January 1999

Physics 30

Grade 12 Diploma Examination

Alberta
EDUCATION

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Physics 30

Grade 12 Diploma Examination

Description

Time: 2.5 h. This examination was developed to be completed in 2.5 h; however, you may take an additional 0.5 h to complete the examination.

This is a **closed-book** examination consisting of

- 37 multiple-choice and 12 numerical-response questions, of equal value, worth 70% of the examination
- 2 written-response questions, of equal value, worth a total of 30% of the examination

This examination contains sets of related questions. A set of questions may contain multiple-choice and/or numerical-response and/or written-response questions.

A tear-out data sheet is included near the back of this booklet. A Periodic Table of the Elements is also provided.

Note: *The perforated pages at the back of this booklet may be torn out and used for your rough work.* ***No marks*** *will be given for work done on the tearout pages.*

Instructions

- You are expected to provide your own scientific calculator.
- Use only an HB pencil for the machine-scored answer sheet.
- Fill in the information required on the answer sheet and the examination booklet as directed by the presiding examiner.
- Read each question carefully.
- Consider all numbers used in the examination to be the result of a measurement or observation.
- When performing calculations, use the values of constants provided on the tear-out sheet. Do **not** use the values programmed in your calculator.
- If you wish to change an answer, erase **all** traces of your first answer.
- Do not fold the answer sheet.
- The presiding examiner will collect your answer sheet and examination booklet and send them to Alberta Education.
- Now turn this page and read the detailed instructions for answering machine-scored and written-response questions.

Multiple Choice

- Decide which of the choices **best** completes the statement or answers the question.

- Locate that question number on the separate answer sheet provided and fill in the circle that corresponds to your choice.

Example

This examination is for the subject of

A. science
B. physics
C. biology
D. chemistry

Answer Sheet

Ⓐ ● Ⓒ Ⓓ

Numerical Response

- Record your answer on the answer sheet provided by writing it in the boxes and then filling in the corresponding circles.

- If an answer is a value between 0 and 1 (e.g., 0.25), then be sure to record the 0 before the decimal place.

- **Enter the first digit of your answer in the left-hand box and leave any unused boxes blank.**

Examples

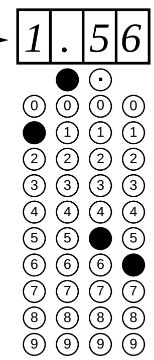
Calculation Question and Solution

If a 121 N force is applied to a 77.7 kg mass at rest on a frictionless surface, the acceleration of the mass will be __________ m/s^2.
(Record your **three-digit answer** in the numerical-response section on the answer sheet.)

$$a = \frac{F}{m}$$

$$a = \frac{121\ \text{N}}{77.7\ \text{kg}} = 1.5572716$$

Record 1.56 on the answer sheet →



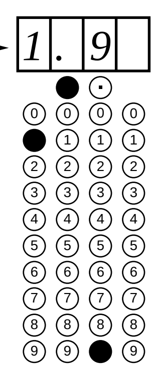
Calculation Question and Solution

A microwave of wavelength 16 cm has a frequency, expressed in scientific notation, of $\boldsymbol{b} \times 10^{w}$ Hz. The value of $\boldsymbol{b}$ is ________ .
(Record your **two-digit answer** in the numerical-response section on the answer sheet.)

$$f = \frac{c}{\lambda}$$

$$f = \frac{3.00 \times 10^{8}\ \text{m/s}}{0.16\ \text{m}} = 1.875 \times 10^{9}$$

Record 1.9 on the answer sheet →



Correct-Order Question and Solution

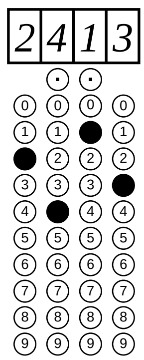
When the following subjects are arranged in alphabetical order, the order is ____, ____, ____, and ____ .

1 physics
2 biology
3 science
4 chemistry

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

Answer: 2413

Record 2413 on the answer sheet →



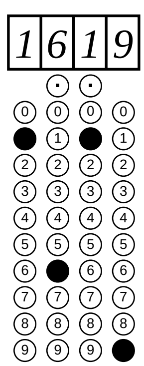
Scientific Notation Question and Solution

The charge on an electron is $-\boldsymbol{a.b} \times 10^{-\boldsymbol{cd}}$ C. The values of ***a***, ***b***, ***c***, and ***d*** are ____, ____, ____, and ____ .

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

Answer: $q = -1.6 \times 10^{-19}$ C

Record 1619 on the answer sheet →



Written Response

- Write your answers in the examination booklet as neatly as possible.
- For full marks, your answers must address **all** aspects of the question.
- Descriptions and/or explanations of concepts must be correct and include pertinent ideas, diagrams, calculations, and formulas.
- Your answers must be presented in a well-organized manner using complete sentences, correct units, and significant digits where appropriate.
- Relevant scientific, technological, and/or societal concepts and examples must be identified and made explicit.

1. In an automobile collision, the severity of injury to the driver can be reduced by an airbag. In a car initially travelling at 100 km/h, the airbag stops a 62 kg driver in 90 ms. The magnitude of average force exerted by the airbag on the driver is

A. 6.9×10^4 N
B. 1.9×10^4 N
C. 9.6×10^3 N
D. 6.1×10^2 N

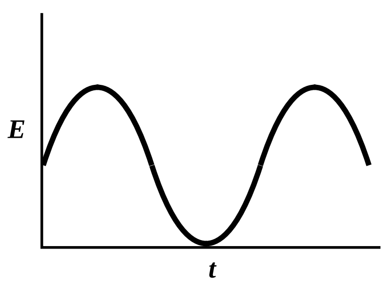
Numerical Response

1. A 2 100 kg van collides with a 1 200 kg car that is at rest. They lock together and move together at a speed of 4.50 m/s. The initial speed of the van is __________ m/s.

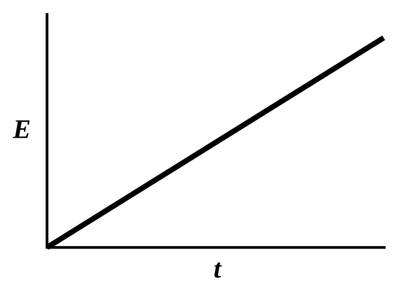
(Record your **three-digit answer** in the numerical-response section on the answer sheet.)

2. On a playground swing, a child reaches the same height with each consecutive cycle. Which of the following graphs represents the sum of the potential and the kinetic energy as a function of time?

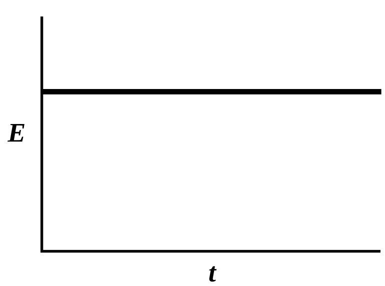
A.



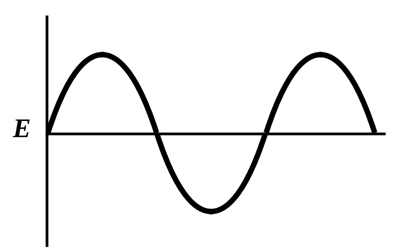
B.



C.



D.



Use the following information to answer the next two questions.

A batter hits a fly ball. The 0.130 kg baseball moves at a rate of 20.0 m/s at the point where it is 5.00 m above the ground.

3. How much mechanical energy does the baseball have with respect to the ground?

A. 32.4 J
B. 26.0 J
C. 7.68 J
D. 6.38 J

Use your recorded answer from ***Multiple Choice 3*** *to answer* ***Multiple Choice 4****.**

4. What is the magnitude of the momentum of the baseball the instant before it reaches the ground?

A. 1.29 kg•m/s
B. 1.41 kg•m/s
C. 2.60 kg•m/s
D. 2.90 kg•m/s

***You can receive marks for this question even if the previous question was answered incorrectly.**

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5. The SI units for **impulse** may be written as

A. $\frac{kg \cdot m^2}{s^2}$

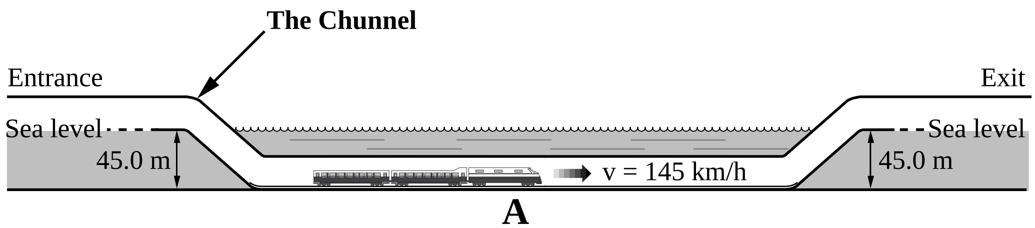
B. $\frac{kg \cdot m}{s}$

C. $\frac{kg \cdot m^2}{s}$

D. $\frac{kg \cdot m}{s^2}$

Use the following information to answer the next two questions.

The Channel Tunnel (or “Chunnel”) is an underwater train tunnel built to carry high-speed trains under the English Channel between Britain and France. The 2.40×10^6 kg train travels at a constant speed of 145 km/h (40.3 m/s) from the entrance to the exit of the Chunnel.



6. The kinetic energy of the train travelling in the Chunnel at point A is

A. 4.83×10^7 J
B. 1.95×10^9 J
C. 3.89×10^9 J
D. 2.52×10^{10} J

*Use your recorded answer from **Multiple Choice 6** to answer **Numerical Response 2**.**

Numerical Response

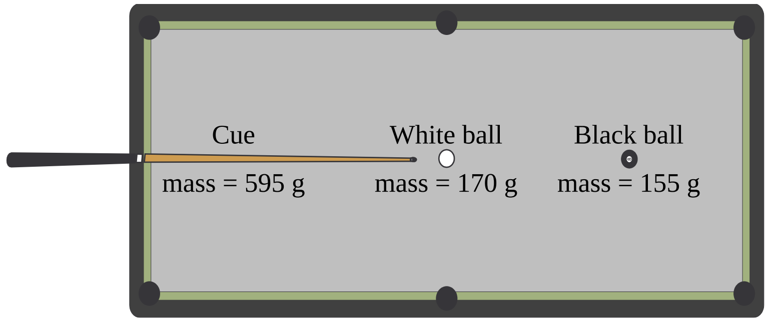
2. The potential energy of the train is zero at point A. The total mechanical energy of the train as it enters the tunnel, expressed in scientific notation, is $\boldsymbol{b} \times 10^w$ J. The value of $\boldsymbol{b}$ is __________.

