January 2000

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 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 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

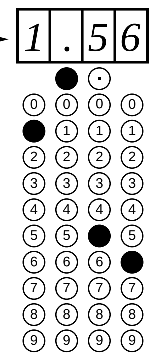
Calculation Question and Solution

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 ⟶



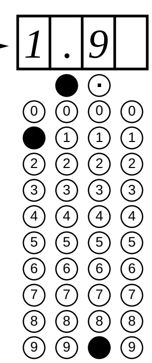
Calculation Question and Solution

A microwave of wavelength 16 cm has a frequency, expressed in scientific notation, of $b \times 10^w$ 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

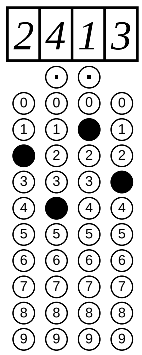
When the following subjects are arranged in alphabetical order, the order is ____, ____, ____, and ____ .

1 physics
2 biology
3 science
4 chemistry

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

Answer: 2413

Record 2413 on the answer sheet ⟶



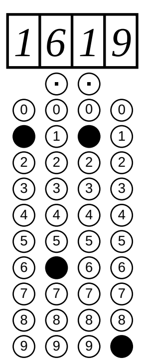
Scientific Notation Question and Solution

The charge on an electron is $-\boldsymbol{a}.\boldsymbol{b} \times 10^{-\boldsymbol{cd}}$ 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.

Use the following information to answer the first two questions.

Communication satellites require rocket thrusters that must be fired periodically, in short bursts, to keep the satellites from drifting out of their orbits. Usually, a gas such as ammonia is heated using electrodes. The expanding hot gas is allowed to escape, which provides the thrust. Unfortunately, the ammonia erodes the electrodes, eventually rendering them useless.

An alternative method to heat the ammonia uses microwaves. A 1.00×10^3 W microwave generator is used. The microwaves in the thrusters heat the gas to tens of thousands of degrees.

Numerical Response

1. A satellite has a mass of 172 kg. To correct its orbit, a thruster is fired for 2.27 s, which changes the velocity of the satellite by 5.86×10^{-3} m/s. The force generated by the thrusters, expressed in scientific notation, is $\boldsymbol{b} \times 10^{-w}$ N. The value of ***b*** is ___________.

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

Numerical Response

2. The energy used to heat the ammonia during the 2.27 s, expressed in scientific notation, is $\boldsymbol{a.bc} \times 10^{\boldsymbol{d}}$ J. 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.

A lump of clay with a mass of $50.0\ \text{g}$ is moving south at a speed of $20.0\ \text{cm/s}$. It collides head on with a second lump of clay with a mass of $70.0\ \text{g}$ that is moving north at a speed of $40.0\ \text{cm/s}$.

1. The two lumps stick together, and no external horizontal forces act on the system. The **velocity** of the combined lump after the collision is

A. 60.0 cm/s, south

B. 31.7 cm/s, south

C. 20.0 cm/s, north

D. 15.0 cm/s, north

---

2. A hair dryer rated at $1.00 \times 10^3\ \text{W}$ operating on a $1.10 \times 10^2\ \text{V}$ power line draws a current of

A. 0.0826 A

B. 0.110 A

C. 9.09 A

D. 1.10×10^5 A

3. A scalar field differs from a vector field in that

A. a scalar field acts in only one direction

B. a vector field acts in only one direction

C. direction is irrelevant for a scalar field

D. direction is irrelevant for a vector field

4. Newton's Law of Universal Gravitation has a mathematical relationship similar to the one developed by

A. Coulomb
B. Einstein
C. Lenz
D. Ohm

Use the following information to answer the next two questions.

Two conducting spheres have identical surface areas. Sphere ***A*** has a charge of 4.50 μC. Sphere ***B*** has a charge of –2.40 μC. Spheres ***A*** and ***B*** are brought into momentary contact and separated to a distance of 2.50 cm.

5. After contact, the charge on sphere ***A*** is

A. 1.05 μC
B. 2.10 μC
C. 3.45 μC
D. 6.90 μC

*Use your recorded answer for **Multiple Choice 5** to answer **Numerical Response 3.****

Numerical Response

3. The magnitude of the electric force exerted by sphere ***A*** on sphere ***B*** after contact and separation is ___________ N.

