January 2001

Physics 30

Grade 12 Diploma Examination

Alberta
LEARNING

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Physics 30

Grade 12 Diploma Examination

Description

Time: 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 questions.

A tear-out Physics 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 tear-out pages.*

Instructions

- You are expected to provide your own calculator. You may use any scientific calculator or a graphing calculator approved by Alberta Learning. **NEW**
- You are expected to have cleared your calculator of all information that is stored in the programmable or parametric memory. **NEW**
- 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 Learning.
- 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

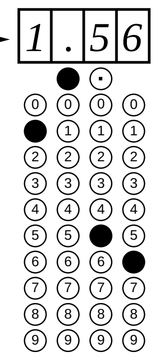
Calculation Question and Solution

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.)

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

$$a = \frac{121\ \text{N}}{77.7\ \text{kg}} = 1.557\ \text{m/s}^2$$

Record 1.56 on the answer sheet →



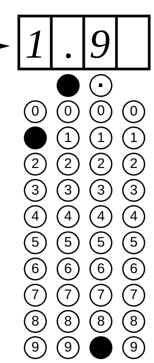
Calculation Question and Solution

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

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

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

Record 1.9 on the answer sheet →



Correct-Order Question and Solution

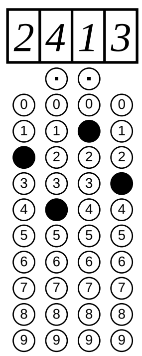
When the following subjects are arranged in alphabetical order, the order is ____, ____, ____, and ____ .

1 physics
2 biology
3 science
4 chemistry

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

Answer: 2413

Record 2413 on the answer sheet →



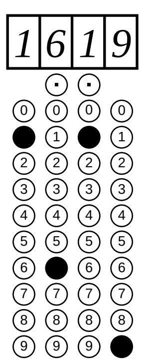
Scientific Notation Question and Solution

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

(Record all **four digits** of your 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. Use formulas as they appear on the equation sheet included with this examination.
- 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. Which of the following quantities is a **scalar** quantity?

- **A.** Force
- **B.** Power
- **C.** Impulse
- **D.** Momentum

Numerical Response

1. A golf ball has a mass of 45.0 g. A golf club is in contact with the golf ball for 3.00×10^{-4} s, and the ball leaves the club with a speed of 72.0 m/s. The average force exerted by the club on the ball, expressed in scientific notation, is $\boldsymbol{b} \times 10^{w}$ N. The value of $\boldsymbol{b}$ is ___________.

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

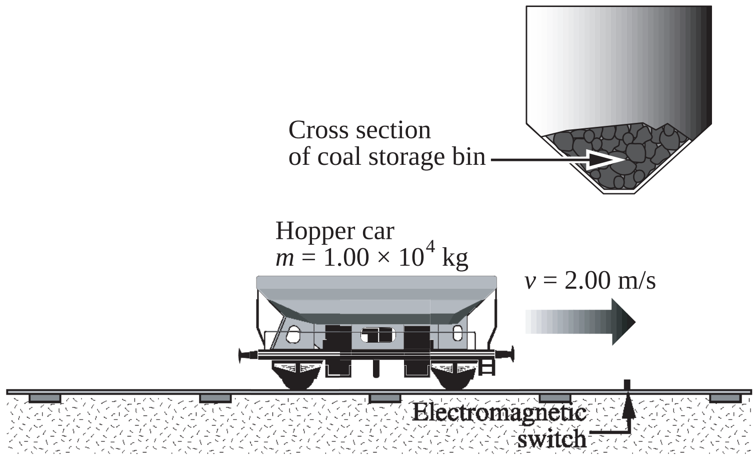
Numerical Response

2. In a vehicle safety test, a 1 580 kg truck travelling at 60.0 km/h collides with a concrete barrier and comes to a complete stop in 0.120 s. The magnitude of the change in the momentum of the truck, expressed in scientific notation, is $\boldsymbol{b} \times 10^{w}$ kg·m/s. 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.

At a coal mine, a train engine bumps an empty hopper car that has a mass of 1.00×10^4 kg such that it rolls at a constant speed of 2.00 m/s under a coal storage bin. When the hopper car triggers an electromagnetic switch on the track below the storage bin, the bin drops a load of 1.20×10^4 kg of coal into the hopper car.



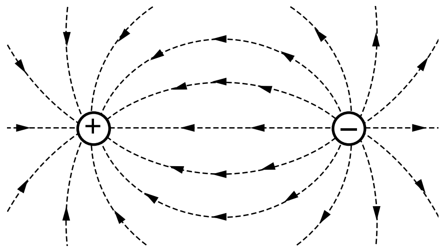
Numerical Response

3. The speed of the hopper car immediately after receiving the load of coal, expressed in scientific notation, is $\boldsymbol{b} \times 10^{-w}$ m/s. The value of $\boldsymbol{b}$ is __________.

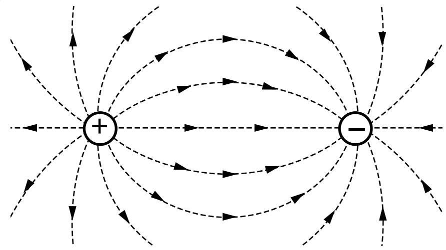
(Record your **three-digit answer** in the numerical-response section on the answer sheet.)

2. The electric field between a positive point charge and a negative point charge is represented by

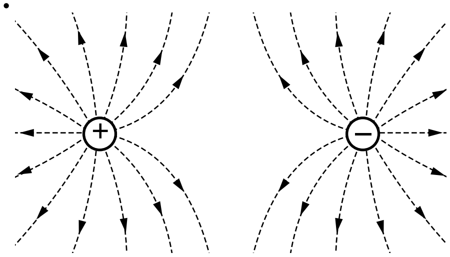
A.



