Y?

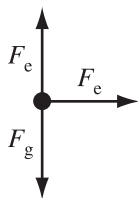
A.



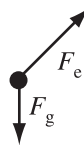
B.



C.

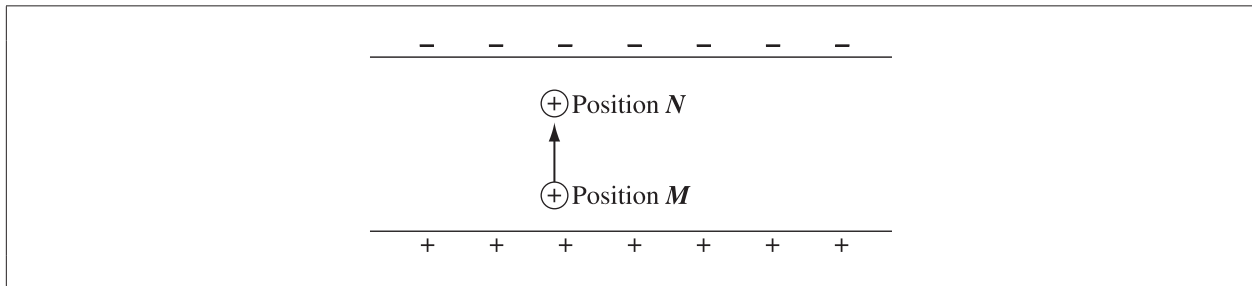


D.



18. In a Millikan-type apparatus, a plastic sphere that has a mass of 6.0×10^{-15} kg is suspended in an electric field that has a strength of 2.0×10^4 N/C. The charge on the sphere is
- A. 1.6×10^{-19} C
 - B. 3.0×10^{-19} C
 - C. 2.9×10^{-18} C
 - D. 2.8×10^{-17} C

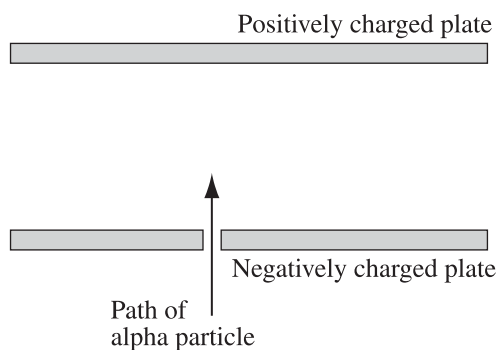
Use the following information to answer the next question.



19. A positively charged object is moved from Position *M* to Position *N* in a region between oppositely charged parallel plates as illustrated above. As a result of this change in position, the
- A. electric force on the object has increased
 - B. electric force on the object has decreased
 - C. electric potential energy of the object has increased
 - D. electric potential energy of the object has decreased

Use the following information to answer the next question.

Two oppositely charged parallel plates have an electric potential difference of 1.2×10^2 V across them. The plates are 4.5×10^{-2} m apart. An alpha particle enters the region between the plates through a hole in the negatively charged plate and comes to rest just before it reaches the positively charged plate.



20. The initial speed of the alpha particle as it enters the electric field is

- A. 1.1×10^5 m/s
- B. 5.1×10^5 m/s
- C. 5.4×10^5 m/s
- D. 7.6×10^5 m/s

Use the following information to answer the next question.

Diagram I, below, shows selected magnetic field lines between opposite poles, point P , and an arrow representing the magnetic field strength at point P .

Diagram I

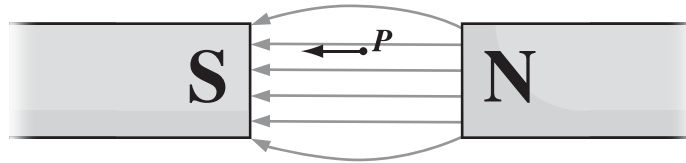
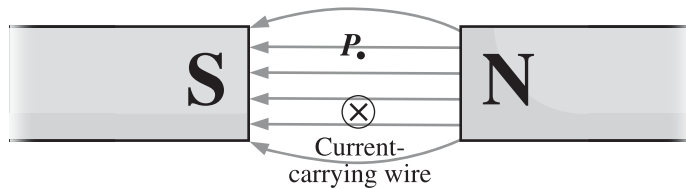


Diagram II shows the same magnetic field, the same point, P , a current-carrying wire oriented perpendicular to the magnetic field, and the direction of the electron flow in the current-carrying wire.

Diagram II



× Represents electron flow directed into the page

21. Which of the following diagrams, drawn to the same scale as Diagram I above, represents the net magnetic field strength at point P in Diagram II?

- A.
- B.
- C.
- D.

22. An alpha particle in a magnetic field travels in a circular path that has a radius of 20.0 cm. If the magnetic field strength is 7.5×10^{-3} T, then the speed of the alpha particle is
- A. 7.2×10^4 m/s
 - B. 1.4×10^5 m/s
 - C. 7.2×10^6 m/s
 - D. 5.3×10^8 m/s

Numerical Response

4. A current-carrying conductor that is 4.00×10^{-2} m long is placed perpendicular to a magnetic field that has a strength of 6.00×10^{-2} T. During a 20.0 s time interval, 7.00×10^{19} electrons pass a point in the conductor. The magnitude of the average magnetic force exerted on the conductor, expressed in scientific notation, is $a.bc \times 10^{-d}$ N. The values of *a*, *b*, *c*, and *d* are _____, _____, _____, and _____.