(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.**

6. The intensity and direction of the electric field produced by an alpha particle at a distance of 5.0×10^{-11} m from the particle is

A. 5.8×10^{11} N/C, toward the alpha particle

B. 5.8×10^{11} N/C, away from the alpha particle

C. 1.2×10^{12} N/C, toward the alpha particle

D. 1.2×10^{12} N/C, away from the alpha particle

7. The magnitude of an electric field at a distance x from a point charge Q is 8.3×10^{-4} N/C. If the distance is increased to $3x$ and the charge is reduced to $\frac{Q}{4}$, then the magnitude of the electric field will be

A. 1.9×10^{-3} N/C

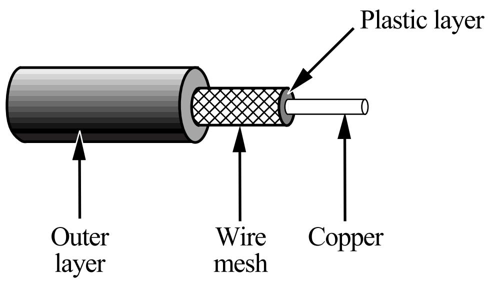
B. 3.7×10^{-4} N/C

C. 6.9×10^{-5} N/C

D. 2.3×10^{-5} N/C

Use the following information to answer the next question.

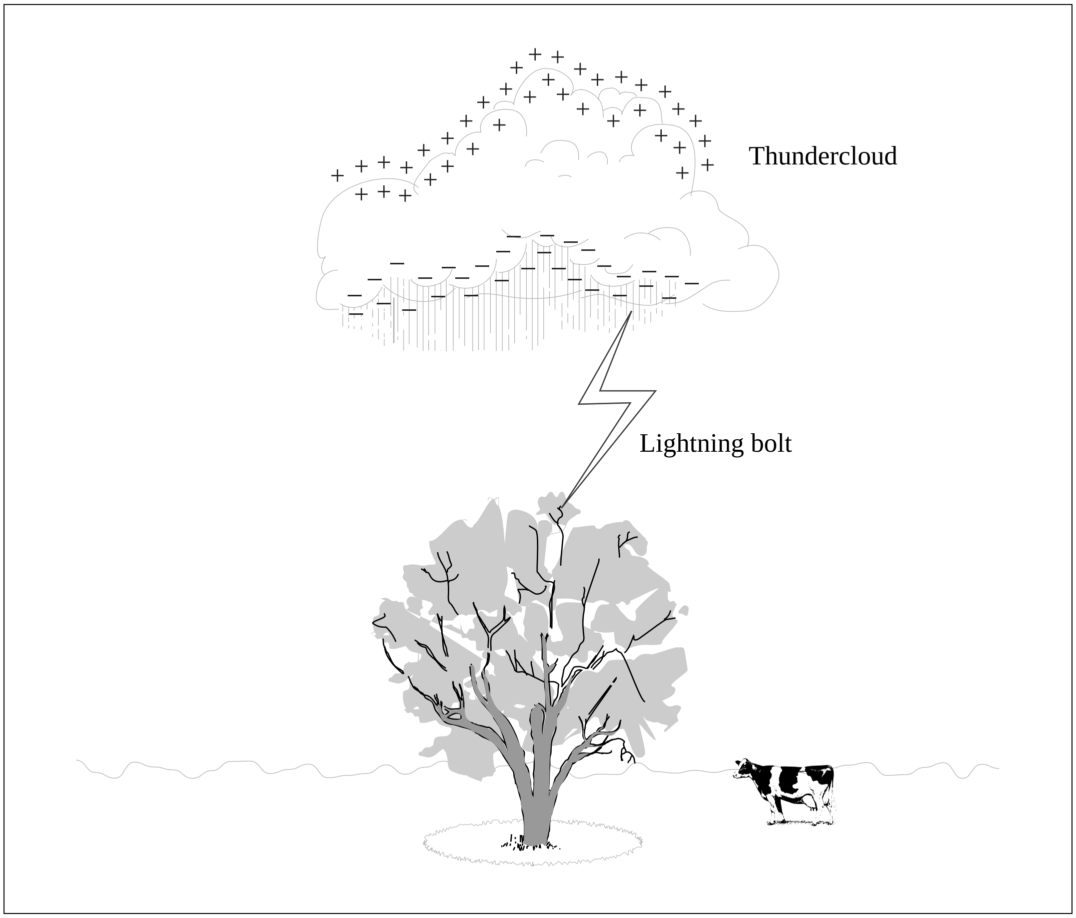
Cable TV sends its signals on a coaxial cable that has a central copper wire. This central wire is surrounded by a layer of plastic that is then surrounded by a conducting cylinder of fine wire mesh. The outer layer of the cable is a durable plastic.



8. The wire mesh layer is necessary because the

A. cable needs a rigid reinforcing layer
B. electric force inside a conductor is not zero
C. electrical signals need to be shielded from strong magnetic and electric fields
D. electrical signals will travel better if they have two different transmitting wires

Use the following diagram to answer the next three questions.