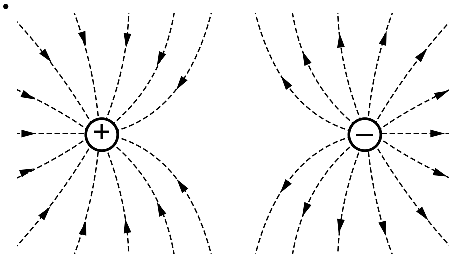
B.



C.



D.



Use the following information to answer the next three questions.

Diagrams **1** and **2** below each show an electron as it enters a field. The fields are different but the electrons enter them with the same instantaneous velocity, $\vec{v}_{inst}$.

Diagram 1

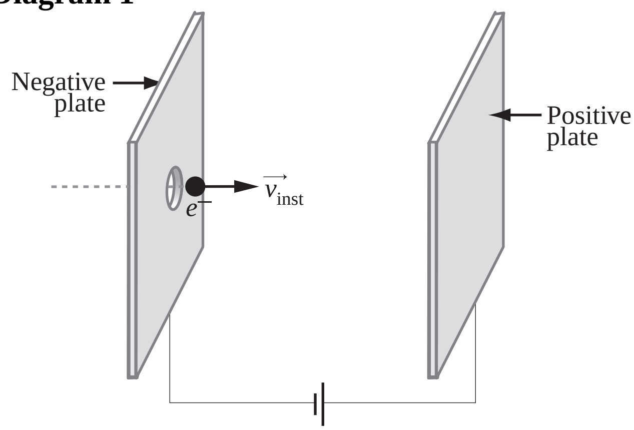
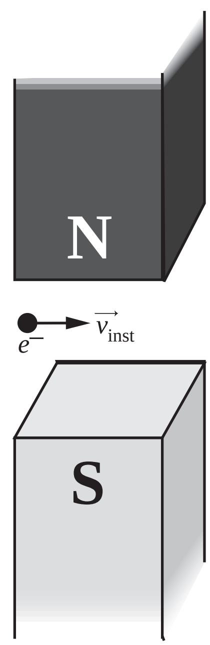


Diagram 2



Statements About the Motion of the Charged Particles as They Travel Through the Fields

I The speed of the particle remains constant.
II The speed of the particle increases.
III The direction of the particle's motion remains constant.
IV The direction of the particle's motion changes.

3. The statements that describe the motion of the charged particle in diagram **1** are

A. I and III

B. I and IV

C. II and III

D. II and IV

4. The statements that describe the motion of the charged particle in diagram **2** are

A. I and III

B. I and IV

C. II and III

D. II and IV

5. The direction of the uniform magnetic field in diagram **2** is

A. toward the top of the page

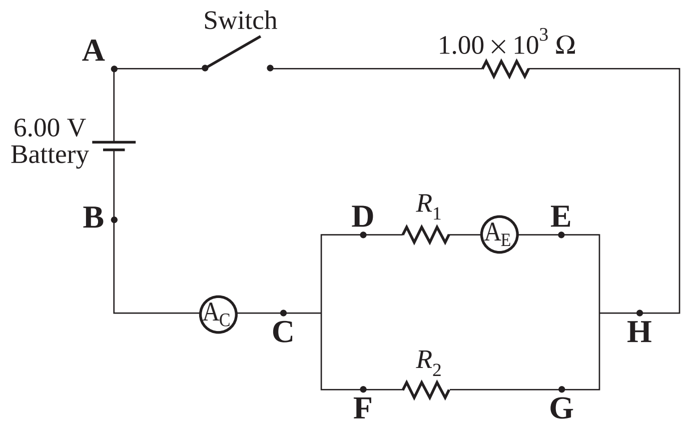
B. toward the bottom of the page

C. to the left of the page

D. to the right of the page

Use the following information to answer the next four questions.

A student is given a circuit and a voltmeter. A schematic diagram of the circuit is shown below.



With the switch closed, the student records the following observations.

Ammeter readings $A_C = 2.73$ mA
$A_E = 1.64$ mA

Voltmeter readings between **A** and **B** = 6.00 V
C and **H** = 3.27 V

6. The student connects the voltmeter to the circuit at two points. A connection that produces a reading **other than** 3.27 V is at