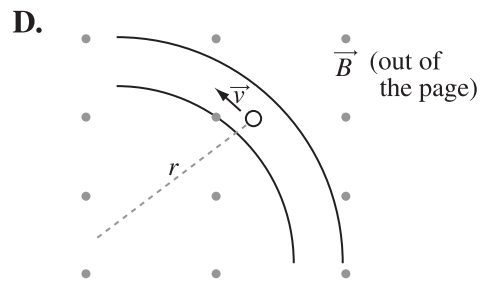
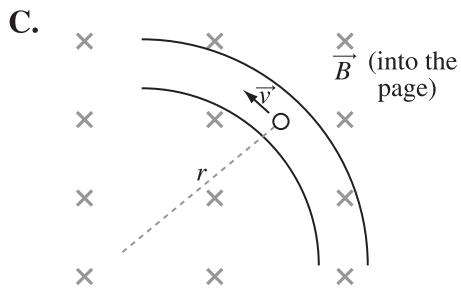
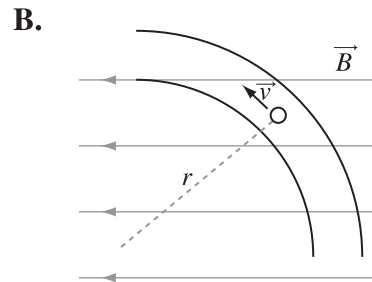
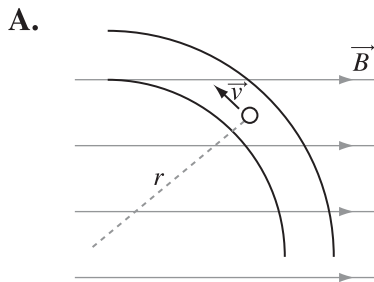
(Record all **four digits** of your answer in the numerical-response section on the answer sheet.)

Use the following information to answer the next three questions.

High-energy particle accelerators can be used to accelerate protons to close to the speed of light. Magnetic fields are used to produce the circular path that these protons follow in the accelerator.

The Large Hadron Collider is designed to accelerate protons to an energy of 7.00 TeV.

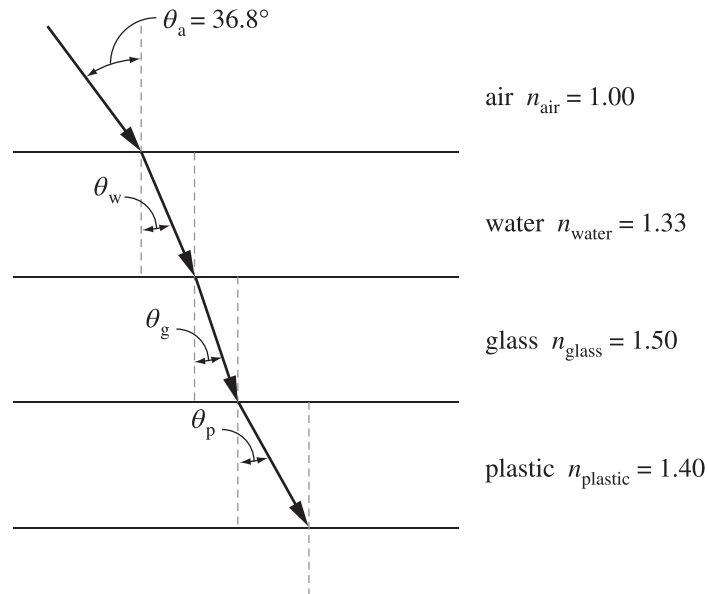
23. Which of the following diagrams shows the orientation that the magnetic field must have in order to deflect the path of the protons in the accelerator?



24. Electromagnetic radiation known as synchrotron radiation is generated by these large accelerators. This radiation is created
- A. by the large electric current used to generate the strong magnetic fields
 - B. from the change in the mass of the protons as they increase in speed
 - C. by the protons as they move in the circular path of the accelerator
 - D. from the change in radius as the protons increase in speed
25. The energy of a proton in the Large Hadron Collider is
- A. 1.12×10^{-18} J
 - B. 1.12×10^{-6} J
 - C. 4.38×10^{19} J
 - D. 4.38×10^{31} J
-
26. An object is 2.0 m tall and is located 7.0 m in front of a concave mirror that has a focal length of 3.0 m. The size and orientation of the image are, respectively,
- A. 0.60 m and erect
 - B. 0.60 m and inverted
 - C. 1.5 m and erect
 - D. 1.5 m and inverted

Use the following information to answer the next two questions.

Several transparent substances are arranged in layers so that their surfaces are parallel. A light ray is directed at the substances, as shown below.



27. The light travels slowest through

- A. air
- B. water
- C. glass
- D. plastic

Numerical Response

5. The angle of refraction in the glass, θ_g , is _____°.

(Record your **three-digit answer** in the numerical-response section on the answer sheet.)

Use the following information to answer the next question.

Light from a source passes through a glass prism and the following spectrum is observed.



28. The prism separates the colours because
- A. different wavelengths refract to different angles
 - B. different wavelengths diffract to different angles
 - C. there is no change in frequency in refraction
 - D. there is no change in frequency in diffraction

Numerical Response

6. The work function of silicon is 7.76×10^{-19} J. The maximum wavelength of electromagnetic radiation that will cause photoelectrons to be emitted from a silicon surface, expressed in scientific notation, is $a.bc \times 10^{-d}$ m. The values of a , b , c , and d are _____, _____, _____, and _____.

(Record all **four digits** of your answer in the numerical-response section on the answer sheet.)

29. Which of the following equations represents the relationship among the stopping voltage, the photon frequency, and the threshold frequency for the photoelectric effect?
- A. $V_{\text{stop}} = \frac{hf - hf_0}{q_e}$
 - B. $V_{\text{stop}} = (hf - hf_0)q_e$
 - C. $f = \frac{h}{q_e V_{\text{stop}} + hf_0}$
 - D. $f = hq_e V_{\text{stop}} - hf_0$

Use the following information to answer the next question.

A photon that had a frequency of 7.20×10^{14} Hz struck a polished metal surface and caused a single electron to be released. The released electron had a kinetic energy of 1.00 eV.

30. The work function of the metal surface was
- A. 1.00 eV
 - B. 1.98 eV
 - C. 2.98 eV
 - D. 3.98 eV

Use the following information to answer the next question.

Classical wave theory and quantum physics make different predictions about the effect of incident electromagnetic radiation on a photoelectric surface.

Four Photoelectric Effect Predictions

- 1 Low-intensity electromagnetic radiation incident on a photoelectric surface for long periods of time will cause photoemission.
- 2 High-intensity electromagnetic radiation will not cause photoemission unless its frequency is greater than the photoelectric surface's threshold frequency.
- 3 The energy of the emitted photoelectrons will increase if the intensity of the incident electromagnetic radiation is increased.
- 4 The energy of the emitted photoelectrons is independent of the intensity of the incident electromagnetic radiation.