9. The bottom of a thundercloud usually becomes negatively charged. Before lightning strikes, the charge of the ground directly beneath the thundercloud will become

A. positive by induction

B. negative by induction

C. positive by conduction

D. negative by conduction

10. During the downward lightning strike, the charge on the top of the tree becomes

A. negative by induction

B. negative by conduction

C. neutral by induction

D. neutral by conduction

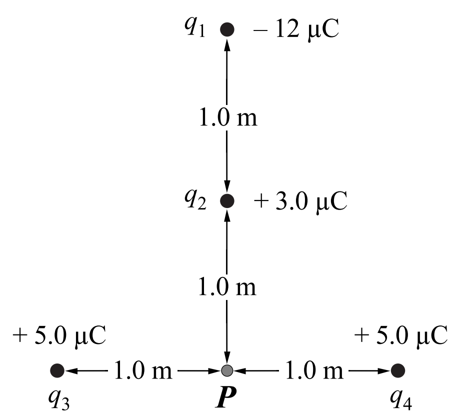
Numerical Response

4. A certain lightning bolt produces a temperature of 3.00×10^4 °C, a current of 8.00×10^4 A, and a voltage of 1.50×10^8 V. If the bolt lasts 1.20×10^{-5} s while striking a tree, the quantity of charge transferred to the tree, expressed in scientific notation, is $\boldsymbol{b} \times 10^{-w}$ C. 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.

Four point charges are arranged as shown.



11. The magnitude of the net electric field at point ***P*** due to these four point charges is

A. 5.4×10^4 N/C

B. 4.5×10^4 N/C

C. 2.7×10^4 N/C

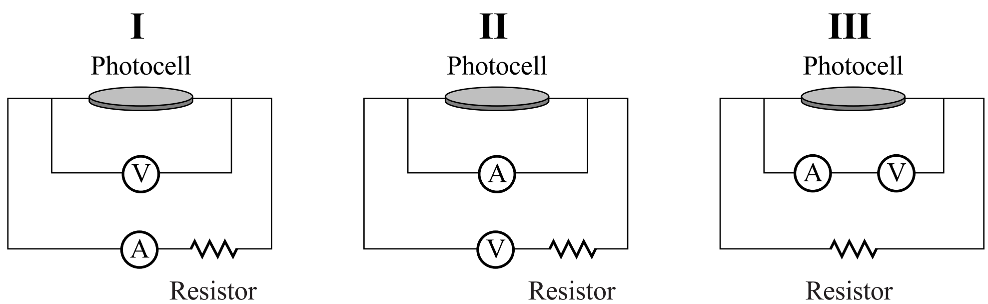
D. 0.0 N/C

Use the following information to answer the next two questions.

Solar-Powered Toy Car

A solar-powered toy car contains a photocell that converts solar energy into the electric energy needed to power its small electric motor. This electric motor converts the electrical energy into the mechanical energy necessary to move the toy car. The operation of the car depends on the amount of power produced by the photocell.

A student decides to investigate the factors affecting the power output of the photocell. The student connects a voltmeter, an ammeter, and a small resistor to the photocell in three different circuits.



12. Which of the three electrical circuits would properly measure the voltage and current output of the photocell?

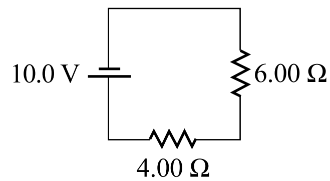
A. Circuit I only
B. Circuit II only
C. Circuit III only
D. Circuits I and II only

13. The power of the photocell could be expressed in units of

A. J/C
B. A/V
C. V/m
D. J/s

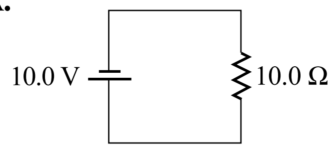
Use the following information to answer the next question.

A $6.00\ \Omega$ resistor and a $4.00\ \Omega$ resistor are placed in series across a potential difference of 10.0 V.

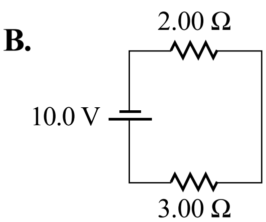


14. A circuit that would use four times as much power as the circuit above is

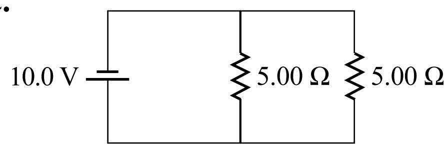
A.