A. points **D** and **E**

B. points **D** and **H**

C. points **F** and **G**

D. points **G** and **H**

7. The current through point **F** is

A. 1.09 mA
B. 1.64 mA
C. 2.73 mA
D. 4.36 mA

8. The value of the unknown resistor R_1 is

A. $1.20 \times 10^3\ \Omega$
B. $1.99 \times 10^3\ \Omega$
C. $3.00 \times 10^3\ \Omega$
D. $5.50 \times 10^3\ \Omega$

9. The total resistance of the circuit is

A. $5.45 \times 10^2\ \Omega$
B. $8.33 \times 10^2\ \Omega$
C. $2.20 \times 10^3\ \Omega$
D. $5.99 \times 10^3\ \Omega$

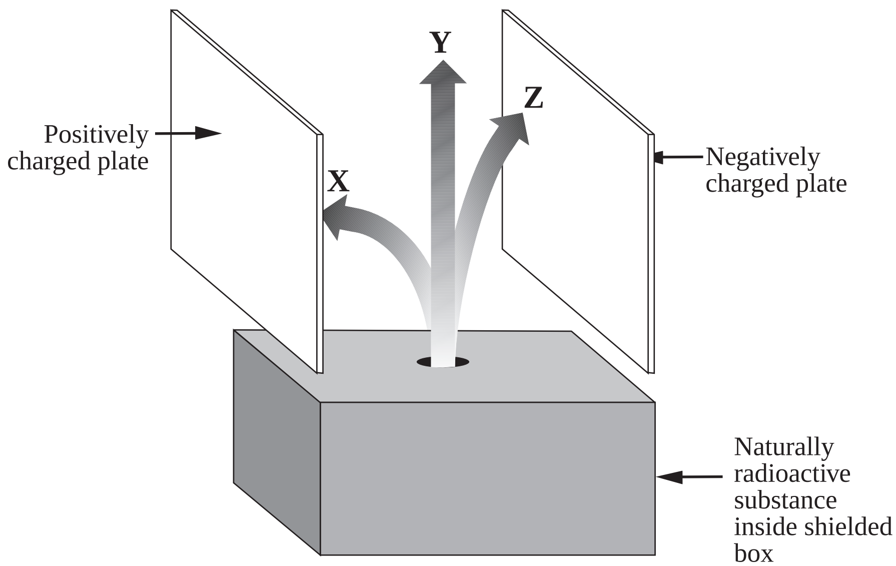
Numerical Response

4. Two charged objects experience a force of 18.0 N when they are placed 5.00×10^{-2} m apart. If the charge on one object is 1.30×10^{-5} C, then the charge on the other object is $\boldsymbol{a.bc} \times 10^{-\boldsymbol{d}}$ C. 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.

Three types of radiation pass through an electric field along the paths shown below.



10. The types of radiation taking paths **X**, **Y**, and **Z** are, respectively,

A. beta, alpha, and gamma

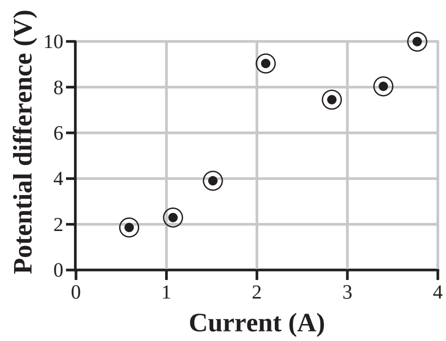
B. beta, gamma, and alpha

C. gamma, alpha, and beta

D. alpha, gamma, and beta

Use the following information to answer the next question.

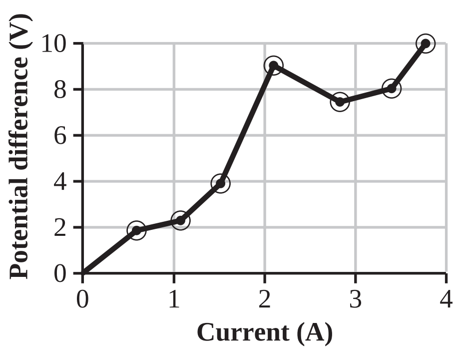
An Experiment to Determine the Resistance of a Metal Wire



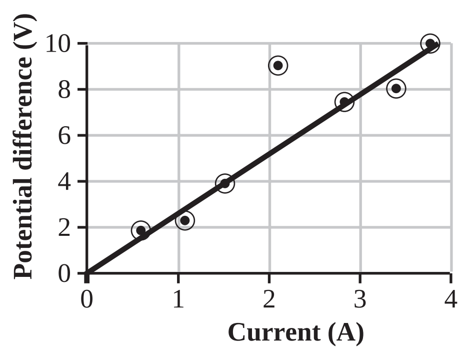
The points plotted on the graph above represent the results obtained from an experiment performed by a student.

11. The **best** completed graph of this data is

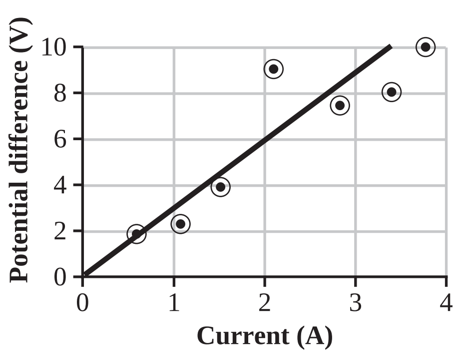
A.



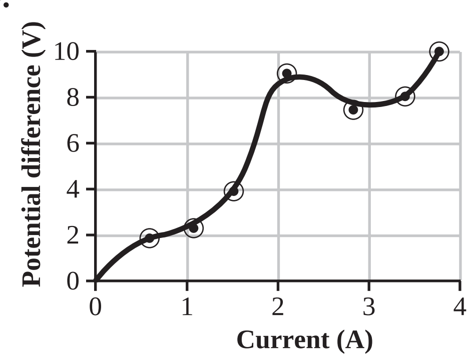
B.



C.



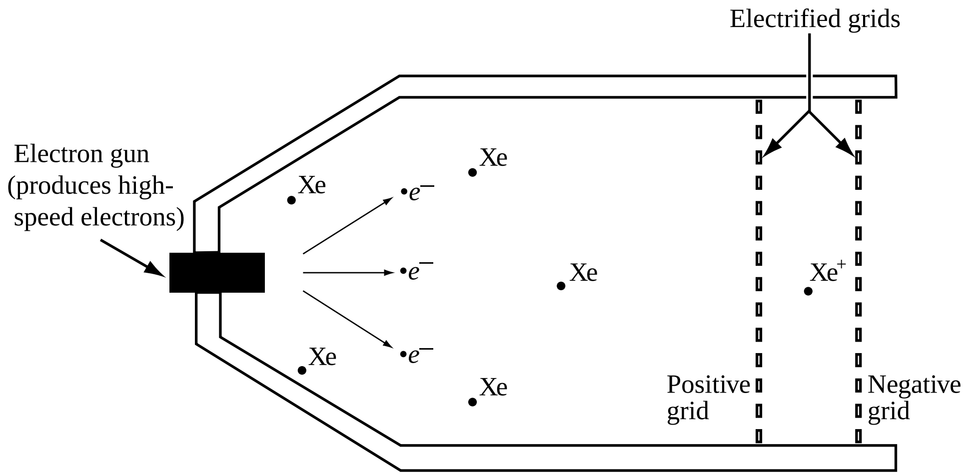
D.



Use the following information to answer the next seven questions.

The Deep Space 1 mission (DS1) uses a ion propulsion system (IPS) on the DS1 capsule. The IPS involves ionizing atoms of xenon, accelerating them through an electric field produced by electrified grids, and ejecting the ions into space behind the capsule.