Numerical Response

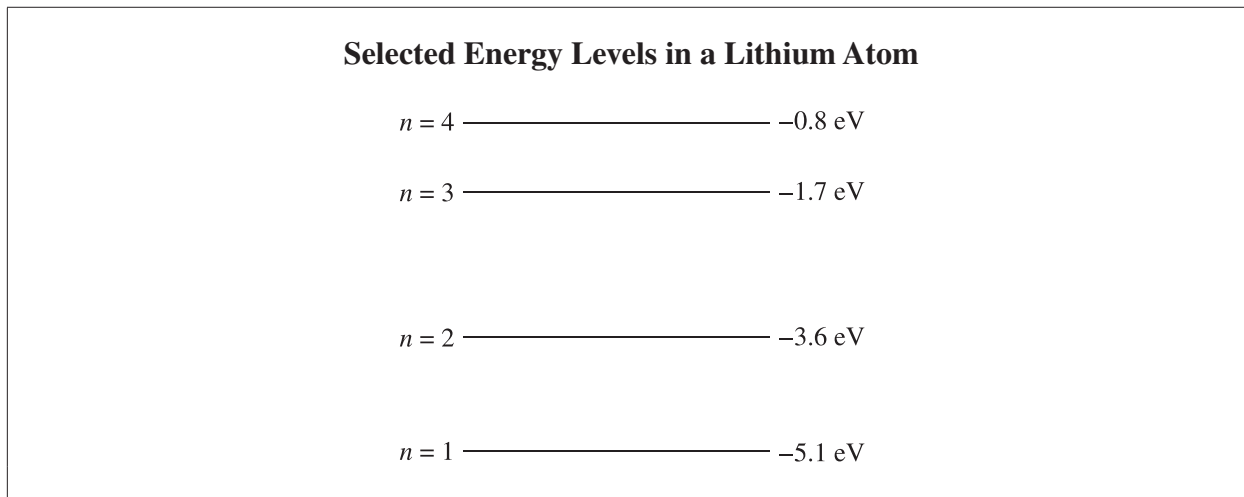
7. Match each of the predictions above with the appropriate theory of physics as labelled below. (There is more than one correct answer.)

Prediction: _____
Appropriate Theory: **Classical wave theory** **Quantum physics**

(Record all **four digits** of your answer in the numerical-response section on the answer sheet.)

31. The nuclear atom was proposed as a consequence of an experiment involving
- A. X-ray diffraction
 - B. charged oil drops
 - C. photon absorption
 - D. alpha particle scattering

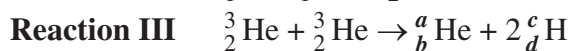
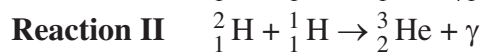
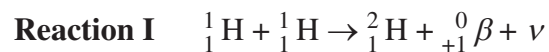
Use the following information to answer the next question.



32. When an electron in a lithium atom drops from the $n = 3$ energy level to the $n = 1$ energy level, the frequency of the emitted photon is
- A. 1.6×10^{15} Hz
 - B. 1.2×10^{15} Hz
 - C. 8.2×10^{14} Hz
 - D. 4.1×10^{14} Hz
-
33. Which of the following types of radiation will have its path deflected by a perpendicular electric field?
- A. Alpha and beta only
 - B. Beta and gamma only
 - C. Alpha and gamma only
 - D. Alpha, beta, and gamma

Use the following information to answer the next four questions.

Selected Reactions that Occur in the Sun



34. Reaction I above is classified as
- A. fusion, since small nuclei make a larger nucleus
 - B. fusion, since a large nucleus makes smaller nuclei
 - C. fission, since small nuclei make a larger nucleus
 - D. fission, since a large nucleus makes smaller nuclei
35. Which of the following statements describes the total measured mass as represented on the left side of reaction II as compared with the total measured mass represented on the right side?
- A. They are the same, since mass must be conserved.
 - B. They are the same, since the number of nucleons must be conserved.
 - C. The mass on the left is smaller, because of the energy equivalence of the mass defect.
 - D. The mass on the left is greater, because of the energy equivalence of the mass defect.
36. As electromagnetic radiation escapes from the super-hot core of the Sun, it passes through cooler gases that form the Sun's atmosphere. This results in the production of
- A. an emission spectrum
 - B. a bright-line spectrum
 - C. a continuous spectrum
 - D. an absorption spectrum

Numerical Response

8. To balance reaction III the numerical values of **a**, **b**, **c**, and **d** could be, respectively, _____, _____, _____, and _____.

(Record all **four digits** of your answer in the numerical-response section on the answer sheet.)

Use the following information to answer the next question.

Solar wind is hot plasma ejected from the surface of the Sun. The plasma consists, in part, of electrons. de Broglie hypothesized that a moving particle has a wavelength that relates to its momentum, given by the formula below.

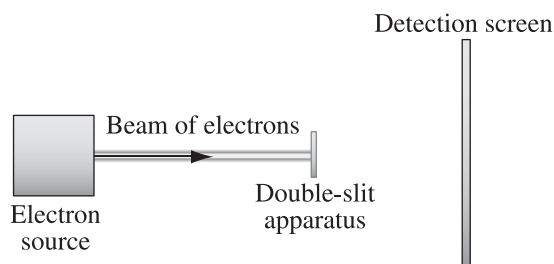
$$\lambda = \frac{h}{p}$$

37. The wavelength of one solar-wind electron that has a measured speed of 4.0×10^5 m/s is
- A. 9.9×10^{-13} m
 - B. 1.8×10^{-9} m
 - C. 6.2×10^6 m
 - D. 1.1×10^{10} m

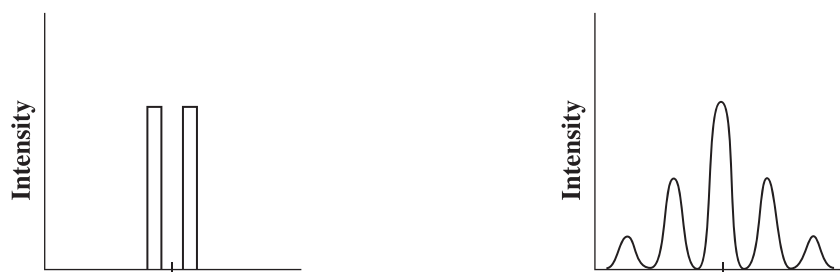
Use the following information to answer the next question.

In certain situations, electrons demonstrate particle-like characteristics, and in other situations, they demonstrate wave-like characteristics.