(Record your **three-digit answer** in the numerical-response section on the answer sheet.)
***You can receive marks for this question even if the previous question was answered incorrectly.**

Use the following information to answer the next three questions.

Pool Table

An illustration depicting an overhead view of a pool table is shown below.



The pool table has rubber cushions around the playing surface so that when a ball hits the side it will be deflected back to the playing surface. A simplified analysis of the physics of playing pool assumes that Hooke's Law is valid:

$$F = -kx \text{ and } E_p = \tfrac{1}{2}kx^2$$

7. A pool cue with a speed of 2.30 m/s strikes a stationary white ball. The pool cue is 53.0% efficient at transferring kinetic energy from itself to the white ball. The speed of the white ball immediately after being struck is

A. 2.07 m/s

B. 3.13 m/s

C. 4.30 m/s

D. 5.91 m/s

Use your recorded answer from ***Multiple Choice 7*** *to answer* ***Numerical Response 3****.**

Numerical Response

3. Assume that the white ball then collides with the black ball, which was initially at rest. The white ball continues in its original direction. The speed of the white ball after the collision is 0.147 m/s. The speed of the black ball immediately after the collision is __________ m/s.

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

***You can receive marks for this question even if the previous question was answered incorrectly.**

Use the following additional information to answer the next question.

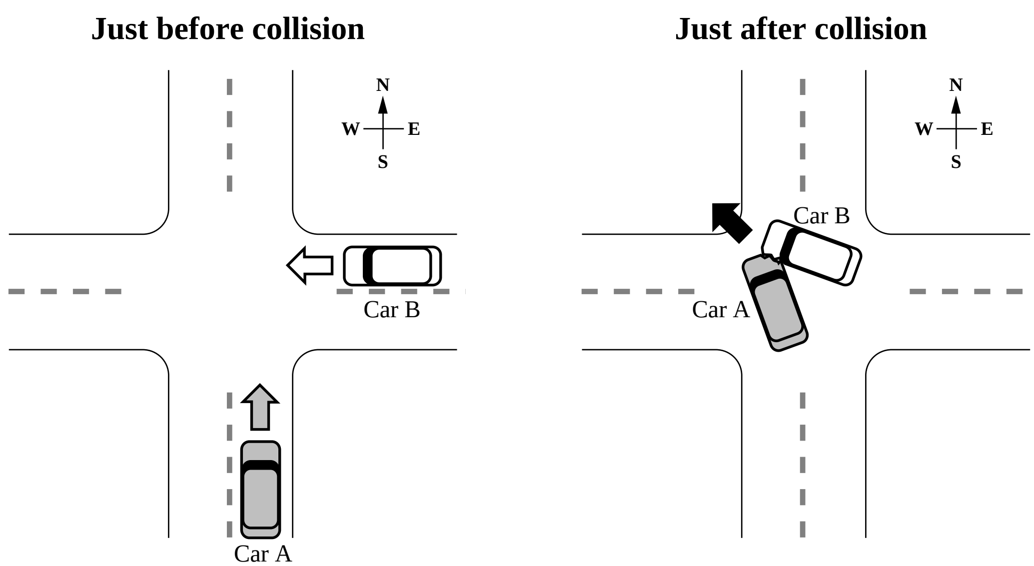
On another shot, the black ball hits the rubber cushion at a speed of 3.0 m/s. The black ball depresses the cushion 0.62 cm while coming to a momentary stop.

8. The spring constant, *k*, of the rubber cushion is

A. 1.1×10^2 N/m
B. 7.3×10^2 N/m
C. 1.8×10^4 N/m
D. 3.6×10^4 N/m

Use the following information to answer the next question.

Two cars collide at an unmarked intersection.

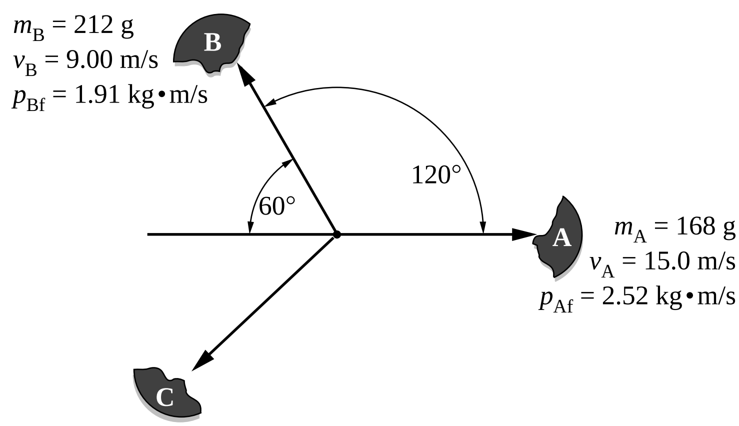


9. Which of the following statements **best** describes the inelastic collision shown above?

A. Momentum is not conserved, and kinetic energy is not conserved.
B. Momentum is conserved, but kinetic energy is not conserved.
C. Momentum is not conserved, but kinetic energy is conserved.
D. Momentum is conserved, and kinetic energy is conserved.

Use the following information to answer the next two questions.

A glass ornament of mass 575 g sitting on a table is subjected to a resonant frequency of 440 Hz. The ornament breaks into three pieces that travel horizontally across the frictionless tabletop. Fragment **A** has a mass of 168 g and fragment **B** has a mass of 212 g.



10. The magnitude of the momentum of the third piece of glass, fragment **C**, is

A. 5.19 kg•m/s
B. 3.85 kg•m/s
C. 2.28 kg•m/s
D. 0.610 kg•m/s

*Use your recorded answer from **Multiple Choice 10** to answer **Numerical Response 4**.**

Numerical Response

4. The speed of the third fragment of glass, expressed in scientific notation, is $\boldsymbol{b} \times 10^{w}$ m/s. The value of $\boldsymbol{b}$ is __________.

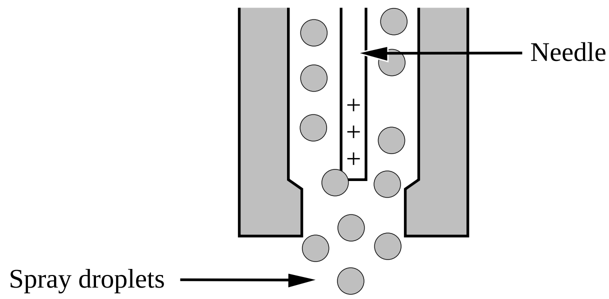
(Record your **three-digit answer** in the numerical-response section on the answer sheet.)
***You can receive marks for this question even if the previous question was answered incorrectly.**

Use the following information to answer the next two questions.

Electrostatic Spray Nozzles

Crop-dusting planes release pesticide through electrostatic spray nozzles in order to minimize pesticide waste. The centre of each nozzle contains a needle with a positive charge. The presence of the charged needle causes the droplets passing through the opening to become charged.

When the charged droplets fall onto the leaves of the crop, they are less likely to be carried away by the wind.



11. The droplets leave the nozzle with a

A. negative charge caused by the movement of protons onto the needle

B. positive charge caused by the movement of electrons onto the needle

C. positive charge caused by the movement of protons onto the droplets

D. negative charge caused by the movement of electrons onto the droplets

12. The charged droplets are kept from being blown off of the leaves by the wind because the charged droplets

A. gain electrons from the air and transfer them to the leaves

B. fall faster through the air because they have similar charges

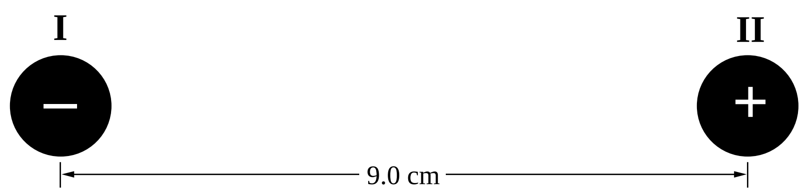
C. induce an opposite charge on the leaves so they are attracted to them

D. repel each other and spread out, thus the effect of the wind is minimized

Use the following information to answer the next two questions.

Electrostatics

Two particles, I and II, of equal mass have opposite charges. The negative charge on particle I is three times greater than is the positive charge on particle II. The particles are placed 9.0 cm apart.



13. The electric field at a point halfway between the particles is

A. zero
B. toward the left of the page
C. toward the top of the page
D. toward the right of the page

14. The electric force between the particles is *F* newtons when they are 9.0 cm apart. They are moved toward each other until they are 6.0 cm apart. The force between them becomes

A. $\frac{2F}{3}$
B. $\frac{3F}{2}$
C. $\frac{4F}{9}$
D. $\frac{9F}{4}$

Use the following information to answer the next two questions.

A set of Christmas tree lights consists of 20 identical bulbs that are connected in series to a 120 V power supply.

Numerical Response

5. The voltage across each bulb is __________ V.

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

*Use your recorded answer from **Numerical Response 5** to answer **Numerical Response 6**.**

Numerical Response

6. If the total current in the circuit is 0.500 A, the power used by one bulb is __________ W.

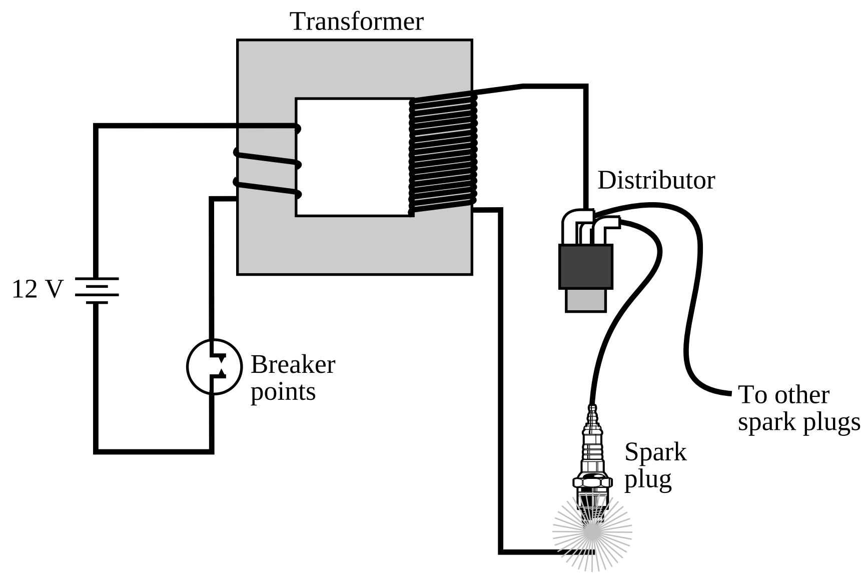
(Record your **three-digit answer** in the numerical-response section on the answer sheet.)