IPS Chamber of the DS1 Capsule



In the IPS chamber, high-speed electrons collide with xenon atoms. These collisions can ionize xenon atoms. The electric field then accelerates the ions and ejects them from the IPS chamber, which propels the DS1 capsule forward.

IPS Operating Specifications for DS1

propellant ions	Xe^{+}
total mass of propellant	81.5 kg
mass of DS1 capsule (without propellant)	489.5 kg
energy required to ionize a xenon atom	12.1 eV
mass of a single xenon atom	2.18×10^{-25} kg
exit speed of xenon ions	43.0 km/s

12. The minimum electron speed necessary to ionize xenon atoms is

A. 2.66×10^{31} m/s

B. 5.15×10^{15} m/s

C. 4.25×10^{12} m/s

D. 2.06×10^{6} m/s

13. The electric potential difference across the electrified grids that is required to accelerate a xenon ion from rest to its exit speed is

A. 2.93×10^{-5} V

B. 1.26×10^{-3} V

C. 1.26×10^{3} V

D. 4.71×10^{29} V

14. If all of the xenon propellant could be expelled in a single short burst, the change in the speed of the DS1 capsule after all the fuel has been exhausted would be

A. 6.14 m/s

B. 7.16 m/s

C. 6.14×10^{3} m/s

D. 7.16×10^{3} m/s

15. The physics principle that **best** describes the propulsion of the DS1 capsule is the Law of Conservation of

A. Charge

B. Energy

C. Momentum

D. Nucleon Number

Numerical Response

5. As xenon ions in the exhaust stream behind the DS1 capsule interact with other charged particles in space, the xenon ions become neutral atoms, and in the process, emit photons. The maximum frequency of these photons, expressed in scientific notation, is $\boldsymbol{b} \times 10^{w}$ Hz. The value of $\boldsymbol{b}$ is __________.

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

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

> One isotope of xenon, xenon-133, is an unstable isotope that undergoes beta decay and has a half-life of 5.24 days.

Numerical Response

6. If the IPS uses 81.5 kg of xenon-133 as a propellant and the launch is delayed by 26.2 days, the amount of xenon-133 that would remain is __________ kg.

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

16. The decay equation for xenon-133 is

A. $^{133}_{54}\text{Xe} \rightarrow {}^{133}_{54}\text{Xe} + \gamma$

B. $^{133}_{54}\text{Xe} \rightarrow {}^{129}_{52}\text{Te} + {}^{4}_{2}\alpha$

C. $^{133}_{54}\text{Xe} \rightarrow {}^{133}_{55}\text{Cs} + {}^{0}_{-1}\beta$

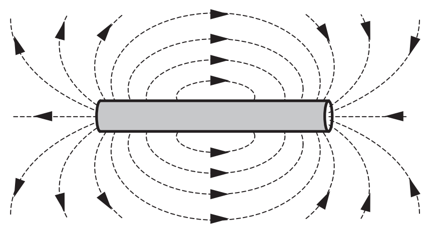
D. $^{133}_{54}\text{Xe} \rightarrow {}^{133}_{53}\text{I} + {}^{0}_{-1}\beta$

Use the following information to answer the next question.

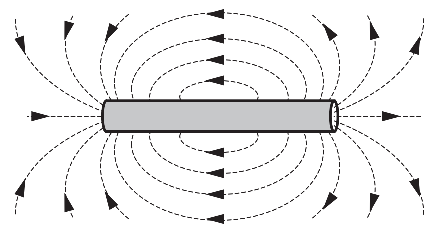
A negatively charged rubber rod is moved from left to right.

17. The magnetic field induced around the rubber rod as it moves is represented by

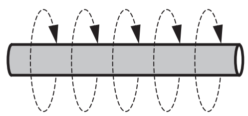
A.



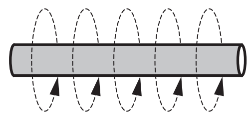
B.



C.



D.



Numerical Response

7. An alpha particle travels at 1.08×10^5 m/s perpendicularly through a magnetic field of strength 1.12×10^{-3} T. The magnitude of the magnetic force on the alpha particle is $\boldsymbol{b} \times 10^{-w}$ N. The value of $\boldsymbol{b}$ is __________.

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

18. A copper wire is connected to a battery so that it has a current in it. A segment of the wire is perpendicular to a horizontal 1.5 T magnetic field. The length of the wire in the magnetic field is 3.0 cm, and the mass of the wire affected by the magnetic field is 20 g. In order to suspend the segment of wire, the minimum current in the wire must be

A. 0.044 A

B. 0.23 A

C. 4.4 A

D. 44 A

Use the following information to answer the next three questions.

The AC adapter for a pocket calculator contains a transformer that converts 120 volts into 3.0 volts. The pocket calculator draws 450 mA of current from the transformer. Assume that the transformer is an ideal transformer.

19. If the transformer's secondary coil has exactly 50 turns, then the number of turns in the primary coil is

A. 7 turns

B. 40 turns

C. 50 turns

D. 2.0×10^3 turns

20. The current in the primary coil of the adapter is

A. 0.80 mA

B. 1.3 mA

C. 11 mA

D. 18 A

Numerical Response

8. The power supplied by the primary coil is __________ W.

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

Numerical Response

9. A microwave signal that has a wavelength of 6.25×10^{-3} m is created by an oscillating current in a microwave generator. The period of this microwave, expressed in scientific notation, is $\boldsymbol{b} \times 10^{-w}$ s. 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.

> A student holds a compass near the top of a filing cabinet and observes the direction that the needle points. When the student holds the compass near the bottom of the filing cabinet, the student observes that the compass needle is deflected 180° from its direction at the top of the cabinet.