The following diagram illustrates the apparatus used to investigate the particle-like and wave-like characteristics of electrons.



Graphs of Predicted Observations

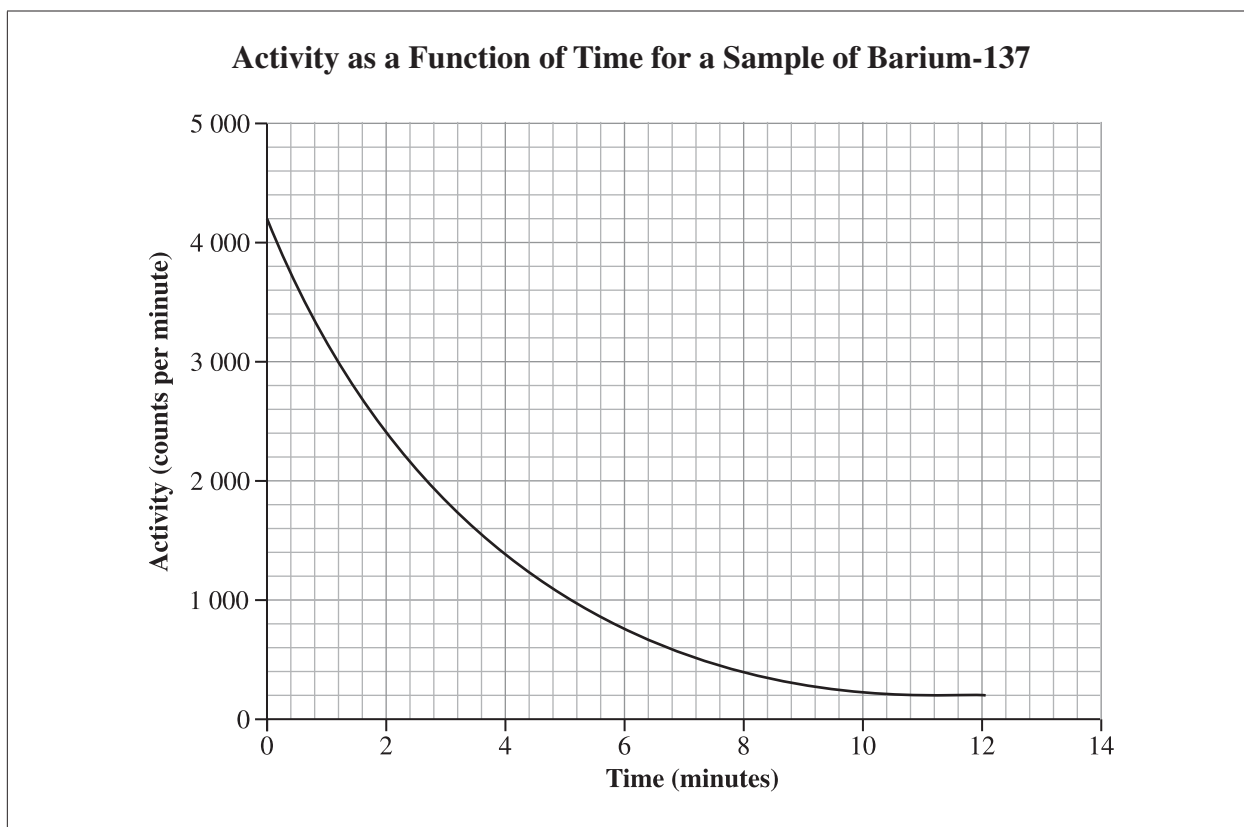


38. To produce the graph on the left, electrons must exhibit *i* characteristics. To produce the graph on the right, electrons must exhibit *ii* characteristics. The phenomenon that the electrons experience as they pass through the double-slit apparatus is *iii* .

The statements above are completed by the information in row

Row	<i>i</i>	<i>ii</i>	<i>iii</i>
A.	particle-like	wave-like	diffraction
B.	particle-like	wave-like	interference
C.	wave-like	particle-like	diffraction
D.	wave-like	particle-like	interference

Use the following information to answer the next question.



39. The activity of this sample after 3 half-lives have elapsed is approximately

- A. 260 counts/min
- B. 520 counts/min
- C. 1 900 counts/min
- D. 2 080 counts/min

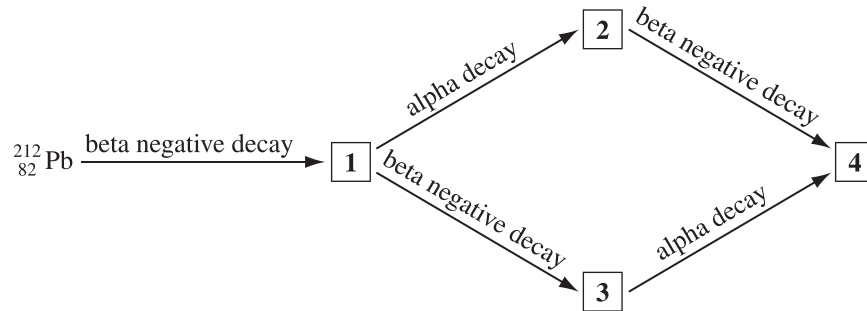
Numerical Response

9. The energy equivalence of the mass of one alpha particle, expressed in units of joules, in scientific notation to two significant digits, is $a.b \times 10^{-cd}$ J. The values of a , b , c , and d are _____, _____, _____, and _____.

(Record all **four digits** of your answer in the numerical-response section on the answer sheet.)

Use the following information to answer the next question.

There are two possible sequences through which the unstable radioactive nucleus lead-212 can decay into a stable nucleus. They are shown below. The daughter nuclei are labelled 1, 2, 3, and 4.



Numerical Response

10. Match each of the boxed numbers above to the daughter nucleus that it represents, as listed below.

Number: _____
 Daughter nucleus: ^{212}Bi ^{208}Pb ^{212}Po ^{208}Tl

(Record all **four digits** of your answer in the numerical-response section on the answer sheet.)