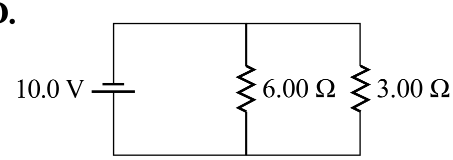
B.



C.

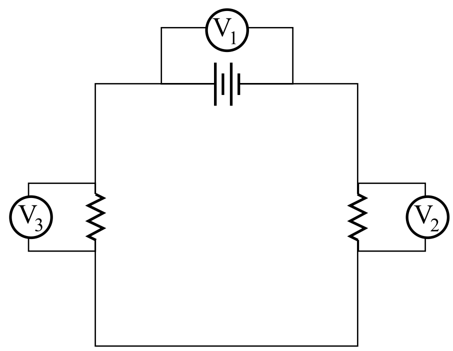


D.



Use the following information to answer the next question.

Three voltmeters are placed in a circuit as shown below.



15. For this circuit, the equation that would satisfy Kirchhoff's rule for potential difference is

A. $V_1 - V_3 = V_2$

B. $V_3 + V_1 = V_2$

C. $V_3 - V_2 = V_1$

D. $V_1 = V_2 = V_3$

---

16. A high-intensity halogen desk lamp operates at 1.25 A and 12.0 V AC. It has a built-in transformer to step down the 110 V AC obtained from the wall outlet. If the transformer is ideal, the current used from the wall outlet when the lamp is switched on is

A. 0.0873 A

B. 0.136 A

C. 1.25 A

D. 11.5 A

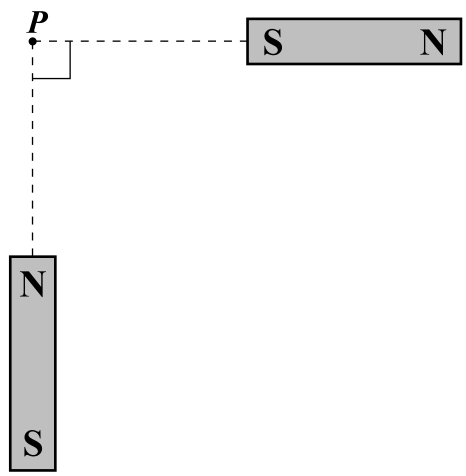
Numerical Response

5. A 50.0 cm length of wire has a weight of 0.389 N and a current of 0.250 A. The wire remains suspended when placed perpendicularly across a magnetic field. The strength of the magnetic field is __________ T.

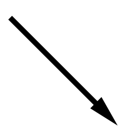
(Record your **three-digit answer** in the numerical-response section on the answer sheet.)

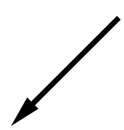
Use the following information to answer the next question.

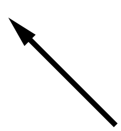
Two bar magnets of equal magnetic strength are placed as shown below. The point ***P*** is the same distance from each of the magnets.

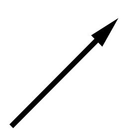


17. The direction of the magnetic field at ***P*** due to the two bar magnets is

A. 

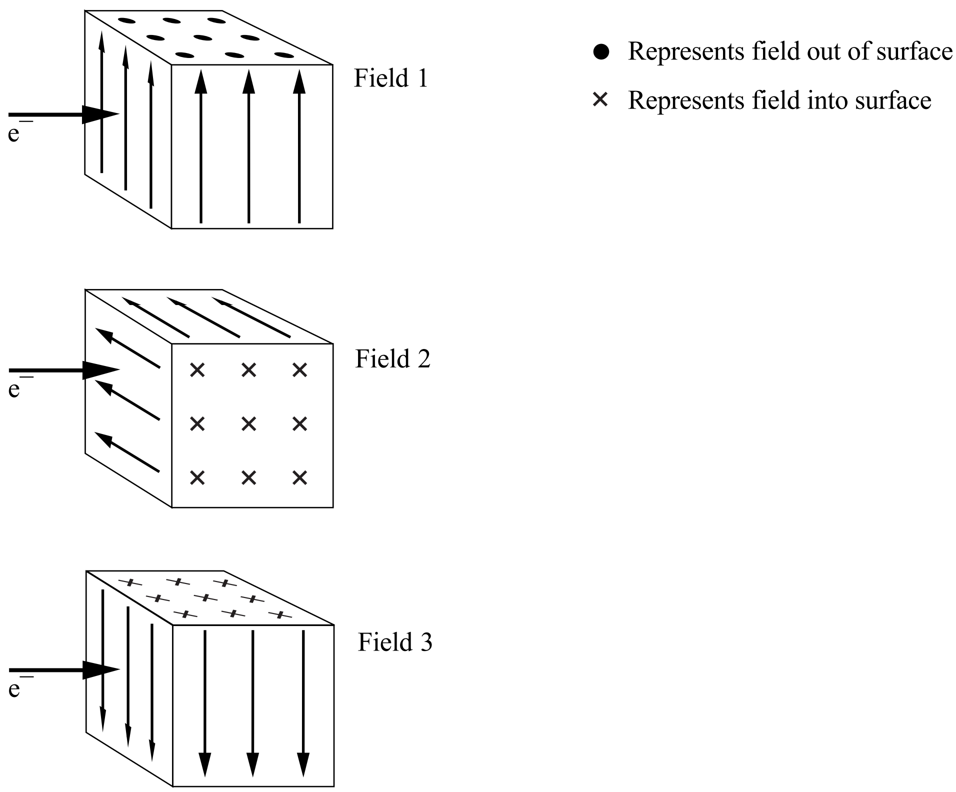
B. 