21. A possible explanation for the deflection of the compass needle is that the

A. bottom of the filing cabinet is positively charged

B. bottom of the filing cabinet is negatively charged

C. induced magnetic polarity of the bottom of the filing cabinet is opposite to that at the top of the filing cabinet

D. bottom of the filing cabinet is closer to Earth so it is more strongly magnetized than the top of the filing cabinet

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Numerical Response

10. An ultraviolet source emits electromagnetic waves with a frequency of 2.47×10^{15} Hz. Its wavelength, 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.)

Use the following information to answer the next two questions.

The different colours seen in exploding fireworks are produced using different elements.

Element	**Predominant Colour**
Strontium	Red
Barium	Green
Copper	Blue-Green
Sodium	Yellow-Orange

22. Given the information above, the element that emits the lowest energy photon of visible light is

A. strontium

B. barium

C. copper

D. sodium

23. The colours are emitted by electrons that are

A. undergoing transitions to higher energy levels

B. undergoing transitions to lower energy levels

C. oscillating between energy levels

D. emitted by the nucleus

24. The energy gained by a proton that moves through a potential difference of 1.0 V is

A. 1.0 J

B. 1.0 eV

C. 6.3×10^{18} J

D. 1.6×10^{-19} eV

Numerical Response

11. A metal has a work function of 2.91×10^{-19} J. Light with a frequency of 8.26×10^{14} Hz is incident on the metal. The stopping voltage is __________V.

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

25. If a light with a wavelength of 3.25×10^{-8} m illuminates a metal surface with a work function of 5.60×10^{-19} J, the maximum kinetic energy of the emitted photoelectrons is

A. 5.60×10^{-19} J

B. 5.56×10^{-18} J

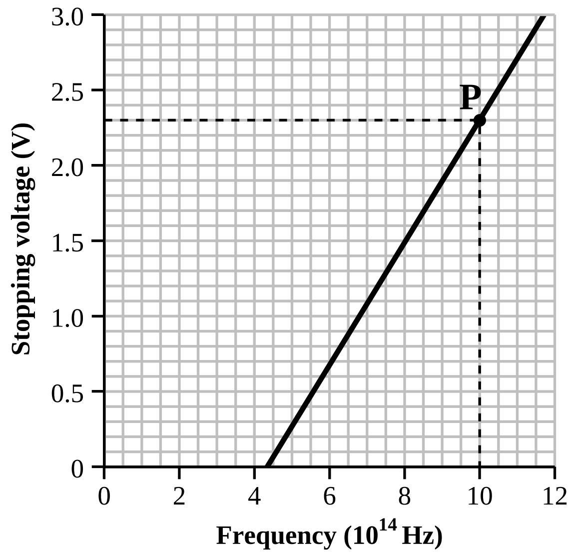
C. 6.12×10^{-18} J

D. 6.68×10^{-18} J

Use the following information to answer the next three questions.

A graph of data obtained from a photoelectric effect experiment is shown below.

Stopping Voltage as a Function of the Frequency of Incident Light on a Cesium Plate



Point **P** corresponds to a trial using light at the frequency indicated.

26. The type of light indicated by point **P** is

A. visible

B. infrared

C. microwave

D. ultraviolet

27. The energy of a photon of light indicated by point **P** is

A. 4.1 eV

B. 2.3 eV

C. 1.7 eV

D. 0.0 eV

28. Photons of light, as indicated by point **P**, bombard the cesium plant. The maximum kinetic energy of an emitted electron is

A. 4.1 eV

B. 2.3 eV

C. 1.7 eV

D. 0.0 eV

29. The Compton experiment was significant in that it demonstrated that photons have

A. mass

B. momentum

C. wave properties

D. a speed of 3.00×10^8 m/s

30. An experiment starts with 1.45 kg of iodine-131. After 32.2 days, 90.6 g are left. The half-life of iodine-131 is

A. 32.2 days

B. 16.1 days

C. 8.05 days

D. 4.04 days

Use the following information to answer the next four questions.

Fusion Research

Interest in nuclear fusion is growing because of the amount of energy available from nuclear reactions. A major difficulty in producing a nuclear fusion reaction is that in order for nuclei to fuse, the nuclei must possess a large amount of kinetic energy. Under most circumstances, 0.25 MeV per nucleus is sufficient. At such high energies, the nuclear fuel is called a plasma.

The average kinetic energy of a nucleus within a plasma can be found using

$$E_{\mathrm{k}} = \frac{3}{2}bT$$

where T is the temperature of the plasma, in Kelvin, and b is a physical constant equal to 1.4×10^{-23} J/K.

One method of obtaining the temperatures necessary for fusion is to use a high-intensity laser to heat a small cluster of nuclei. One such laser emits a 1.0×10^{15} W pulse of ultraviolet radiation that lasts for 1.0×10^{-12} s. The wavelength of this laser is 280 nm.

A Fusion Reaction Equation

$${}^{2}_{1}\mathrm{H} + {}^{3}_{1}\mathrm{H} \rightarrow \underline{\ \boldsymbol{X}\ } + \text{neutron}$$

31. The missing product, ***X***, in the fusion reaction given above is

A. ${}^{5}_{2}\mathrm{He}$

B. ${}^{4}_{2}\mathrm{He}$

C. ${}^{4}_{1}\mathrm{H}$

D. ${}^{3}_{2}\mathrm{He}$

32. The main reason that the nuclei need to have such large kinetic energies is that

A. fusion releases large amounts of energy

B. fission must occur before fusion can occur

C. this kinetic energy is converted into nuclear energy

D. the nuclei must overcome a strong electrostatic repulsion

33. When the average kinetic energy of the nuclei in a plasma is 0.25 MeV, then the temperature is

A. 1.9×10^{9} K

B. 2.9×10^{9} K

C. 4.3×10^{9} K

D. 1.2×10^{28} K

34. The energy of a single photon of the ultraviolet laser is

A. 7.1×10^{-19} J

B. 1.0×10^{-27} J

C. 7.1×10^{-28} J

D. 1.9×10^{-40} J

35. The absorption spectrum of hydrogen is produced when electrons

A. emit radio frequency photons

B. emit short wavelength photons

C. jump from a higher orbital to a lower orbital

D. jump from a lower orbital to a higher orbital

36. An accelerated electron with 8.77 eV of energy strikes a mercury atom and leaves the collision with 2.10 eV of energy. The maximum frequency of light that can be emitted by the mercury atom is