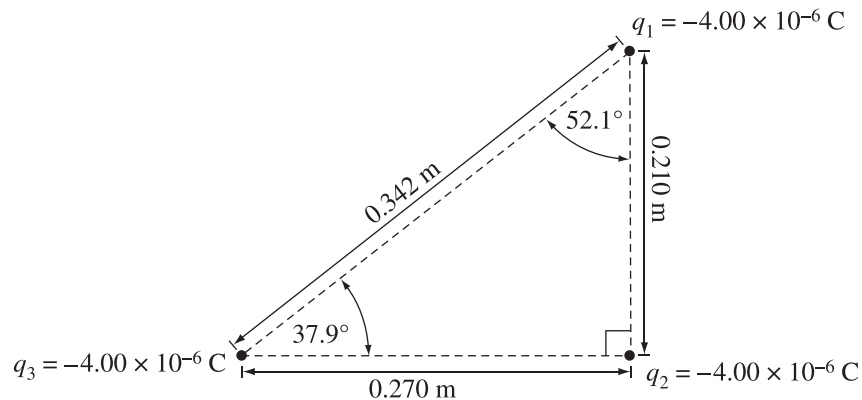
40. A neutron and a proton can be modelled using quark combinations. Which of the following rows matches the quark combination to the nucleon?

Row	Neutron	Proton
A.	udd	uud
B.	uud	udd
C.	\overline{udd}	\overline{uud}
D.	\overline{uud}	\overline{udd}

Physics 30 June 2009 Diploma Examination Written-Response Released Questions

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

Three identical point charges are located in a region of space as shown in the diagram below.



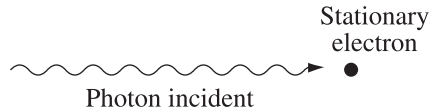
Written Response—10%

- Determine** the net electric force acting on q_1 . In your response, **sketch** a free-body diagram of the two electric forces acting on q_1 , **explain** how you determined the direction of each of these forces, and **sketch** a vector addition diagram consistent with the vector analysis method you are choosing. **State** all necessary physics concepts and formulas.

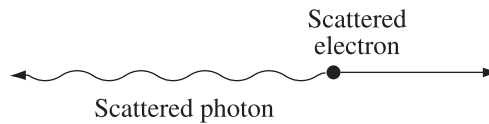
Marks will be awarded based on your vector diagrams, the physics that you use, and on the mathematical treatment that you provide.

Use the following information to answer this analytic question.

An X-ray photon that has a wavelength of 2.000×10^{-10} m collides with a stationary electron.



The scattered X-ray photon, which has a wavelength of 2.049×10^{-10} m, returns along the initial path.



Written Response—10%

2. Verify that this collision is elastic.

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.

Use the following information to answer this holistic question.

A group of students is given the task of determining the speed of the alpha particles emitted by a radioactive sample.

The students have the following equipment available:

- the radioactive sample in a container that allows the alpha particles to exit in a straight line
- parallel plates
- variable voltage source
- magnets of determined strength, B
- phosphorescent screen that glows when hit by an alpha particle
- vacuum chamber
- voltmeter
- ammeter
- electrical wires
- metre stick

Written Response—15%

3. Using the concepts of the effect of an external field on a moving charge, the properties of alpha particles, and experimental design, **describe** a method to determine the speed of the emitted alpha particles. In your response,
- **identify** the equipment that will be used
 - **describe** the relative orientation of the velocity of the alpha particles to the external field or fields being used
 - **design** a procedure that could be followed to produce the appropriate measurements required to determine the speed of the alpha particles
 - **describe** the analysis, including necessary formulas, required to determine the speed of the alpha particles

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

***Physics 30 June 2009 Diploma Examination
Released Question Written-Response 1—Vector Skills
Scoring Guide***

Scoring Guide for Two-Dimensional Vector Questions – Vector Diagrams

Score	Description
5	<ul style="list-style-type: none"> • 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 <p>Note: One minor error may be present***</p>
4	<ul style="list-style-type: none"> • 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 <p>or</p> <ul style="list-style-type: none"> • The situational diagram may be missing from an otherwise complete response <p>or</p> <ul style="list-style-type: none"> • A solution using components is given, but the relationship between the components and one of the vectors is missing
3	<ul style="list-style-type: none"> • 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	<ul style="list-style-type: none"> • A complete diagram showing the directions of the significant vectors is present (e.g., a free body diagram or a situational diagram) <p>or</p> <ul style="list-style-type: none"> • The vector addition diagram is given as a triangle with some labels present <p>or</p> <ul style="list-style-type: none"> • 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	<ul style="list-style-type: none"> • There is a valid start present (e.g., a labelled situational diagram drawn as lines with some labels present)
0	<ul style="list-style-type: none"> • Nothing valid to vector addition is provided
NR	<ul style="list-style-type: none"> • 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	<ul style="list-style-type: none"> • The physics concepts related to the solution are explicitly communicated (e.g., conservation of momentum, work done equals change in energy, equilibrium means $F_{\text{net}} = \text{zero}$) • 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 <p>One minor error may be present*</p>
4	<ul style="list-style-type: none"> • A complete solution is present, but it contains two minor errors or one major error or omission**
3	<ul style="list-style-type: none"> • A valid method is begun and contains no errors <p style="text-align: center;">or</p> <ul style="list-style-type: none"> • The solution is complete, but there are significant errors or omissions
2	<ul style="list-style-type: none"> • A valid method is begun <p style="text-align: center;">or</p> <ul style="list-style-type: none"> • A linear analysis is present***
1	<ul style="list-style-type: none"> • A valid start is present. This may be one valid calculation
0	<ul style="list-style-type: none"> • Only inappropriate mathematical treatment is present
NR	<ul style="list-style-type: none"> • No response to the mathematical treatment is provided

*Minor errors include

- Stating the final answer with incorrect (but not disrespectful) units
- Stating the final answer with incorrect (but not disrespectful) significant digits
- Missing one of several different formulas

**Major omissions include

- Missing the physics concept
- 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

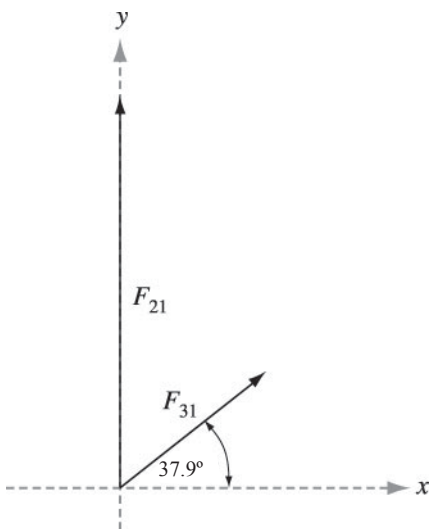
*****Linear Analysis**

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 Solutions

This is the FBD for the forces acting on the charge at the top of the triangle. Since like charges repel, the forces are all away from the source charge.