C. 

D. 

Use the following information to answer the next question.

Moving electrons can be deflected by electric fields, gravitational fields, and magnetic fields. One electron is allowed to enter each type of field, as shown below.



18. If the electron is deflected downward in each field, then field 1, field 2, and field 3 are, respectively,

A. electric, magnetic, and gravitational

B. gravitational, magnetic, and electric

C. magnetic, gravitational, and electric

D. magnetic, electric, and gravitational

Use the following information to answer the next question.

Selected Regions of the Electromagnetic Spectrum

I	television
II	AM radio
III	gamma radiation
IV	ultraviolet light
V	visible light

19. When the regions of the electromagnetic spectrum listed above are arranged in order of increasing wavelength, this order is

A. III, I, V, II, IV

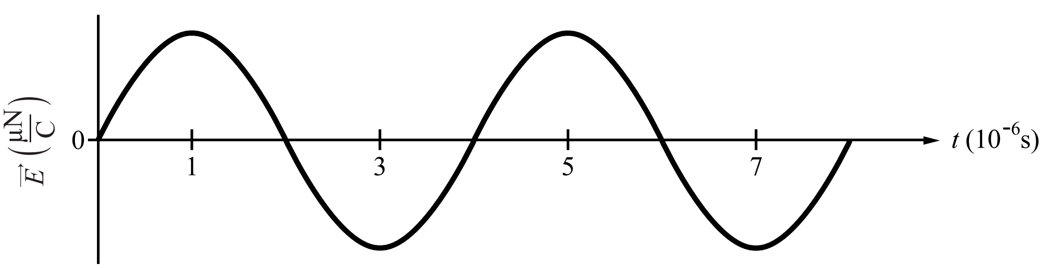
B. II, I, V, IV, III

C. III, IV, V, I, II

D. IV, V, III, I, II

Use the following diagram to answer the next question.

The Electric Field Component of an Electromagnetic Wave in a Vacuum



20. The wavelength of this electromagnetic wave is

A. 6.0×10^{2} m

B. 1.2×10^{3} m

C. 2.5×10^{5} m

D. 7.5×10^{13} m

Use the following information to answer the next three questions.

A fluorescent tube operates by exciting mercury atoms from their ground state to an excited state. The return of the atoms to a lower energy level results in the emission of electromagnetic radiation that cannot be seen.

Through a process called fluorescence, a phosphor powder coating on the inside of the glass tube converts the radiation emitted by the mercury atoms into electromagnetic radiation that can be seen.

A fluorescent light fixture draws 80.0 W of electrical power when connected to a 110 V AC power supply.

Numerical Response

6. The mercury atoms emit electromagnetic radiation with a wavelength of 254 nm. The minimum amount of energy that must be transferred to a mercury atom during excitation to enable this emission, expressed in scientific notation, is $\boldsymbol{b} \times 10^{-w}$ J. The value of ***b*** is __________.

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

21. The electromagnetic radiation emitted by the mercury atoms cannot be seen because it is

A. in the ultraviolet region
B. of too low an intensity
C. in the infrared region
D. of too slow a speed

22. In a circuit protected by a 15.0 A circuit breaker, the maximum number of fluorescent light fixtures that can be connected in parallel is

A. 21
B. 20
C. 1
D. 0

23. The threshold frequency of light for the emission of photoelectrons from a metal is 4.4×10^{14} Hz. If light of frequency 6.6×10^{14} Hz shines on the metal, then the maximum kinetic energy of the emitted photoelectrons is