***You can receive marks for this question even if the previous question was answered incorrectly.**

Use the following information to answer the next three questions.

Automotive Wiring

In an automobile, a transformer is used to produce the high voltage that causes sparks in the spark plugs. A simplified automobile electrical system is shown below.



The 12 V direct current battery is connected to a switch called "breaker points" that turns the current in the primary coil on and off. The required voltage of 20 000 V is induced in the secondary coil. The secondary coil is connected to the distributor, which distributes the electrical voltage to each of the spark plugs. This voltage is high enough to cause a spark to jump across the 2.0 mm gap of a spark plug. This spark ignites the gasoline–air mixture in the automobile's cylinder.

15. If this device acts like an ideal AC transformer, then the ratio of the number of turns in the primary coil to the number of turns in the secondary coil is

A. $1.7 \times 10^{-4} : 1$
B. $6.0 \times 10^{-4} : 1$
C. $1.7 \times 10^{3} : 1$
D. $6.0 \times 10^{3} : 1$

16. The strength of the electrical field induced in the gap of the spark plug is

A. 6.0 N/C
B. 6.0×10^{3} N/C
C. 1.0×10^{4} N/C
D. 1.0×10^{7} N/C

Use your recorded answer from ***Multiple Choice 16*** *to answer* ***Numerical Response 7****.**

Numerical Response

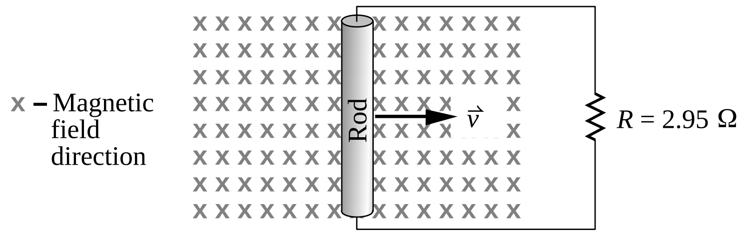
7. The acceleration of the electrons across the gap of the spark plug, expressed in scientific notation, is $\boldsymbol{a.b} \times 10^{\boldsymbol{cd}}$ m/s^2. The values of ***a***, ***b***, ***c***, and ***d*** are ____, ____, ____, and ____ .

(Record your **four-digit answer** in the numerical-response section on the answer sheet.)
***You can receive marks for this question even if the previous question was answered incorrectly.**

Use the following information to answer the next question.

Current Induction

A 27.0 cm conducting rod is moved through a perpendicular external magnetic field of magnitude 0.845 T at a constant speed of 1.35 m/s. The rod is attached to a circuit with a resistance of 2.95 Ω.



17. The current induced by the rod's movement is

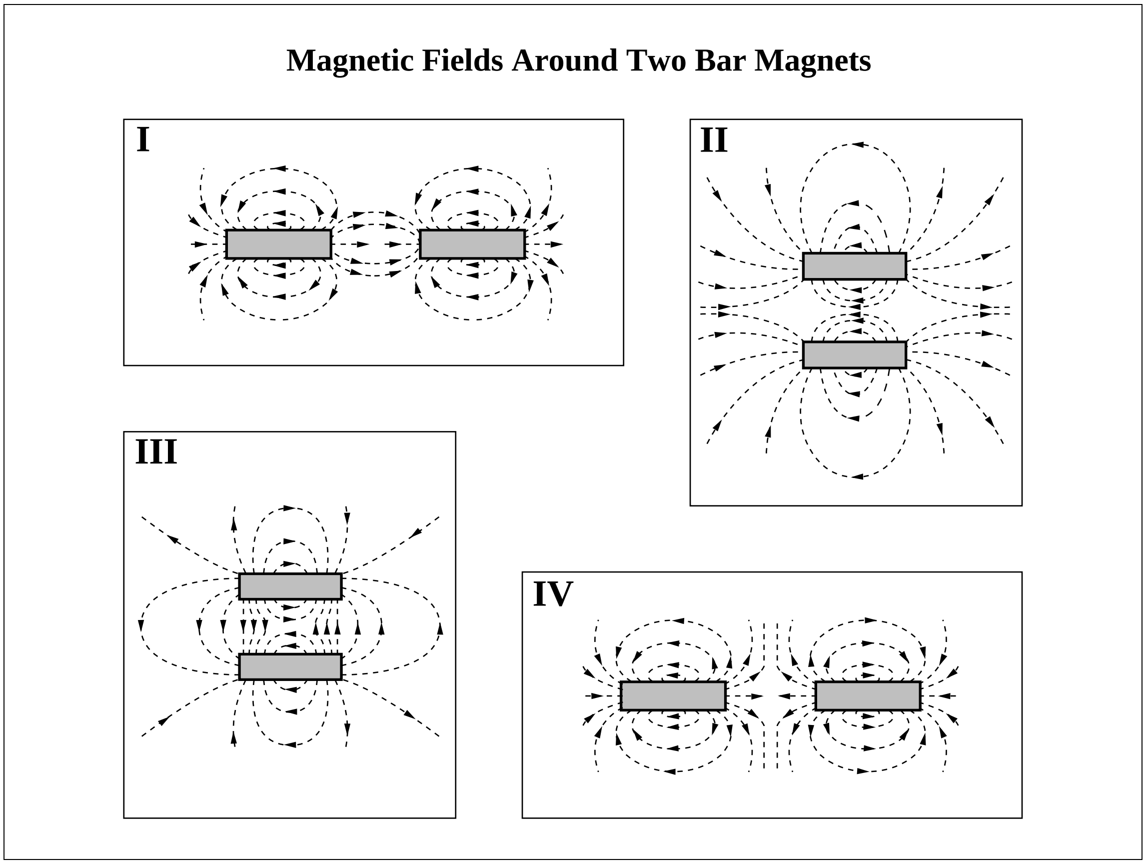
A. 0.104 A

B. 0.308 A

C. 10.4 A

D. 30.8 A

Use the following information to answer the next question.

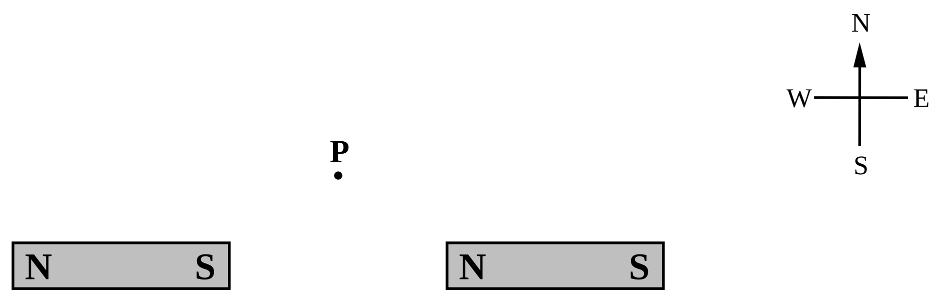


18. Given the magnetic fields illustrated above, the magnets will repel in diagrams

- **A.** I and II only
- **B.** II and III only
- **C.** I and IV only
- **D.** II and IV only

Use the following information to answer the next question.

Two identical magnets and a point P are located as shown below. The point P is equidistant between the two magnets.



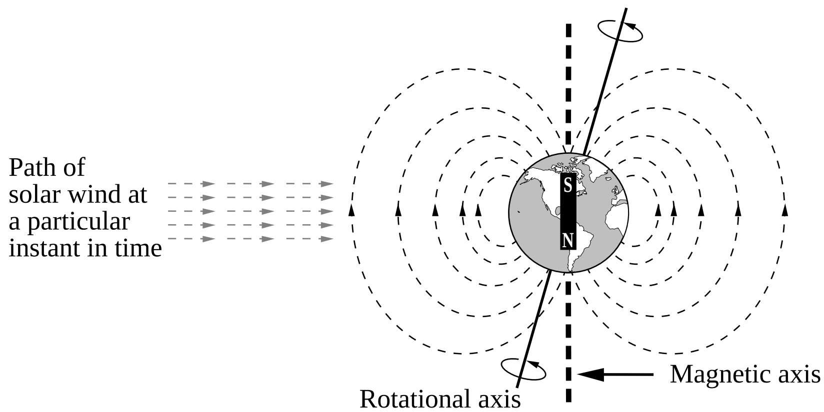
19. The two bar magnets cause the net magnetic field at P to be in the direction

A. east
B. west
C. north
D. south

Use the following information to answer the next two questions.

Earth's Magnetic Field

The solar wind consists of particles emitted by the Sun. Some of these particles are charged; therefore, when they enter Earth's magnetic field, they experience a magnetic force. A stream of charged particles travelling with a speed of 8.00×10^5 m/s encounters Earth's magnetic field, as shown below, at an altitude where the field has a magnitude of 1.10×10^{-7} T.



20. The protons in the solar wind experience a magnetic force

A. into the plane of the page
B. out of the plane of the page
C. in the direction the solar wind is travelling
D. opposite to the direction the solar wind is travelling

Numerical Response

8. Assume that the velocity of the solar wind particles is perpendicular to the magnetic field. The radius of the circular path that protons in a solar wind follow, expressed in scientific notation, is $\boldsymbol{a.bc} \times 10^{\boldsymbol{d}}$ m. The values of ***a, b, c,*** and ***d*** are ____, ____, ____, and ____ .

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

21. The *Advanced Composition Explorer* (ACE) telescope began operation in August 1997. It detects electromagnetic radiation in the range of 1.0×10^{2} eV to 5.0×10^{2} MeV. The wavelength range measured by this telescope is

A. 2.0×10^{-27} m to 4.0×10^{-34} m

B. 8.0×10^{-11} m to 1.6×10^{-17} m

C. 1.2×10^{-8} m to 2.5×10^{-15} m

D. 1.2×10^{23} m to 2.4×10^{16} m

22. Gamma radiation can be produced by

A. radioactive decay

B. incandescent solids

C. moving charges in a conductor

D. the acceleration of electrons in a television picture tube

Numerical Response

9. An electromagnetic wave is sent from Earth to the Moon and reflected back to Earth. If the total time taken is 2.48 s, then the distance from Earth to the Moon, expressed in scientific notation, is $\boldsymbol{b} \times 10^{w}$ m. The value of $\boldsymbol{b}$ is __________.