The magnitudes of the forces are found using Coulomb's law:

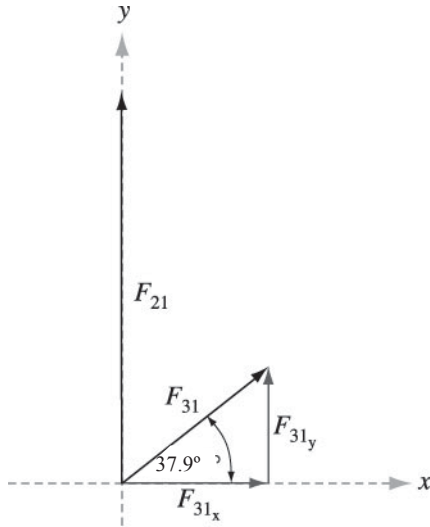
$$\begin{aligned} F_{21} &= \frac{kq_1q_2}{r^2} \\ &= \frac{(8.99 \times 10^9 \text{ N}\cdot\text{m}^2/\text{C}^2)(4.00 \times 10^{-6} \text{ C})^2}{(0.210 \text{ m})^2} \\ &= 3.261678 \text{ N} \end{aligned}$$

$$\begin{aligned} F_{31} &= \frac{kq_1q_2}{r^2} \\ &= \frac{(8.99 \times 10^9 \text{ N}\cdot\text{m}^2/\text{C}^2)(4.00 \times 10^{-6} \text{ C})^2}{(0.342 \text{ m})^2} \\ &= 1.22978 \text{ N} \end{aligned}$$

Perpendicular components: Method 1

A direction convention must be established for this method.

- For convenience it is standard practice to use Cartesian coordinate axes (labelled).
- Students must define the coordinate axes that will be considered to be +ve either by diagram or statement. e.g., right and up are + or



F_{21} has components

$$F_{21x} = 0 \text{ N}$$

$$F_{21y} = +3.261678 \text{ N}$$

F_{31} has components

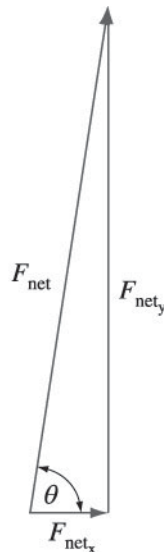
$$\begin{aligned} F_{31x} &= F_{31} \cos \theta \\ &= (1.2298 \text{ N}) \cos 37.9^\circ \\ &= +0.9704 \text{ N} \end{aligned}$$

$$\begin{aligned} F_{31y} &= F_{31} \sin \theta \\ &= (1.2298 \text{ N}) \sin 38.0^\circ \\ &= +0.7554 \text{ N} \end{aligned}$$

The addition of the components gives

$$\begin{aligned} F_{\text{net}x} &= F_{21x} + F_{31x} \\ &= 0 \text{ N} + +0.9704 \text{ N} \\ &= +0.9704 \text{ N} \end{aligned}$$

$$\begin{aligned} F_{\text{net}y} &= F_{21y} + F_{31y} \\ &= +3.2617 \text{ N} + +0.7554 \text{ N} \\ &= +4.0171 \text{ N} \end{aligned}$$



$$F_{\text{net}}^2 = F_{\text{net}x}^2 + F_{\text{net}y}^2$$

$$\begin{aligned} F_{\text{net}} &= \sqrt{(+0.9704 \text{ N})^2 + (+4.0171 \text{ N})^2} \\ &= 4.1326 \text{ N} \\ &= 4.13 \text{ N} \end{aligned}$$

and

$$\begin{aligned} \tan \theta &= \frac{F_{\text{net}y}}{F_{\text{net}x}} \\ \tan \theta &= \frac{4.0171 \text{ N}}{0.9704 \text{ N}} \end{aligned}$$

$$\theta = \tan^{-1} \left(\frac{+4.0171 \text{ N}}{+0.9704 \text{ N}} \right)$$

$$\theta = 76.4^\circ$$

The net force is 4.13 N at 76.4° from the x-axis (Cartesian reference)
or 76.4° from the +ve axis (individual reference)

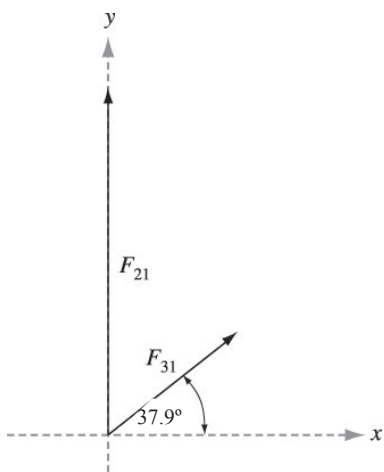
Perpendicular components: Method 2 (Book Keeping)

A direction convention must be established for this method.

- For convenience it is standard practice to use Cartesian coordinate axes (labelled).

or

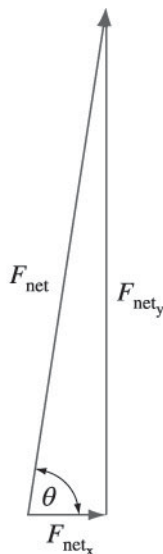
- Students must define the coordinate axes that will be considered to be +ve either by diagram or statement. e.g., right and up are + or



Force	x-component	y-component
F_{21}	$F_{21} \cos \theta$ 3.261678 N $\cos 90^\circ$ 0	$F_{21} \sin \theta$ 3.261678 N $\sin 90^\circ$ + 3.261678 N
F_{31}	$F_{31} \cos \theta$ 1.2298 N $\cos 37.9^\circ$ + 0.9704 N	$F_{31} \sin \theta$ 1.2298 N $\sin 37.9^\circ$ + 0.7554 N
F_{net}	0 N + +0.9704 N + 0.9704 N	+ 3.261678 N + +0.7554 N + 4.0171 N

Note: It is insufficient for students to include numbers without a rationale for how those numbers are determined.