A. 7.3×10^{-19} J

B. 4.4×10^{-19} J

C. 2.9×10^{-19} J

D. 1.5×10^{-19} J

24. J. J. Thomson's experiments indicated that cathode rays are

A. photons

B. electromagnetic radiation

C. positively charged particles

D. negatively charged particles

25. The highest X-ray frequency that can be produced by an X-ray tube operating at 6.5×10^{4} V is

A. 6.4×10^{-20} Hz

B. 1.0×10^{-14} Hz

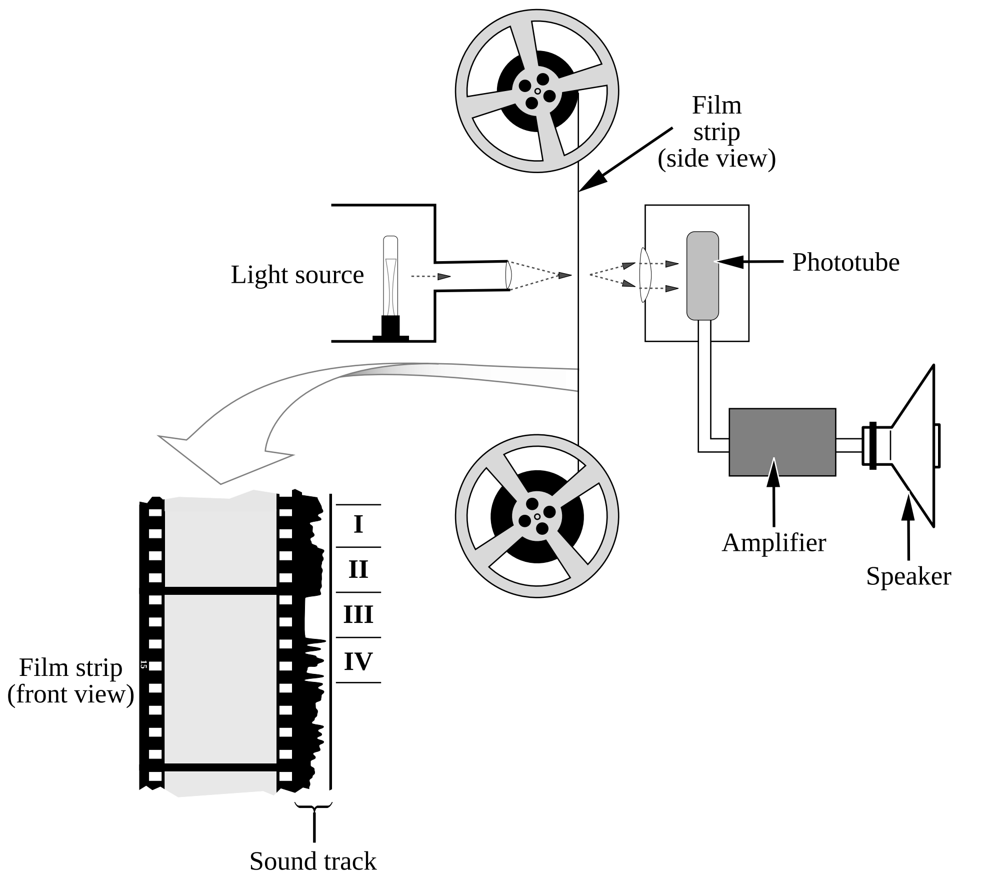
C. 1.6×10^{19} Hz

D. 3.2×10^{19} Hz

Use the following information to answer the next three questions.

An Application of the Photoelectric Effect

On movie film, the sound track is located along the side of the film strip and consists of light and dark regions. Light from the projector is directed through the sound track and onto a phototube. Variations in the transparency of the regions on the sound track allow varying intensities of light to reach the phototube.



26. The region of the sound track that will allow the most electrical current to be produced in the phototube is labelled

A. I
B. II
C. III
D. IV

27. The energy that is required to remove the electron from the photoelectric surface in the phototube is called the

A. work function
B. threshold frequency
C. electric potential energy
D. maximum kinetic energy

Numerical Response

7. In one second, 1.45×10^{16} photons are incident on the phototube. If each of the photons has a frequency greater than the threshold frequency, then the maximum current to the amplifier, expressed in scientific notation, is $\boldsymbol{a.bc} \times 10^{-\boldsymbol{d}}$ A. The values of $\boldsymbol{a}$, $\boldsymbol{b}$, $\boldsymbol{c}$, and $\boldsymbol{d}$ 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.

Electron microscopes use the wave nature of electrons to detect objects that are too small to see with visible light. In order to detect an object, the wavelength used must be the same size or smaller than the object.

The momentum of a particle is related to its wavelength by the formula $p = \frac{h}{\lambda}$.