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

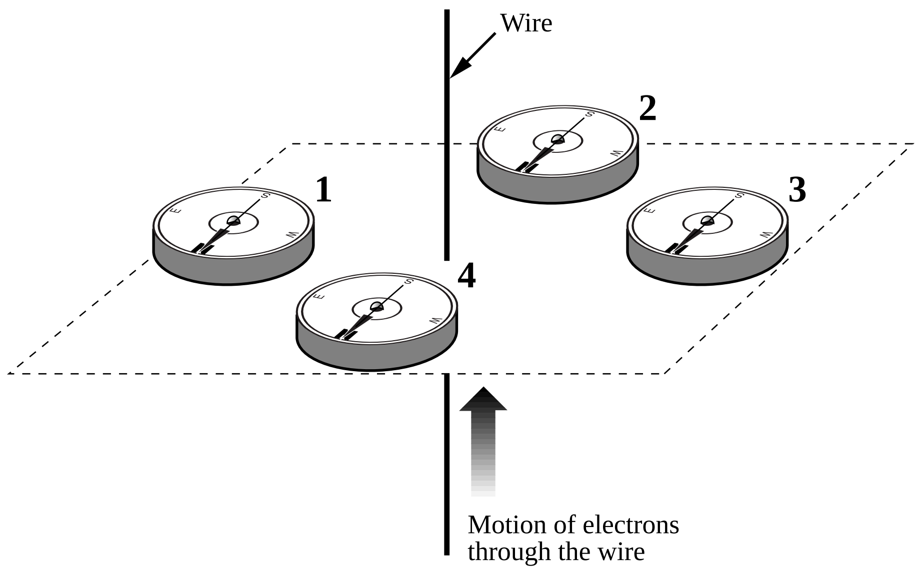
Numerical Response

10. During the Second World War, to help aircraft avoid radar detection, metal-foil strips cut to one-half of the radar's wavelength were dropped from the aircraft. These strips reduced the effectiveness of the radar. The 30.2 cm metal-foil strips were designed for a radar frequency, expressed in scientific notation, of $\boldsymbol{b} \times 10^{w}$ Hz. The value of $\boldsymbol{b}$ is __________.

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

Use the following information to answer the next question.

Magnetic Field Surrounding a Current in a Wire



23. The compass that correctly indicates the direction of the magnetic field produced by a wire conducting electrons is numbered

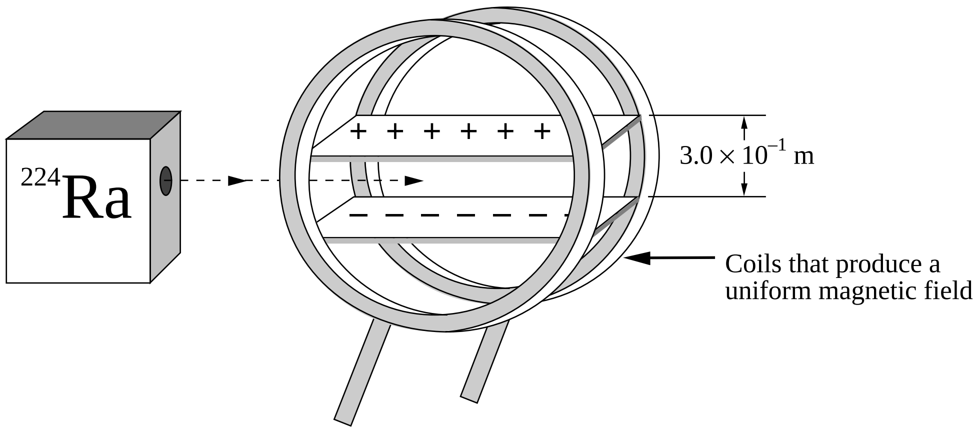
A. 1
B. 2
C. 3
D. 4

24. Which of the following types of radiation has the longest period?

A. Radio waves
B. Infrared light
C. Ultraviolet light
D. Gamma radiation

Use the following information to answer the next three questions.

A scientist places a 10 g sample of ^{224}Ra, which has a half-life of 3.66 d, into a shielded box that allows a stream of high energy particles to escape. The scientist then applies a potential difference of 5.3×10^{5} V across horizontal plates that are 3.0×10^{-1} m apart and a perpendicular magnetic field of 0.70 T. She observes that the particle beam passes through the apparatus undeflected. When the electric field is eliminated, the magnetic field causes the particles to orbit in a circle with a radius of 7.5×10^{-2} m. Note: The entire apparatus is in a vacuum.



25. The mass of ^{224}Ra remaining after 22 days is

A. 0.16 g
B. 0.31 g
C. 2.7 g
D. 3.7 g

Numerical Response

11. The particles in the undeflected beam are moving at a speed of $\boldsymbol{a.b} \times 10^{\boldsymbol{c}}$ m/s. The values of ***a, b,*** and ***c,*** are, respectively, ____, ____, and ____ .

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

26. Using the charge-to-mass ratio of the particles, the scientist determines the particles to be

A. protons

B. neutrons

C. electrons

D. alpha particles

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27. A light source with a wavelength of 548 nm shines on a photocell with a 1.60 eV work function. In order to have an output voltage of 12.0 V DC, the number of photocells that must be linked in series is

A. 5 photocells

B. 8 photocells

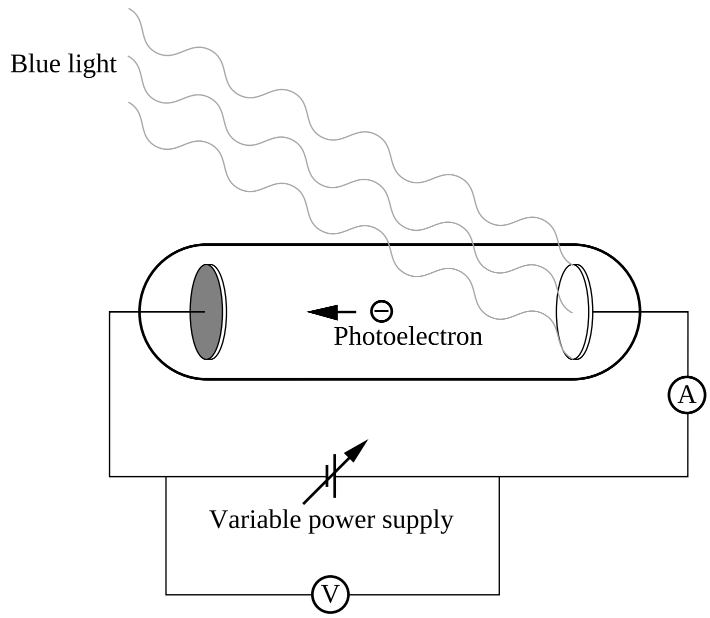
C. 10 photocells

D. 18 photocells

Use the following information to answer the next question.

Photoelectric Effect

Photoelectrons are emitted when blue light of frequency 6.40×10^{14} Hz shines on a metal surface, as shown below. The stopping voltage is measured to be 1.25 V.



28. What is the maximum kinetic energy of the emitted photoelectrons?

A. 4.91×10^{-19} J

B. 2.91×10^{-19} J

C. 2.00×10^{-19} J

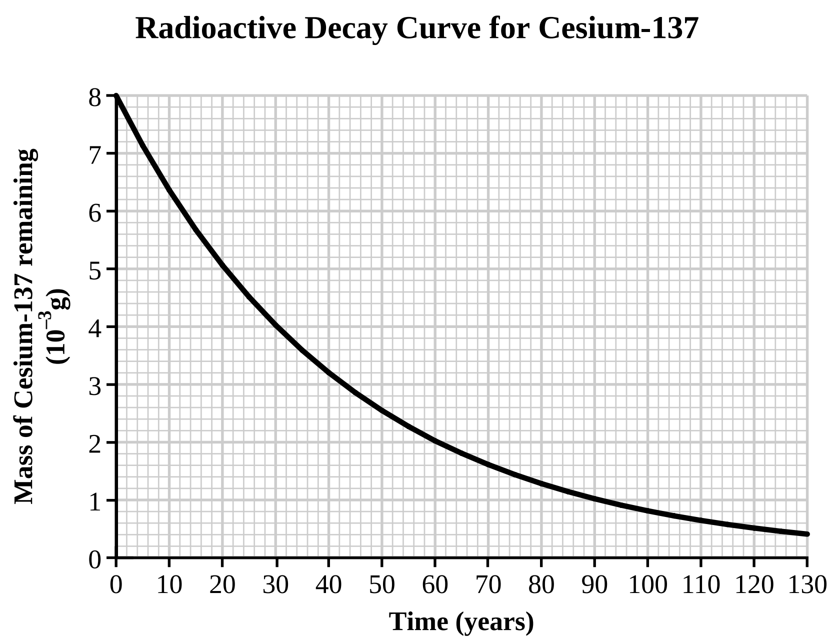
D. 1.28×10^{-19} J

Numerical Response

12. An X-ray tube operates with a potential difference of 4.5×10^4 V. The minimum wavelength of X-rays being produced, expressed in scientific notation, is $\boldsymbol{a.b} \times 10^{-\boldsymbol{cd}}$ m. The values of ***a, b, c,*** and ***d*** are ____, ____, ____, and ____ .

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

Use the following information to answer the next question.



29. Based on the graph above, the approximate half-life of ${}^{137}_{55}\mathrm{Cs}$ is

A. 130 years
B. 60 years
C. 30 years
D. 2 years

Use the following information to answer the next four questions.

Photon–Matter Interactions

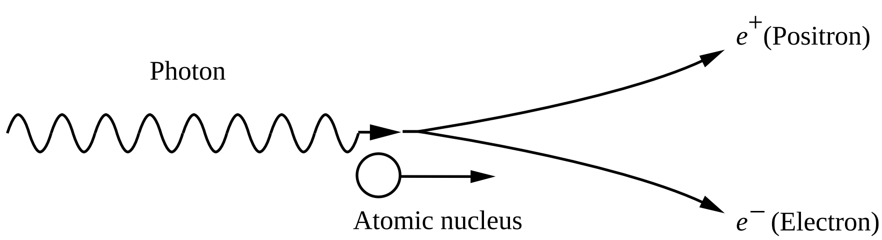
When a photon passes through matter, it interacts with the atoms and their electrons. There are four important interactions with matter that a photon can undergo.