A. 1.01×10^{14} Hz

B. 5.07×10^{14} Hz

C. 1.61×10^{15} Hz

D. 2.12×10^{15} Hz

37. For a hydrogen atom, the difference in radii between the sixth Bohr orbital and the second Bohr orbital is

A. 1.69×10^{-9} m
B. 8.46×10^{-10} m
C. 1.17×10^{-11} m
D. 1.32×10^{-11} m

Numerical Response

12. An electron in a hydrogen atom is in the fourth orbital and jumps down to the second orbital. The energy released is __________ eV.

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

Use the following information to answer the next question.

In a physics demonstration, a student inflates a balloon by blowing into it. The end of the balloon is then tied. The balloon is rubbed with fur and develops an electrostatic charge. The balloon is placed against the ceiling and released. It remains "stuck" to the ceiling.

The teacher then presents the following challenges to the students:

- explain how the balloon received the electrostatic charge
- explain why the balloon is attracted to the ceiling
- provide a procedure that would determine if the charge on the balloon is positive or negative. Include a list of any additional equipment needed.
- provide a procedure that could be used to determine if there is a relationship between the amount of rubbing and the amount of charge developed on an inflated balloon. Include a list of any additional equipment needed.

Written Response—15%

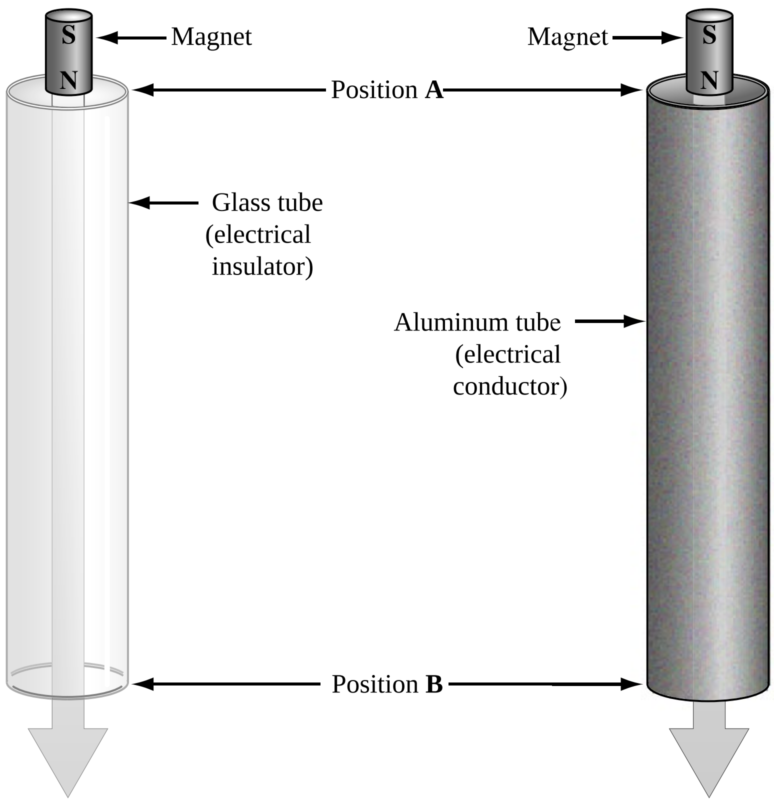
1. Using concepts from Physics 30, provide a response to each of the teacher's challenges.

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

Use the following information to answer the next question.

Falling Magnet Experiment

Two hollow tubes, one made of glass and the other made of aluminum, are positioned vertically. A student holds identical cylindrical magnets against the outside of the tubes and observe that neither tube attracts a magnet. Based on this observation, the student predicts that each magnet will fall through its respective tube with an acceleration of $9.81\ m/s^2$. The student and his lab partner then drop the magnets into the tubes from rest at position A, as shown below.



The students make the following observations:
The magnets do not touch the sides of the tubes as they fall. The time for the magnet to fall through the aluminum tube is much greater than is the time for the identical magnet to fall through the glass tube.

	Glass Tube	Aluminum Tube
Mass of magnet (kg)	0.150	0.150
Tube length (m)	0.95	0.95
Time for magnet to fall from position A to position B (s)	0.44	0.76

Written Response—15%

2. Analyze the students' observations from the falling magnet experiment by

- completing the chart below. Include calculations to support the values you write in the chart
- explaining the results of this experiment in terms of Lenz's Law

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.

	Glass Tube	**Aluminum Tube**
Potential Energy of the magnet at position A (J)		
Acceleration of the magnet through the tube (m/s^2)		
Kinetic Energy of the magnet at position B (J)		
Mechanical Energy of the magnet at position A (J)		
Mechanical Energy of the magnet at position B (J)		
Resisting Force on the magnet (N)		

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

Fold and tear along perforation.

PHYSICS DATA SHEET

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

Atomic Physics

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

Particles

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

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 $\vec{R}$

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

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

$$R_x = R\cos\theta$$

$$R_y = R\sin\theta$$

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}

Tear-out Page

EQUATIONS

Kinematics

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

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

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

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

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

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

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

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

Dynamics

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

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

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

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

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

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

$F_f = \mu F_N$

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

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

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

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

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

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

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

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

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

$v = f\lambda$

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

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

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

Atomic Physics

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

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

$W = hf_0$

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

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

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

$r_n = n^2 r_1$

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

Quantum Mechanics and Nuclear Physics

$E = mc^2$

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

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

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

Key: Atomic number → 3; Symbol → Li; Atomic molar mass → 6.94; Name → lithium

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

( ) Indicates mass of the most stable isotope

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
IA	IIA	IIIB	IVB	VB	VIB	VIIB		VIIIB	VIIIB	IB	IIB	IIIA	IVA	VA	VIA	VIIA	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

Tear-out Page

Tear-out Page

No marks will be given for work done on this page.

mm

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Fold and tear along perforation.