Important medical breakthroughs have resulted from viewing viruses that are 5.00×10^{-9} m in diameter.

Numerical Response

8. In order for a virus to be detected by an electron microscope, the minimum speed that the electrons must have in the electron microscope, 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.)

Numerical Response

9. For a 768 g sample of an unknown radioactive element, 48.0 g remain after 10.2 h. The half-life of the element is __________ h.

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

Use the following information to answer the next two questions.

In medical diagnosis, a patient may be injected with a radioactive isotope. As the isotope decays, the gamma ray emissions are detected and a computer builds images of the patient's blood flow and organs.

A radioactive isotope commonly used in medical diagnosis is technetium-99. This isotope has a half-life of 6.00 h and decays to a stable isotope by gamma ray emission.

28. If the biological processes that might eliminate some of the technetium-99 from the body are ignored, the maximum percentage of radioactive technetium-99 that could still be present in a patient's system 24.0 h after injection is

A. 12.5%

B. 6.25%

C. 2.00%

D. 0.841%

29. A photon of gamma radiation emitted by the radioactive decay of technetium-99 has an energy of 3.85 MeV. This radiation has a wavelength of

A. 5.17×10^{-26} m

B. 3.23×10^{-13} m

C. 3.10×10^{12} m

D. 9.29×10^{20} m

30. Polonium has more isotopes than any other element, and they are all radioactive. The isotope $^{218}_{84}\text{Po}$ has

A. 218 protons and 84 neutrons

B. 84 protons and 218 neutrons

C. 134 protons and 84 neutrons

D. 84 protons and 134 neutrons

31. Nuclear radiation exists in several different forms. Listed from greatest to least in their ability to penetrate human tissue, the order of three of these forms is

A. alpha, beta, gamma

B. gamma, beta, alpha

C. gamma, alpha, beta

D. alpha, gamma, beta

Use the following information to answer the next question.

When a neutron is captured by a nucleus of uranium-238, the event shown below occurs.

$$^{238}_{92}\text{U} + {}^{1}_{0}\text{n} \rightarrow {}^{239}_{92}\text{U}$$

The uranium-239 then undergoes a series of decays:

$$^{239}_{92}\text{U} \xrightarrow{\text{decay } \mathbf{I}} {}^{239}_{93}\text{Np} \xrightarrow{\text{decay } \mathbf{II}} {}^{239}_{94}\text{Pu}$$

32. In both decays I and II, the type of emitted particle is

A. an alpha particle

B. an electron

C. a neutron

D. a proton

33. When white light passes through a cool gas and then into a spectroscope, the spectrum produced is

A. a continuous spectrum
B. an absorption spectrum
C. a bright-line spectrum
D. an emission spectrum

Use the following information to answer the next three questions.

In 1939, four German scientists, Otto Hahn, Lise Meitner, Fritz Strassmann, and Otto Frisch, made an important discovery that ushered in the atomic age. They found that a uranium nucleus, after absorbing a neutron, splits into two fragments that each have a smaller mass than the original nucleus. This process is known as nuclear fission.

There are many possible fission reactions that can occur, two of which are shown below.

I $\quad {}^{1}_{0}n + {}^{235}_{92}U \rightarrow {}^{236}_{92}U \rightarrow {}^{141}_{56}Ba + {}^{92}_{36}Kr + 3\,{}^{1}_{0}n + \text{energy}$

II $\quad {}^{1}_{0}n + {}^{235}_{92}U \rightarrow {}^{236}_{92}U \rightarrow {}^{140}_{54}Xe + {}^{92}_{38}Sr + \boldsymbol{x}\,{}^{1}_{0}n + \text{energy}$

34. The value of $\boldsymbol{x}$ in reaction II is

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

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

The measurements given below indicate that the uranium-235 nucleus has a smaller mass than the mass of a corresponding number of free protons and neutrons. This difference in mass is called the mass defect.

Einstein's concept of mass-energy equivalence, $E = mc^2$, can be used to predict the energy that binds a nucleus together by using the mass defect.

mass of uranium-235 nucleus = 3.9021×10^{-25} kg
mass of proton = 1.6726×10^{-27} kg
mass of neutron = 1.6749×10^{-27} kg

Numerical Response

10. The mass defect of uranium-235, expressed in scientific notation, is $\boldsymbol{b} \times 10^{-w}$ kg. The value of $\boldsymbol{b}$ is __________.