Determining the net force from the components gives



$$F_{\text{net}}^2 = F_{\text{net}_x}^2 + F_{\text{net}_y}^2$$

$$F_{\text{net}} = \sqrt{(+0.9704 \text{ N})^2 + (+4.0171 \text{ N})^2}$$

$$= 4.1326 \text{ N}$$

$$= 4.13 \text{ N}$$

and

$$\tan \theta = \frac{0}{a}$$

$$\tan \theta = \frac{F_{\text{net}_y}}{F_{\text{net}_x}}$$

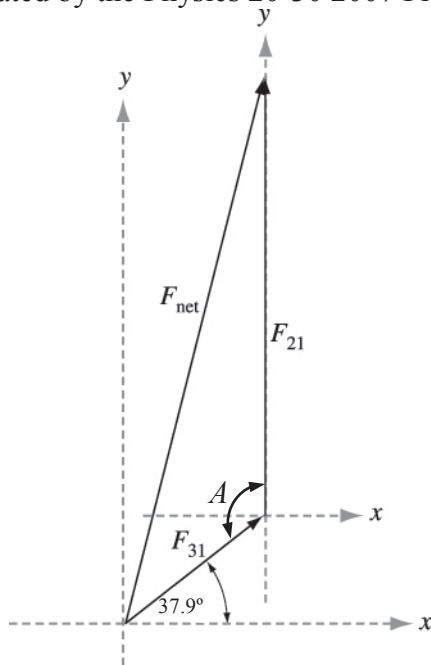
$$\theta = \tan^{-1} \left(\frac{+4.0171 \text{ N}}{+0.9704 \text{ N}} \right)$$

$$\theta = 76.4^\circ$$

The net force is 4.13 N at 76.4° from the x-axis (Cartesian reference)
or 76.4° from the +ve axis (individual reference)

Method 2: Use of cosine law and sine law:

(This is not mandated by the Physics 20-30 2007 Program of Studies).



$$a^2 = b^2 + c^2 - 2bc \cos A \quad \text{where } A = 90^\circ + 38^\circ = 128^\circ$$

so

$$F_{\text{net}}^2 = F_{21}^2 + F_{31}^2 - 2F_{21}F_{31} \cos 128^\circ$$

and

$$\begin{aligned} F_{\text{net}} &= \sqrt{F_{21}^2 + F_{31}^2 - 2F_{21}F_{31} \cos 128^\circ} \\ &= \sqrt{(3.26 \text{ N})^2 + (1.23 \text{ N})^2 - 2(3.26 \text{ N})(1.24 \text{ N}) \cos 128^\circ} \\ &= 4.1326 \text{ N} \\ &= 4.13 \text{ N} \end{aligned}$$

$$\frac{a}{\sin A} = \frac{b}{\sin B}$$

so

$$\sin \theta = \frac{F_{31} \sin 128^\circ}{F_{\text{net}}}$$

$$\theta = \sin^{-1} \left(\frac{(1.23 \text{ N})(\sin 128^\circ)}{4.13 \text{ N}} \right)$$

$$\theta = 13.6^\circ$$

$\theta = 13.6^\circ$ from the y-axis, which is $90^\circ - 13.6^\circ = 76.4^\circ$ to the x-axis

The net force is 4.13 N at 76.4° from the x-axis (Cartesian reference)

***Physics 30 June 2009 Diploma Examination
Released Question Written-Response 2—Analytic
Scoring Guide***

Analytic Scoring Guide

Physics Principles

Score	Description
NOTE:	Extraneous principles not required to answer the question <i>may</i> 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; for example, length measurements into length variables or energy measurements into energy variables
0	Substitutions are missing or The response contains one invalid substitution; for example, electric field strength for energy, speed for electric potential difference, or a vertical value in to a horizontal equation or vice versa
NR	No substitutions are shown

Formulas

Score	Description
NOTE:	Extraneous formulas not required to answer the question <i>may</i> 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 Solution

Use the principle of conservation of energy to classify the collision: if kinetic energy is conserved, the collision is elastic; if the kinetic energy is not conserved, then the collision is inelastic.

$$E_i = E_{\text{photon}} = \frac{hc}{\lambda}$$

$$E_i = \frac{(6.63 \times 10^{-34} \text{ J} \cdot \text{s})(3.00 \times 10^8 \text{ m/s})}{2.000 \times 10^{-10} \text{ m}}$$

$$E_i = 9.945 \times 10^{-16} \text{ J}$$

$$E_i = 9.95 \times 10^{-16} \text{ J}$$

$$E_f = E_{\text{photon}_{\text{scattered}}} + E_{\text{k}_{\text{electron}}}$$

$$E_{\text{photon}_{\text{scattered}}} = \frac{hc}{\lambda_{\text{scattered}}}$$

$$E_{\text{photon}_{\text{scattered}}} = \frac{(6.63 \times 10^{-34} \text{ J} \cdot \text{s})(3.00 \times 10^8 \text{ m/s})}{2.049 \times 10^{-10} \text{ m}}$$

$$E_{\text{photon}_{\text{scattered}}} = 9.7017 \times 10^{-16} \text{ J}$$

To get the kinetic energy of the electron after the collision, must use Conservation of Momentum

Initial momentum

$$\vec{p}_i = \vec{p}_{\text{photon}} + \vec{p}_{\text{electron}}$$

$$\vec{p}_i = \frac{h}{\lambda} + 0$$

$$\begin{aligned} \vec{p}_i &= \frac{6.63 \times 10^{-34} \text{ J} \cdot \text{s}}{2.000 \times 10^{-10} \text{ m}} \\ &= 3.32 \times 10^{-24} \text{ kg} \cdot \text{m/s} \end{aligned}$$

Final momentum

$$\vec{p}_f = \vec{p}'_{\text{ph}} + \vec{p}'_{\text{e}}$$

The \vec{p}'_{ph} value is negative since it travels in the opposite direction.