Physics 30 January 2001 Diploma Examination
Multiple Choice and Numerical Response Keys

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

1.	1.08
2.	2.63
3.	9.09
4.	3857
5.	2.92
6.	2.55
7.	3.87
8.	1.4
9.	2.08
10.	1.21
11	1.60
12	2.55 or 2.56

Holistic Scoring Guide Draft

Major Concepts: Charging by contact, induced charge separation, experimental design

Score	Criteria
5 **Excellent**	• The student provides a complete solution covering the full scope of the question. – The reader has no difficulty following the strategy or solution presented by the student. – Statements made in the response are supported explicitly but may contain minor errors or have minor omissions.
4 **Good**	• The student provides a solution to the significant parts of the question. – The reader may have some difficulty following the strategy or solution presented by the student. – Statements made in the response are supported, but the support may be implicit.
3 **Satisfactory**	• The student provides a solution in which he/she has made significant progress toward answering the question. – The reader has difficulty following the strategy or solution presented by the student. – Statements made in the response may be open to interpretation and may lack support.
2 **Limited**	• The student provides a solution in which he/she has made some progress toward answering the question. – Statements made in the response lack support.
1 **Poor**	• The student provides a solution that begins to answer the question.
0 **Insufficient**	• The student provides a solution that is invalid for the major concepts addressed by the question.
NR	No response is given.

Use the following information to answer the next question.

In a physics demonstration, a student inflates a balloon by blowing into it. The end of the balloon is then tied. The balloon is rubbed with fur and develops an electrostatic charge. The balloon is placed against the ceiling and released. It remains “stuck” to the ceiling.

The teacher then presents the following challenges to the students:

- explain how the balloon received the electrostatic charge
- explain why the balloon is attracted to the ceiling
- provide a procedure that would determine if the charge on the balloon is positive or negative. Include a list of any additional equipment needed.
- provide a procedure that could be used to determine if there is a relationship between the amount of rubbing and the amount of charge developed on an inflated balloon. Include a list of any additional equipment needed.

Written Response—15%

1. Using concepts from Physics 30, provide a response to each of the teacher’s challenges.

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

A complete response should include the following content. The clarity of the response is considered in assigning a mark.

Expected Content:

This question requires both a theoretical and an empirical understanding of electrostatics.

Theoretical

To completely address the theoretical aspect of the question, the student needs to address the movement of charges. The response should include the following:

- A statement that the balloon receives its charge by friction or by contact.
- A statement that electrons move between the balloon and the fur. (Students do not need to specify that the balloon will become negatively charged, or identify the charge that remains on the fur after contact.)
- A description of the charge separation that occurs on the ceiling.
- An explanation of the process of inducing a charge.
- A statement that opposite charges attract.

Empirical

Two procedures are required to completely address the empirical aspect of the question.

- A procedure is required to determine the type of charge on the balloon. The response must include instructions and equipment needed. The procedure must result in the determination of the nature of the charge.

- A procedure is required to determine if there is a relationship between the amount of rubbing and the amount of charge developed on an inflated balloon. The response must include instructions and equipment needed. Instructions must specify repeated trials, and identify both the manipulated and responding variables. (Examples of the manipulated variable include: time of rubbing, number of strokes, or amount of pressure applied. Examples of the responding variable include: the time that the balloon remains stuck to the ceiling, divergence of the leaves of an electroscope, or force of attraction of the balloon to the ceiling.)