I. The photon may be scattered by an electron and in the process lose some energy, transferring momentum and energy to the electron.

II. The photon may move an electron out of an atom, and in the process, the photon disappears (the photoelectric effect).

III. The photon may move an electron to a higher energy state in the atom, and in the process, the photon disappears.

IV. A photon may actually create matter. The most common process, called pair production, is the production of an electron and a positron. A positron has the same mass as an electron, but it has the opposite charge. In addition, a massive particle, such as an atomic nucleus, must gain some of the photon's initial momentum. (See the diagram below.)



30. The name given to interaction I is

A. Lenz's Law

B. X-ray production

C. the Compton effect

D. the de Broglie hypothesis

31. The curved paths of the particles in the pair production diagram result from the electron and positron moving through an external magnetic field. In this diagram, the direction of the magnetic field causing these paths to curve is

A. into the page

B. out of the page

C. to the left

D. to the right

32. The reason that pair production occurs, rather than the production of a single electron, is that the production of a single electron would violate the Law of Conservation of

A. Mass

B. Charge

C. Energy

D. Momentum

33. During pair production, the speed of the electron or of the positron can be calculated by measuring the radius of the circular path it travels within the magnetic field. The speed of a charged particle moving in a circular path in a uniform magnetic field is given by

A. $v = \dfrac{B_{\perp}qr}{m}$

B. $v = B_{\perp}qrm$

C. $v = \dfrac{m}{B_{\perp}qr}$

D. $v = \dfrac{rB_{\perp}}{qm}$

Use the following information to answer the next question.

A Transmutation Reaction

$^{12}_{7}N$ + alpha particle $\rightarrow$ unstable nucleus $\rightarrow$ proton + $^{A}_{Z}X$

34. In the transmutation reaction above, an alpha particle is absorbed by a nitrogen nucleus. An unstable nucleus that decays by producing a proton and an unidentified nucleus $^{A}_{Z}X$ is produced. The values of A and Z are, respectively,

A. 16 and 9
B. 15 and 8
C. 11 and 6
D. 8 and 15

Use the following information to answer the next question.

A student obtains samples of pure quantities of two radioactive isotopes: X and Y. The samples contain equal numbers of atoms. The half-life of each isotope is given below.

Half-life of radioactive isotope X: 120 days
Half-life of radioactive isotope Y: 15.2 days

Both isotopes undergo beta decay.

35. Which of the following situations would result in a person experiencing the **most** exposure to radioactivity?

A. Being exposed to isotope X at a distance of two metres for two hours
B. Being exposed to isotope X at a distance of one metre for two hours
C. Being exposed to isotope Y at a distance of two metres for two hours
D. Being exposed to isotope Y at a distance of one metre for two hours

Use the following information to answer the next question.

Selected Energy Levels of a Mercury Atom

Level	Energies (eV)
∞	0
.	.
.	.
.	.
Z	–1.6
Y	–3.7
X	–5.5
W	–10.4

36. What frequency of electromagnetic radiation is required to excite mercury atoms from energy level W to energy level Z?

A. 2.1×10^{15} Hz

B. 2.5×10^{15} Hz

C. 2.9×10^{15} Hz

D. 3.1×10^{15} Hz

---

37. The energy of an excited hydrogen atom when its electron is in the seventh Bohr energy level is

A. –667 eV

B. –95.2 eV

C. –1.94 eV

D. –0.278 eV

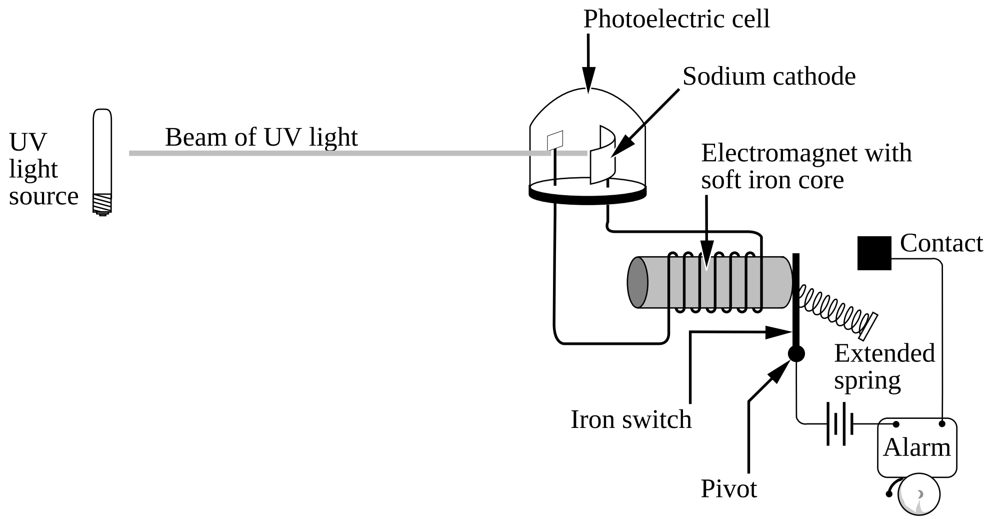
Written-response question 1 begins on the next page.

Use the following information to answer the next question.

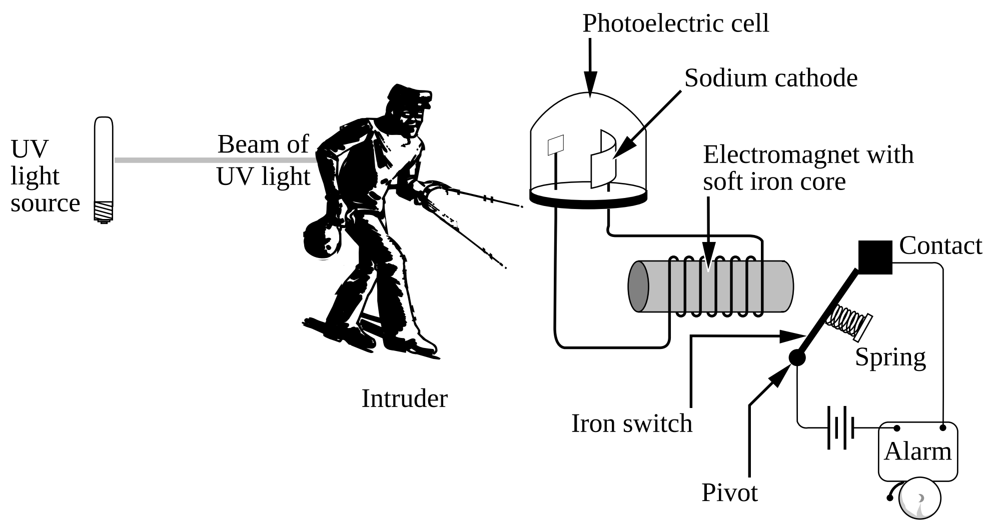
Burglar Alarm

Shown below is a simplified circuit of a burglar alarm.

Burglar alarm not activated



Burglar alarm activated



A beam of ultraviolet light is directed toward a photoelectric cell, as shown above. As long as this beam is not interrupted, light will be incident on the sodium cathode, and there will be a current in the electromagnet. The electromagnet is of sufficient strength to hold the iron switch. As a result, the alarm will not be activated.

An intruder walking between the UV light source and the phototube will cause the alarm to sound.

Written Response — 15%

1. Using the concepts of the photoelectric effect, electromagnetism, and electrical circuits, analyze the operation of this burglar alarm

- when the beam of UV light is incident on the sodium cathode
- while the intruder interrupts the beam of UV light

Note: Marks will be awarded for the physics principles used in your response and for the effective communication of your response.

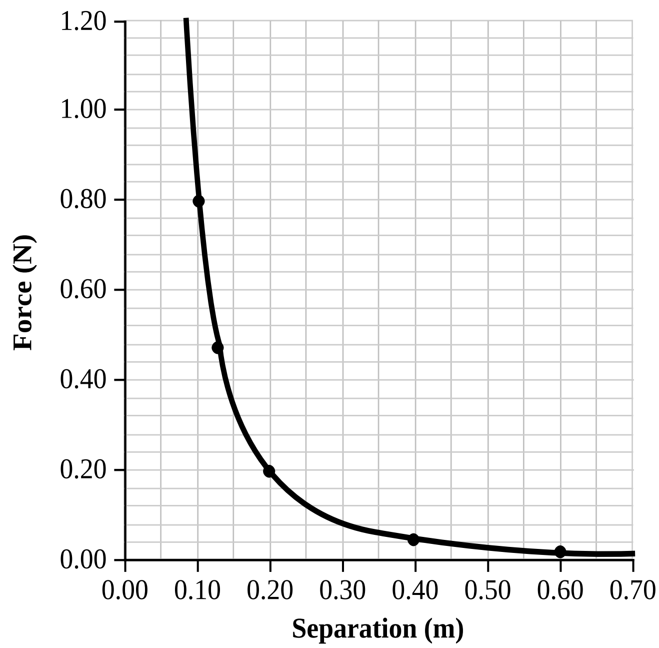
Written-response question 2 begins on the next page.

Use the following information to answer the next question.

A student performed an experiment that verified Coulomb's Law of Electrostatics by measuring the repulsion between two charged spheres, A and B, as a function of the separation of the spheres. The spheres were identical in size and mass. The measurements are shown in the table of values and plotted on the graph below.

Separation (m)	**Force (N)**
0.10	0.790
0.13	0.480
0.20	0.200
0.40	0.050
0.60	0.022

Force of Repulsion as a Function of the Separation



Written Response — 15%

2.
- Show that the results verify Coulomb's Law by manipulating the data and providing a new table of values that, when plotted, will produce a straight-line graph.

- Plot the new data with the responding variable on the vertical axis.