$$\vec{p}_i = \vec{p}'_{\text{ph}} + \vec{p}'_{\text{e}}$$

$$\vec{p}'_{\text{e}} = \vec{p}_i - (-\vec{p}'_{\text{ph}})$$

$$\begin{aligned} &= 3.32 \times 10^{-24} \text{ kg} \cdot \text{m/s} - \left(-\frac{h}{\lambda} \right) \\ &= 3.32 \times 10^{-24} \text{ kg} \cdot \text{m/s} + \frac{(6.63 \times 10^{-34} \text{ J} \cdot \text{s})}{(2.049 \times 10^{-10} \text{ m})} \\ &= 6.55572 \times 10^{-24} \text{ kg} \cdot \text{m/s} \end{aligned}$$

$$p = m\vec{v} \qquad \vec{v} = \frac{\vec{p}}{m} = \frac{6.55 \times 10^{-24} \text{ kg}\cdot\text{m/s}}{9.11 \times 10^{-31} \text{ kg}}$$

$$= 7.19 \times 10^6 \text{ m/s}$$

$$E_{k_{\text{electron}}} = \frac{1}{2}mv^2$$

$$E_{k_{\text{electron}}} = \frac{1}{2}(9.11 \times 10^{-31} \text{ kg})(7.19 \times 10^6 \text{ m/s})^2$$

$$E_{k_{\text{electron}}} = 2.3588 \times 10^{-17} \text{ J}$$

$$E_f = E_{\text{photon}_{\text{scattered}}} + E_{k_{\text{electron}}}$$

$$E_f = 9.7095 \times 10^{-16} \text{ J} + 2.3588 \times 10^{-17} \text{ J}$$

$$E_f = 9.944538 \times 10^{-16} \text{ J}$$

$$E_f = 9.94 \times 10^{-16} \text{ J}$$

Comparing this to the initial kinetic energy, the energies are the same; therefore the collision is elastic.

Method 2:

For a collision to be elastic, kinetic energy must be conserved.

By the Compton effect formula which requires both conservation of momentum and energy

$$\Delta\lambda = \frac{h}{mc}(1 - \cos\theta)$$

$$\text{expected} \quad \Delta\lambda = \left[\frac{6.63 \times 10^{-34} \text{ J}\cdot\text{s}}{(9.11 \times 10^{-31} \text{ kg})(3.00 \times 10^8 \text{ m/s})} \right] [1 - \cos 180^\circ]$$

$$= 4.8518 \times 10^{-12} \text{ m}$$

$$= 4.85 \times 10^{-12} \text{ m}$$

$$\text{actual} \quad \Delta\lambda = \lambda_f - \lambda_i$$

$$= 2.049 \times 10^{-10} \text{ m} - 2.000 \times 10^{-10} \text{ m}$$

$$= 4.9 \times 10^{-12} \text{ m}$$

Since the observed and predicted values are the same, the assumption that both momentum and energy are conserved is validated. The collision is elastic.

Note: A student response that assumes energy or delta lambda will be the same, contains a significant error and cannot receive a score higher than 7 out of 10.

***Physics 30 June 2009 Diploma Examination
Released Question Written-Response 3—Holistic
Scoring Guide***

Holistic Scoring Guide

<p>Major Concepts: Effect of external field: Properties of types of radiation: Experimental design:</p>		<p>Outcomes: A: describing the orientation of field and alpha particle velocity (to produce the path required for the experimental procedure) K: state (or use) that alpha particles are positively charged K: identify equipment (checked in information box, list in response, labelled diagram) K: measurement A: providing a complete algebraic derivation of how the observations can be used to determine the speed of the alpha particle</p>	
Score	Description		
5	<ul style="list-style-type: none"> • 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 <p>Note: the response may contain minor errors or have minor omissions</p>		
4	<ul style="list-style-type: none"> • 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 <p>Note: the response may contain errors or have omissions <i>The response is mostly complete and mostly correct, and contains some application of physics principles</i></p>		
3	<ul style="list-style-type: none"> • The response addresses, with some appropriate knowledge, all the major concepts in the question <p style="text-align: center;">or</p> <p>The response addresses more than half of the full scope of the question with a mixture of knowledge and application</p> <ul style="list-style-type: none"> • 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	<ul style="list-style-type: none"> • The response addresses, with some appropriate knowledge, two of the outcomes in the question 		
1	<ul style="list-style-type: none"> • The response addresses, with some appropriate knowledge, one of the outcomes in the question 		
0	<ul style="list-style-type: none"> • The student provides a solution that is invalid for the question 		
NR	<ul style="list-style-type: none"> • There is no response to the question 		

Sample response

Procedure

1. Set up the phosphorescent screen so that the alpha particles (placed in a vacuum chamber) can hit it when the cover is removed from the hole in the lead container.
2. Mark where the alpha particles hit.
3. Cover the hole in the lead container.
4. Set up the parallel plates so the stream of alpha particles passes through the opening between the plates.
5. Connect the variable voltage source so that the plates have an electric potential difference, V , between them.
6. Connect a voltmeter, in parallel, across the variable voltage source to measure V .
7. Measure the plate separation, d .
8. Set up the magnets so the magnetic field is perpendicular to the electric field, and so that the magnetic force is in the opposite direction to the electric force. To get the directions of the forces: the electric force is in the same direction as the electric field – from positive to negative plate because alpha particles are positively charged. To get the direction of the magnetic force use the right (for positive charges) hand rule in which the palm points in the direction of the magnetic force, the fingers in the direction of the external field (from north to south pole) and the thumb in the direction of the charge motion.
9. Use RHR to determine where alpha particles will go with only the magnetic field acting. Stand on the other side.
10. Remove the cover and allow the alpha particles out.
11. Turn up the voltage to create an electric field between the plates that straightens out the path of the alpha beam until the beam is hitting the screen where it did in step 2.
12. Record this value of V .
13. Calculate $|\vec{E}|$ using V/d .
14. Calculate v using $v = \frac{|\vec{E}|}{B}$

or

Alternate Procedure

1. Set up lead box inside parallel plates so that the alpha particles will exit the box and hit one of the plates.
2. Connect the ammeter across the parallel plates.
3. Open the lead box and verify there is a current.
4. Connect the variable voltage supply across the plates so that the plate the alpha particles hit will be positive. Because alpha particles are positively charged, the electric force will act to slow the alpha particles down. Once the particles are brought to a rest, the electric potential difference is the stopping voltage.
5. Put a voltmeter in parallel with the variable voltage supply.
6. Increase the voltage until the current drops to zero.
7. Record the voltage as V_{stop} .
8. Use $E_{\text{elec}} = E_{\text{k}}$ to calculate v .

$$V_{\text{stop}}q = \frac{1}{2}mv^2$$

$$v = \sqrt{\frac{2Vq}{m}}$$