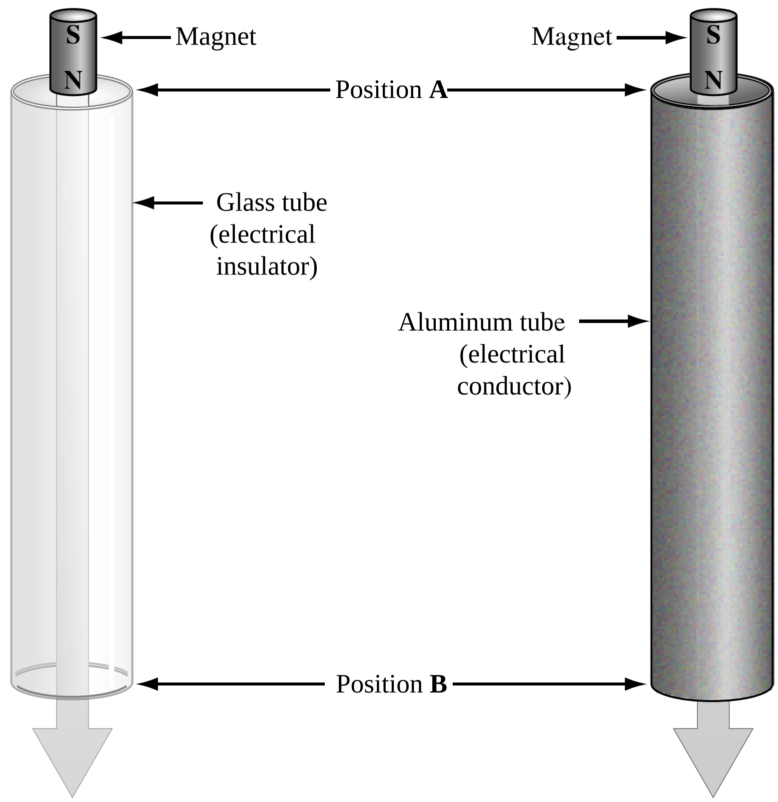
Scoring Guide for Anaholistic Questions

<table>
<tr><td colspan="2">Major Concepts: Potential energy; Acceleration and kinetic energy; Resisting force; Lenz’s Law</td></tr>
<tr><th>Score</th><th>Criteria</th></tr>
<tr><td>5</td><td>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; however, 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</td></tr>
<tr><td>4</td><td>In the response, the student
• uses an appropriate method that reflects a good understanding of all major concepts or that reflects an excellent understanding of three of the major concepts
• provides explanations that are correct and detailed
• states most formulas explicitly and applies them correctly
• makes minor errors, omissions, or inconsistencies in calculations and/or substitutions; however, 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</td></tr>
<tr><td>3</td><td>In the response, the student
• uses an appropriate method that reflects a basic understanding of all four of the major concepts or that reflects 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 that reflects a basic understanding of one of the two remaining concepts
• uses formulas and/or diagrams that may be implicit, and these are applied correctly; however, errors in calculations and/or substitutions that hinder the understanding of the physics content are present
• provides explanations that are correct but lack detail
• has a major omission or inconsistency</td></tr>
<tr><td>2</td><td>In the response, the student
• uses an appropriate method that reflects a basic understanding of three of the four major concepts or that reflects 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, and the answer is consistent with calculated results</td></tr>
<tr><td>1</td><td>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</td></tr>
<tr><td>0</td><td>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</td></tr>
<tr><td>NR</td><td>No response is given.</td></tr>
</table>

Use the following information to answer Written Response 2.

Falling Magnet Experiment

Two hollow tubes, one made of glass and the other made of aluminum, are positioned vertically. A student holds identical cylindrical magnets against the outside of the tubes and observe that neither tube attracts a magnet. Based on this observation, the student predicts that each magnet will fall through its respective tube with an acceleration of $9.81\ m/s^2$. The student and his lab partner then drop the magnets into the tubes from rest at position A, as shown below.



The students make the following observations:
The magnets do not touch the sides of the tubes as they fall. The time for the magnet to fall through the aluminum tube is much greater than is the time for the identical magnet to fall through the glass tube.

	Glass Tube	Aluminum Tube
Mass of magnet (kg)	0.150	0.150
Tube length (m)	0.95	0.95
Time for magnet to fall from position A to position B (s)	0.44	0.76

Written Response—15%

2. Analyze the students' observations from the falling magnet experiment by

- completing the chart below. Include calculations to support the values you write in the chart
- explaining the results of this experiment in terms of Lenz's Law

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:

	Glass Tube	**Aluminum Tube**
Potential Energy of the magnet at position A (J)	1.4	1.4
Acceleration of the magnet through the tube (m/s^2)	9.8	3.3
Kinetic Energy of the magnet at position B (J)	1.4	0.47
Mechanical Energy of the magnet at position A (J)	1.4	1.4
Mechanical Energy of the magnet at position B (J)	1.4	0.47
Resisting Force on the magnet (N)	0	0.98

• Potential Energy

$$E_{p_A} = mgh$$
$$= (0.150 \text{ kg})(9.81 \text{ m/s}^2)(0.95 \text{ m})$$
$$E_{p_A} = 1.398 \text{ J}$$

• Acceleration: from $d = v_i t + \frac{1}{2} a t^2$ $\quad a = \frac{2d}{t^2}$

$$a_{\text{glass}} = \frac{2(0.95\text{ m})}{(0.44\text{s})^2} \qquad a_{\text{aluminum}} = \frac{2(0.95\text{ m})}{(0.76\text{ s})^2}$$
$$a_{\text{glass}} = 9.814 \text{ m/s}^2 \qquad a_{\text{aluminum}} = 3.289 \text{ m/s}^2$$

• Kinetic Energy

$$v_f^{\,2} = v_i^2 + 2ad \qquad v_f^{\,2} = 2ad \text{ since } v_i = 0$$
$$E_k = \frac{1}{2} m v_f^{\,2} \qquad E_k = \frac{1}{2} m(2a_{\text{net}} d) = m a_{\text{net}} d$$

$$E_{\text{glass}} = m a_{\text{net}} d \qquad E_{\text{aluminum}} = m a_{\text{net}} d$$
$$= (0.150 \text{ kg})(9.8 \text{ m/s}^2)(0.95\text{ m}) \qquad = (0.150\text{ kg})(3.3\text{ m/s}^2)(0.95\text{ m})$$
$$E_{\text{glass}} = 1.397 \text{ J} \qquad E_{\text{aluminum}} = 0.470 \text{ J}$$

Students can calculate v_f from $d = \frac{v_i + v_f}{2} t$. Since $v_i = 0$, $v_f = \frac{2d}{t}$. As a result:

$$v_{f(\text{glass})} = 4.32 \text{ m/s, and } v_{f(\text{aluminum})} = 2.50 \text{ m/s}$$

• Resisting Force

Method 1

$$\Delta E = \text{Work done} = Fd$$

$$F_{\text{glass}} = \frac{\Delta E}{d}$$

$$= \frac{1.4\text{ J} - 1.4\text{ J}}{0.95\text{ m}}$$

$$F_{\text{glass}} = 0\text{ N}$$

$$F_{\text{aluminum}} = \frac{\Delta E}{d}$$

$$= \frac{1.4\text{ J} - 0.47\text{ J}}{0.95\text{ m}}$$

$$F_{\text{aluminum}} = 0.979\text{ N}$$

Method 2

$$F_{\text{net}} = ma$$

$$F_g - F_A = ma$$

$$(0.150\text{ kg})(9.81\text{ m/s}^2) - F_A = (0.150\text{ kg})(3.29\text{ m/s}^2)$$

$$F_A = 0.98\text{ N}$$

• Lenz's Law Explanation

By Lenz's Law, a changing magnetic field will cause an induced magnetic field in the aluminum tube that opposes the original changing magnetic field.

Since the glass tube is an electrical insulator, there is no induced magnetic field.