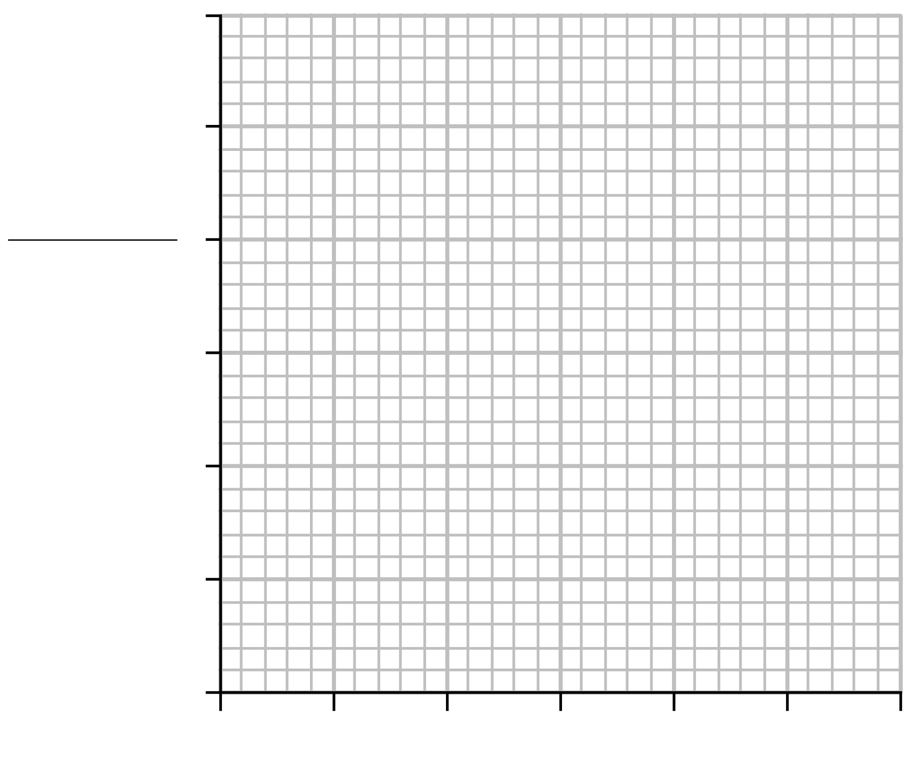
- Calculate the slope of your graph.

- Using the slope value, or another suitable averaging techniques, determine the charge on sphere B if the charge on sphere A is 3.08×10^{-7} C.

- Determine the magnitude of the force between spheres A and B when they are at a distance of 2.00 m apart. Use the hypothetical value of 3.00×10^{-6} C for the charge on sphere B if you were unable to determine the actual value.

Clearly communicate your understanding of the physics principles that you are using to solve this question. You may communicate this understanding mathematically, graphically, and/or with written statements.

______________________________(Title)



You may continue your explanation on page 32.

You have now completed the examination.
If you have time, you may wish to check your answers.

Fold and tear along perforation.

PHYSICS DATA SHEETS

CONSTANTS

Gravity, Electricity, and Magnetism

Acceleration Due to Gravity **or** Gravitational Field Near Earth	a_g or $g = 9.81\ \text{m/s}^2$ or $9.81\ \text{N/kg}$
Gravitational Constant	$G = 6.67 \times 10^{-11}\ \text{N•m}^2/\text{kg}^2$
Mass of Earth	$M_e = 5.98 \times 10^{24}\ \text{kg}$
Radius of Earth	$R_e = 6.37 \times 10^{6}\ \text{m}$
Coulomb's Law Constant	$k = 8.99 \times 10^{9}\ \text{N•m}^2/\text{C}^2$
Electron Volt	$1\ \text{eV} = 1.60 \times 10^{-19}\ \text{J}$
Elementary Charge	$e = 1.60 \times 10^{-19}\ \text{C}$
Index of Refraction of Air	$n = 1.00$
Speed of Light in Vacuum	$c = 3.00 \times 10^{8}\ \text{m/s}$

Trigonometry and Vectors

$$\sin\theta = \frac{\textit{opposite}}{\textit{hypotenuse}}$$

$$\cos\theta = \frac{\textit{adjacent}}{\textit{hypotenuse}}$$

$$\tan\theta = \frac{\textit{opposite}}{\textit{adjacent}}$$

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

$$c^2 = a^2 + b^2 - 2ab\cos C$$

For any Vector $\vec{R}$

$$R = \sqrt{R_x^{\,2} + R_y^{\,2}}$$

$$\tan\theta = \frac{R_y}{R_x}$$

$$R_x = R\cos\theta$$

$$R_y = R\sin\theta$$

Atomic Physics

Energy of an Electron in the 1st Bohr Orbit of Hydrogen	$E_1 = -2.18 \times 10^{-18}\ \text{J}$ or $-13.6\ \text{eV}$
Planck's Constant	$h = 6.63 \times 10^{-34}\ \text{J•s}$ or $4.14 \times 10^{-15}\ \text{eV•s}$
Radius of 1st Bohr Orbit of Hydrogen	$r_1 = 5.29 \times 10^{-11}\ \text{m}$
Rydberg's Constant for Hydrogen	$R_H = 1.10 \times 10^{7}/\text{m}$

Prefixes Used With SI Units

Prefix	Symbol	Exponential Value	Prefix	Symbol	Exponential Value
pico	p	10^{-12}	tera	T	10^{12}
nano	n	10^{-9}	giga	G	10^{9}
micro	µ	10^{-6}	mega	M	10^{6}
milli	m	10^{-3}	kilo	k	10^{3}
centi	c	10^{-2}	hecto	h	10^{2}
deci	d	10^{-1}	deka	da	10^{1}

Particles

	Rest Mass	Charge
Alpha Particle	$m_\alpha = 6.65 \times 10^{-27}\ \text{kg}$	α^{2+}
Electron	$m_e = 9.11 \times 10^{-31}\ \text{kg}$	e^-
Neutron	$m_n = 1.67 \times 10^{-27}\ \text{kg}$	n^0
Proton	$m_p = 1.67 \times 10^{-27}\ \text{kg}$	p^+

Tear-out Page

EQUATIONS

Kinematics

$\vec{v}_{ave} = \frac{\vec{d}}{t}$

$\vec{d} = \vec{v}_f t - \frac{1}{2}\vec{a}t^2$

$\vec{a} = \frac{\vec{v}_f - \vec{v}_i}{t}$

$\vec{d} = \left(\frac{\vec{v}_f + \vec{v}_i}{2}\right)t$

$\vec{d} = \vec{v}_i t + \frac{1}{2}\vec{a}t^2$

$v_f^2 = v_i^2 + 2ad$

$v = \frac{2\pi r}{T}$

$a = \frac{v^2}{r}$

Dynamics

$\vec{F} = m\vec{a}$

$F_g = \frac{Gm_1m_2}{r^2}$

$\vec{F}\Delta t = m\Delta\vec{v}$

$g = \frac{Gm_1}{r^2}$

$\vec{F}_g = m\vec{g}$

$F_f = \mu F_N$

$F_c = \frac{mv^2}{r}$

$\vec{F}_s = -k\vec{x}$

$F_c = \frac{4\pi^2 mr}{T^2}$

Momentum and Energy

$\vec{p} = m\vec{v}$

$E_k = \frac{1}{2}mv^2$

$W = Fd$

$E_p = mgh$

$W = \Delta E = Fd\cos\theta$

$E_p = \frac{1}{2}kx^2$

$P = \frac{W}{t} = \frac{\Delta E}{t}$

Waves and Light

$T = 2\pi\sqrt{\frac{m}{k}}$

$\frac{\sin\theta_1}{\sin\theta_2} = \frac{v_1}{v_2} = \frac{\lambda_1}{\lambda_2} = \frac{n_2}{n_1}$

$T = 2\pi\sqrt{\frac{l}{g}}$

$\lambda = \frac{xd}{nl}$

$T = \frac{1}{f}$

$\lambda = \frac{d\sin\theta}{n}$

$v = f\lambda$

$m = \frac{h_i}{h_0} = \frac{-d_i}{d_0}$

$\frac{\lambda_1}{2} = l;\quad \frac{\lambda_1}{4} = l$

$\frac{1}{f} = \frac{1}{d_0} + \frac{1}{d_i}$

Atomic Physics

$hf = E_{k_{max}} + W$

$\frac{1}{\lambda} = R_H\left(\frac{1}{n_f^2} - \frac{1}{n_i^2}\right)$

$W = hf_0$

$E_{k_{max}} = qV_{stop}$

$E_n = \frac{1}{n^2}E_1$

$r_n = n^2 r_1$

$E = hf = \frac{hc}{\lambda}$

$N = N_0\left(\frac{1}{2}\right)^n$

Quantum Mechanics and Nuclear Physics

$E = mc^2$

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

$p = \frac{hf}{c};\quad E = pc$

Electricity and Magnetism

$F_e = \frac{kq_1q_2}{r^2}$

$V = IR$

$|\vec{E}| = \frac{kq_1}{r^2}$

$P = IV$

$\vec{E} = \frac{\vec{F}_e}{q}$

$I = \frac{q}{t}$

$|\vec{E}| = \frac{V}{d}$

$F_m = IlB_\perp$

$V = \frac{\Delta E}{q}$

$F_m = qvB_\perp$

$V = lvB_\perp$

$R = R_1 + R_2 + R_3$

$\frac{N_p}{N_s} = \frac{V_p}{V_s} = \frac{I_s}{I_p}$

$\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$

$I_{eff} = 0.707\ I_{max}$

$V_{eff} = 0.707\ V_{max}$

Fold and tear along perforation.

Periodic Table of the Elements

1 IA	2 IIA	3 IIIB	4 IVB	5 VB	6 VIB	7 VIIB	8	9 VIIIB	10 VIIIB	11 IB	12 IIB	13 IIIA	14 IVA	15 VA	16 VIA	17 VIIA	18 VIIIA or O
1 H 1.01 hydrogen																	2 He 4.00 helium
3 Li 6.94 lithium	4 Be 9.01 beryllium											5 B 10.81 boron	6 C 12.01 carbon	7 N 14.01 nitrogen	8 O 16.00 oxygen	9 F 19.00 fluorine	10 Ne 20.17 neon
11 Na 22.99 sodium	12 Mg 24.31 magnesium											13 Al 26.98 aluminum	14 Si 28.09 silicon	15 P 30.97 phosphorus	16 S 32.06 sulphur	17 Cl 35.45 chlorine	18 Ar 39.95 argon
19 K 39.10 potassium	20 Ca 40.08 calcium	21 Sc 44.96 scandium	22 Ti 47.90 titanium	23 V 50.94 vanadium	24 Cr 52.00 chromium	25 Mn 54.94 manganese	26 Fe 55.85 iron	27 Co 58.93 cobalt	28 Ni 58.71 nickel	29 Cu 63.55 copper	30 Zn 65.38 zinc	31 Ga 69.72 gallium	32 Ge 72.59 germanium	33 As 74.92 arsenic	34 Se 78.96 selenium	35 Br 79.90 bromine	36 Kr 83.80 krypton
37 Rb 85.47 rubidium	38 Sr 87.62 strontium	39 Y 88.91 yttrium	40 Zr 91.22 zirconium	41 Nb 92.91 niobium	42 Mo 95.94 molybdenum	43 Tc (98.91) technetium	44 Ru 101.07 ruthenium	45 Rh 102.91 rhodium	46 Pd 106.40 palladium	47 Ag 107.87 silver	48 Cd 112.41 cadmium	49 In 114.82 indium	50 Sn 118.69 tin	51 Sb 121.75 antimony	52 Te 127.60 tellurium	53 I 126.90 iodine	54 Xe 131.30 xenon
55 Cs 132.91 cesium	56 Ba 137.33 barium	57-71	72 Hf 178.49 hafnium	73 Ta 180.95 tantalum	74 W 183.85 tungsten	75 Re 186.21 rhenium	76 Os 190.20 osmium	77 Ir 192.22 iridium	78 Pt 195.09 platinum	79 Au 196.97 gold	80 Hg 200.59 mercury	81 Tl 204.37 thallium	82 Pb 207.19 lead	83 Bi 208.98 bismuth	84 Po (208.98) polonium	85 At (209.98) astatine	86 Rn (222.02) radon
87 Fr (223.02) francium	88 Ra (226.03) radium	89-103	104 Unq (266.11) unnilquadium	105 Unp (262.11) unnilpentium	106 Unh (263.12) unnilhexium	107 Uns (262.12) unnilseptium	108 Uno (265) unniloctium	109 Une (266) unnilennium									

57 La 138.91 lanthanum	58 Ce 140.12 cerium	59 Pr 140.91 praseodymium	60 Nd 144.24 neodymium	61 Pm (144.91) promethium	62 Sm 150.35 samarium	63 Eu 151.96 europium	64 Gd 157.25 gadolinium	65 Tb 158.93 terbium	66 Dy 162.50 dysprosium	67 Ho 164.93 holmium	68 Er 167.26 erbium	69 Tm 168.93 thulium	70 Yb 173.04 ytterbium	71 Lu 174.97 lutetium
89 Ac (277.03) actinium	90 Th (232.04) thorium	91 Pa (231.04) protactinium	92 U 238.03 uranium	93 Np (237.05) neptunium	94 Pu (244.06) plutonium	95 Am (243.06) americium	96 Cm (247.07) curium	97 Bk (247.07) berkelium	98 Cf (242.06) californium	99 Es (252.08) einsteinium	100 Fm (257.10) fermium	101 Md (258.10) mendelevium	102 No (259.10) nobelium	103 Lr (260.11) lawrencium

Key

Atomic number → 3 Li ← Symbol

Atomic molar mass → 6.94

Name → lithium

Based on $^{12}_{6}C$

( ) Indicates mass of the most stable isotope

Tear-out Page

PHYSICS 30

DIPLOMA EXAMINATION

JANUARY 1999

Multiple Choice
and
Numerical Response
Key

Written Response
Scoring Guide

Physics 30 – January 1999

MULTIPLE-CHOICE KEY

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

NUMERICAL-RESPONSE KEY

1.	7.07
2.	3.01*
3.	3.27*
4.	1.17*
5.	6.00
6.	3.00*
7.	1818*
8.	7594
9.	3.72
10.	4.97
11.	256
12.	2811

* A linked item. You can receive marks for this question even if the previous question was answered incorrectly.

Holistic Scoring Guide

Reporting Category: Physics COMMUNICATION

When marking **COMMUNICATION**, the marker should consider how effectively the response **describes in detail the method, procedure, or strategy used to provide a solution to the problem.**	
Score	**Criteria**
3	In the response, the student • provides a complete, well organized, and clear solution to the problem • provides, in detail, a strategy in a logical manner • demonstrates consistency of thought • uses physics vocabulary appropriately and precisely • provides an explicit relationship between the explanation and diagrams (if used) • states formula(s) explicitly • may have a mathematical error that does not hinder the understanding of either the strategy or the solution
2	In the response, the student • provides an organized response, however, errors sometimes affect the clarity • provides a strategy, but details are general and/or sometimes lacking • demonstrates consistency of thought most of the time, however, some gaps in logic leave the response somewhat open to interpretation • uses physics vocabulary, however, it may not be precise • provides an implicit relationship between explanation and diagrams (if used) • uses formula(s) that are likely inferred by analyzing the calculations • likely has mathematical errors that may hinder the understanding of either the strategy or the solution
1	In the response, the student • lacks organization, and errors affect the clarity • attempts to provides a strategy with little or no detail • demonstrates a lack of consistency of thought, and the response is difficult to interpret • uses physics vocabulary, however, it is often misused • provides a weak relationship between the explanation and diagrams (if used) • may not state formula(s), however, it is possible that the formula(s) can be deciphered by analyzing the calculations • has mathematical errors that hinder the understanding of the strategy and/or the solution
0	In the response, the student • writes very little and/or presents very little relevant information • provides a response that is not organized, and is confusing and/or frustrating to the reader • does not provide a strategy to solve the problem • uses little or no physics vocabulary, however, if present, it is misused • provides no relationship between the explanation, if present, and diagrams (if used) • may state a formula but it does not contribute toward the solution
NR	No response given.

Holistic Scoring Guide

Reporting Category: Physics CONTENT

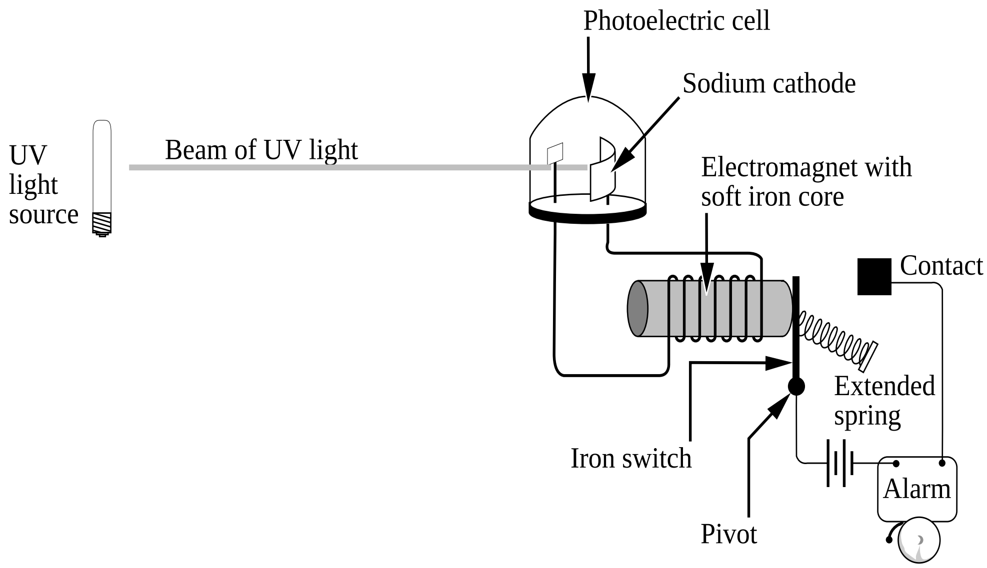
When marking **CONTENT**, the marker should consider how effectively the response **uses physics concepts, knowledge, and skills to provide a solution to the problem**.	
Score	**Criteria**
4	In the response, the student • uses an appropriate method that reflects a **thorough understanding** of the photoelectric effect, electromagnets, and circuits • provides a complete description of the method used **and** shows how to solve the problem • correctly uses formula(s) and although minor errors in substitution and/or calculation may be present they do not hinder the understanding of the physics content • has drawn diagrams and/or sketches, if applicable, that are appropriate, correct, and complete • has no major omissions or inconsistencies
3	In the response, the student • uses an appropriate method that reflects a **good understanding** of the main concepts and/or laws, and indicates where they apply to the solution • provides a description of the method used **and/or** shows how to solve the problem • correctly uses formula(s) however, errors in substitution and/or calculation may hinder the understanding of the physics content • has drawn diagrams and/or sketches, if applicable, that are appropriate, although some aspect may be incorrect or incomplete • may have several minor inconsistencies or perhaps one major inconsistency, however, there is little doubt that the understanding of physics content is good
2	In the response, the student • uses a method that reflects a **basic understanding** of the major concepts and/or laws but experiences some difficulty indicating where they apply to the solution • provides either a description of the method used **or** shows how to solve the problem • uses formula(s), however, errors and inconsistencies in substitution and/or calculation hinder the understanding of the physics content presented • has drawn diagrams and/or sketches, if applicable, that may be appropriate, although some aspect is incorrect or incomplete • has inconsistencies or a major omission
1	In the response, the student • uses a method that reflects a **poor understanding** of the major concepts and/or laws, and experiences difficulty indicating where they apply to the solution • provides a description of the method used, or a solution, that is incomplete • may use formula(s) however, the application is incorrect or inappropriate • has drawn diagrams and/or sketches, if applicable, that are inappropriate, incorrect, and/or incomplete • has minor and major inconsistencies and/or omissions
0	In the response, the student • uses a method that reflects little or no understanding of the major concepts and/or laws • does not provide a description of the method used • may use formula(s) and substitution, but they do not address the question • has drawn diagrams and/or sketches, if applicable, that are incorrect, inappropriate, and incomplete • has major omissions
NR	No response is given.

Use the following information to answer the next question.

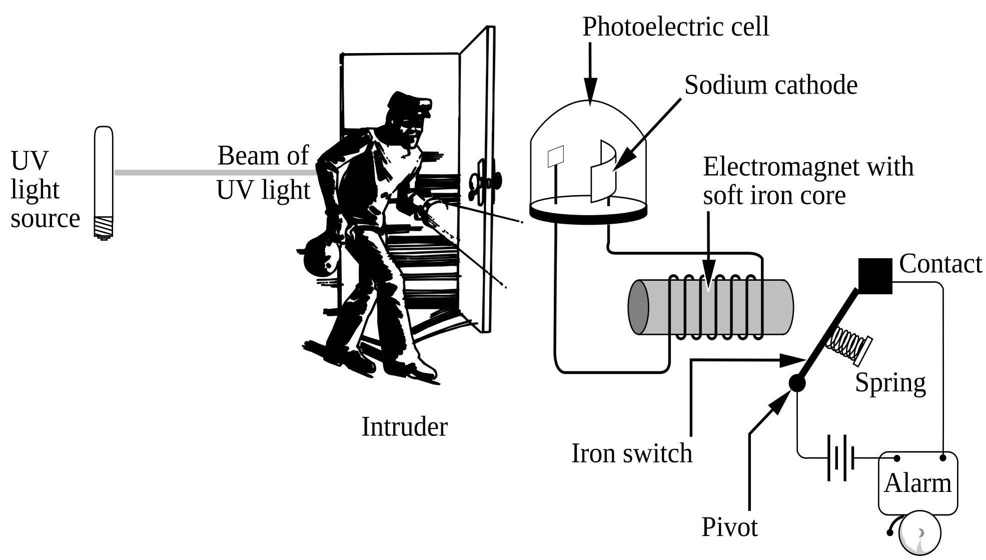
Burglar Alarm

Shown below is a simplified circuit of a burglar alarm.

Burglar alarm not activated



Burglar alarm activated



A beam of ultraviolet light is directed toward a photoelectric cell, as shown above. As long as this beam is not interrupted, light will be incident on the sodium cathode, and there is a current in the electromagnet. The electromagnet is of sufficient strength to hold the iron switch. As a result, the alarm will not be activated.

An intruder walking between the UV light source and the phototube will cause the alarm to sound.

Written Response — 15%

1. Using the Physics 30 concepts of the photoelectric effect, electromagnetism and electrical circuits, analyze the operation of this burglar alarm

- while the beam of UV light is incident on the sodium cathode
- while the intruder interrupts the beam of UV light

Note: Marks will be awarded for the physics principles used in your response and for the effective communication of your response.

"Anaholistic" Scoring Guide

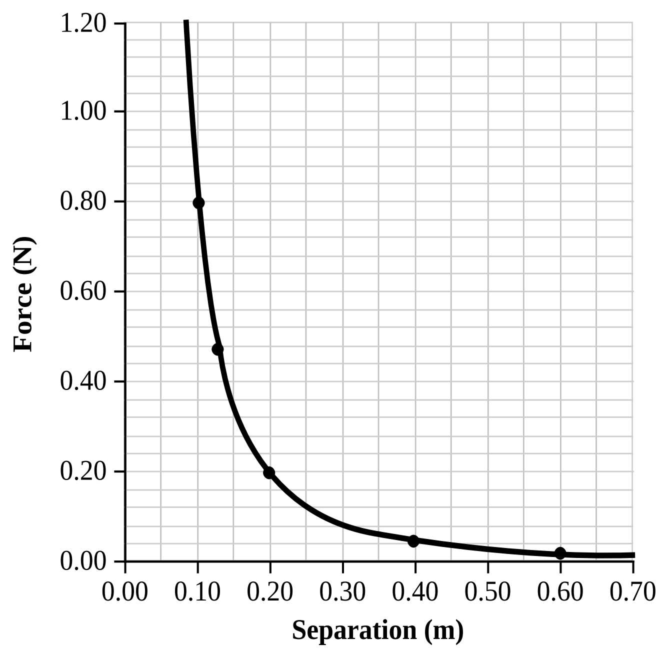
Major Concepts: Data Manipulation; Data Presentation; Data Analysis (slope and finding charge); Coulomb's Law	
Score	**Criteria**
NR	No response is given.
0	In the response, the student • identifies an area of physics that does not apply to the major concepts • uses inappropriate formulas, diagrams, and/or explanations
1	In the response, the student • attempts at least two of the major concepts **or** uses an appropriate method that reflects a good understanding of one of the major concepts • makes errors in the formulas, diagrams, and/or explanations, and the answer is not consistent with calculated results
2	In the response, the student • uses an appropriate method that reflects a basic understanding of three of the four major concepts **or** a good understanding of two of the major concepts • gives formulas and/or diagrams that are implicitly correct, however they are not applied to determine the final solution **or** errors in the application of equations are present but the answer is consistent with calculated results
3	In the response, the student • uses an appropriate method that reflects a basic understanding of all four of the major concepts **or** a good understanding of three of the major concepts • uses an appropriate method that reflects an excellent understanding of two of the major concepts **and** a basic understanding of one of the two remaining concepts • uses formulas and/or diagrams that may be implicit, but are applied correctly; errors in calculations and/or substitutions are present that hinder the understanding of the physics content • provides explanations that are correct but lack detail • has a major omission or inconsistency
4	In the response, the student • uses an appropriate method that reflects a good understanding of all major concepts **or** an excellent understanding of three of the major concepts • provides explanations that are correct and detailed • states most formulas explicitly and applies them correctly • has minor errors, omissions, or inconsistencies in calculations and/or substitutions but these do not hinder the understanding of the physics content • draws most diagrams appropriately, correctly, and completely • may have errors in units, significant digits, rounding, or graphing
5	In the response, the student • uses an appropriate method that reflects an excellent understanding of all major concepts • provides a complete description of the method used and shows a complete solution for the problem • states formulas explicitly • may make a minor error, omission, or inconsistency, but this does not hinder the understanding of the physics content • draws diagrams that are appropriate, correct, and complete • may have an error in significant digits or rounding

Use the following information to answer the next question.

A student performed an experiment which verified Coulomb's Law of Electrostatics by measuring the repulsion between two charged spheres A and B as a function of the separation of the spheres. The spheres were identical in size and mass. The measurements are shown in the table of values and plotted on the graph below.

Separation (m)	**Force (N)**
0.10	0.790
0.13	0.480
0.20	0.200
0.40	0.050
0.60	0.022

Force of Repulsion as a Function of the Separation



Written Response — 15%

2.

- Show that the results verify Coulomb's Law by manipulating the data and providing a new table of values that, when plotted, will produce a straight-line graph.

- Plot the new data with the responding variable on the vertical axis.

- Calculate the slope of your graph.

- Using the slope value, or another suitable averaging techniques, determine the charge on sphere B if the charge on sphere A is 3.08×10^{-7} C.

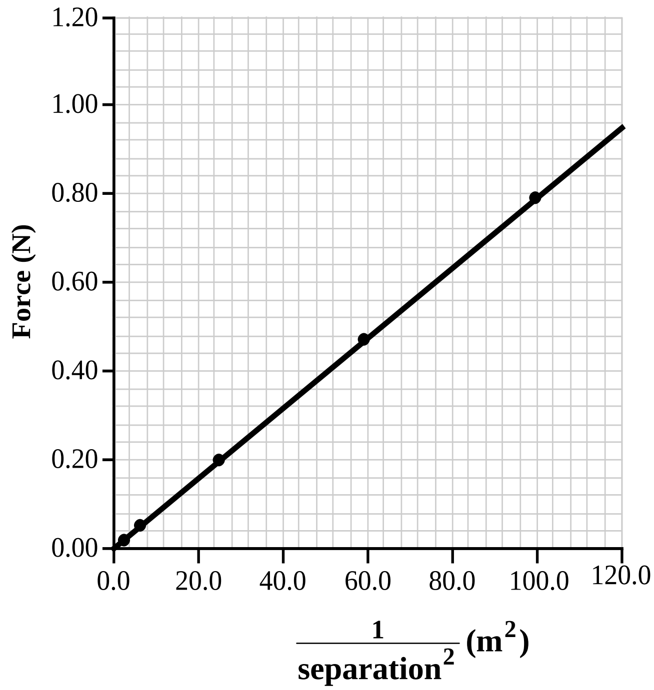
- Determine the magnitude of the force between spheres A and B when they are at a distance of 2.00 m apart. Use the hypothetical value of 4.00×10^{-6} C for the charge on sphere B if you were unable to determine the actual value.

Clearly communicate your understanding of the physics principles that you are using to solve this question. You may communicate this understanding mathematically, graphically, and/or with written statements.

Sample Solution

Table of Values	
$\frac{1}{\text{separation}^2}$ (m^2)	**Force (N)**
100	0.790
59	0.480
25	0.200
6.3	0.050
2.8	0.022

Graph



- Calculate the slope of your graph.

$$\begin{aligned} \text{slope} &= \text{rise/run} \\ &= \frac{0.60\text{N} - 0.16\text{N}}{(76 - 20)\text{m}^{-2}} \\ &= 7.86 \times 10^{-3}\ \text{N}\cdot\text{m}^2 \\ \text{slope} &= 7.9 \times 10^{-3}\ \text{N}\cdot\text{m}^2 \ \textbf{or} \text{ consistent with the graph} \end{aligned}$$

Note:
A straight line graph may be obtained from other suitable data manipulations. The manipulated variable must be placed on the horizontal axis. The slope will be different, but the value of *q* will not change.

- Using the slope value, or another suitable averaging techniques, determine the charge on sphere B, if the charge on sphere A is 3.08×10^{-7} C.

$$F_e = \frac{kq_A q_B}{r^2}$$

$$q_B = \frac{F_e r^2}{(kq_A)} = \frac{\text{slope}}{kq_A}$$

$$= \frac{7.86 \times 10^{-3}\ \text{N·m}^2}{8.99 \times 10^9\ \text{N·m}^2 / \text{C}^2)(3.08 \times 10^{-7}\text{C})}$$

$$q_B = 2.8 \times 10^{-6}\ \text{C or consistent with slope}$$

Method 2

$$F_e = \frac{kq_A q_B}{r^2}$$

$$q_1 = \frac{F_e r^2}{kq_A} = \frac{(0.79\text{N})(0.10\text{m})^2}{(8.99 \times 10^9\ \text{N•m}^2 / \text{C}^2)(3.08 \times 10^{-7}\ \text{C})} = 2.85 \times 10^{-6}\ \text{C}$$

q_1	q_2	q_3	q_4	q_5
2.85×10^{-6} C	2.93×10^{-6} C	2.89×10^{-6} C	2.89×10^{-6} C	2.86×10^{-6} C

$$q_{ave} = \frac{\sum q}{5}$$

$$q_B = 2.9 \times 10^{-6}\ \text{C}$$

- Determine the magnitude of the force between spheres A and B when they are at a distance of 2.00 m.

$$F_e = \frac{kq_A q_B}{r^2}$$

$$= \frac{(8.99 \times 10^9\ \text{N·m}^2 / \text{C}^2)(2.84 \times 10^{-6}\ \text{C})(3.08 \times 10^{-7}\ \text{C})}{2.00\ \text{m}}$$

$F_e = 2.0 \times 10^{-3}$ N or consistent with q values for q_A and q_B

Note: using $q_A = 3.00 \times 10^{-6}$ C as the hypothetical value gives

$$F_e = 2.08 \times 10^{-3}\ \text{N}$$