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

*Use your answer for **Numerical Response 10** to answer **Numerical Response 11.****

Numerical Response

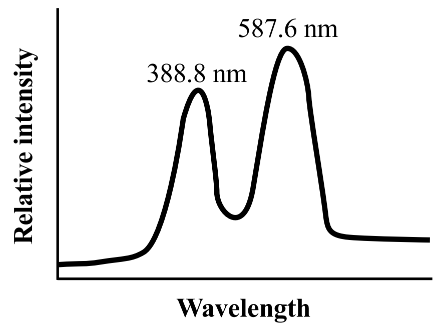
11. The nuclear binding energy of uranium-235, expressed in scientific notation, is $\boldsymbol{b} \times 10^{w}$ eV. The value of $\boldsymbol{b}$ is __________.

(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 question.

A computer monitor displays the relative intensities of two emission lines of the helium spectrum, as shown below.



35. The difference in energy associated with the photons from the two lines of the helium spectrum is

A. 1.60×10^{-19} J

B. 1.73×10^{-19} J

C. 4.07×10^{-19} J

D. 8.14×10^{-19} J

Use the following information to answer the next question.

When an electron makes the energy level transition from $n = 1$ to $n = 2$ in a hydrogen atom, it absorbs a photon with a frequency f_{12}. When an electron makes the transition from $n = 1$ to $n = \infty$ in a hydrogen atom, it absorbs a photon with a frequency of $f_{1\infty}$.

36. The ratio $f_{12} : f_{1\infty}$ is

A. 1:2

B. 1:4

C. 2:13

D. 3:4

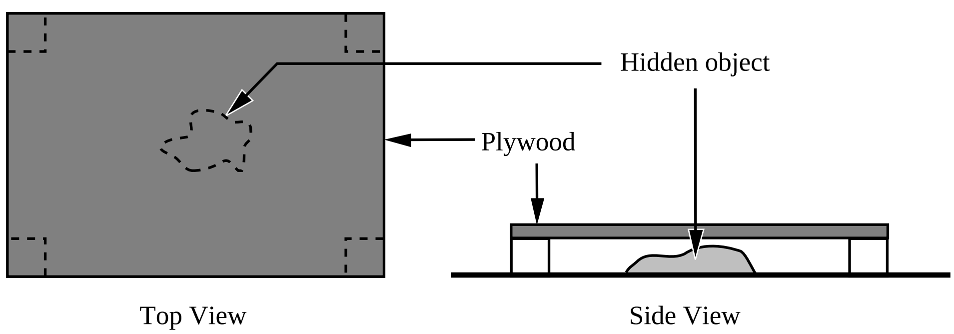
Numerical Response

12. In an excited hydrogen atom, an electron makes a transition from the third to the second energy level. The frequency of light emitted, 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 information to answer the next question.

Students attempt to determine the nature of an object that is hidden beneath a sheet of plywood by rolling marbles under the plywood.



37. This exercise would help students appreciate the difficulties encountered by

A. Compton in his work on wave–particle theory

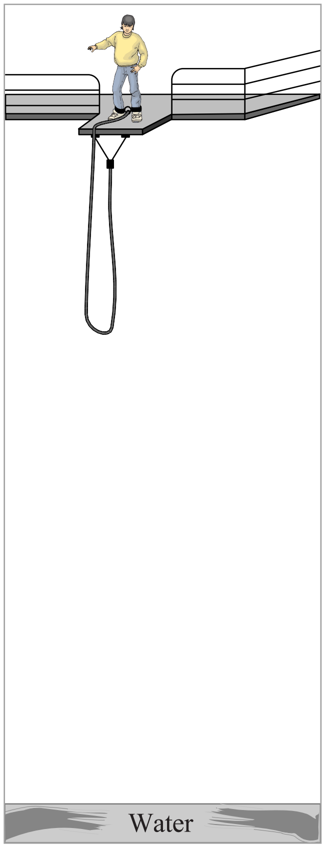
B. Einstein in his work on the photoelectric effect

C. Rutherford in his work on the nucleus of the atom

D. Thomson in his work on cathode rays

Written-response question 1 begins on the next page.

Use the following information to answer the next question.



One end of an elastic bungee cord is attached to a bungee jumper's ankles, and the other end is attached to a high platform. The cord stretches when a force is applied to it. The bungee jumper steps off the edge of the platform, comes to rest just above the water, and rises back up. The "jump" is considered over when the jumper is hanging head down from the end of the cord and is no longer moving.

Written Response — 15%

1. • Explain what happens to the bungee jumper from the time he steps off the edge until the time when he is closest to the water. In your answer:

—fully describe the mechanical energy transformations (gravitational potential energy, elastic potential energy, and kinetic energy) that occur

—fully describe the forces that act on the bungee jumper

• Clearly explain why an elastic bungee cord must be used rather than a standard rope. Use appropriate formulas to support your answer.

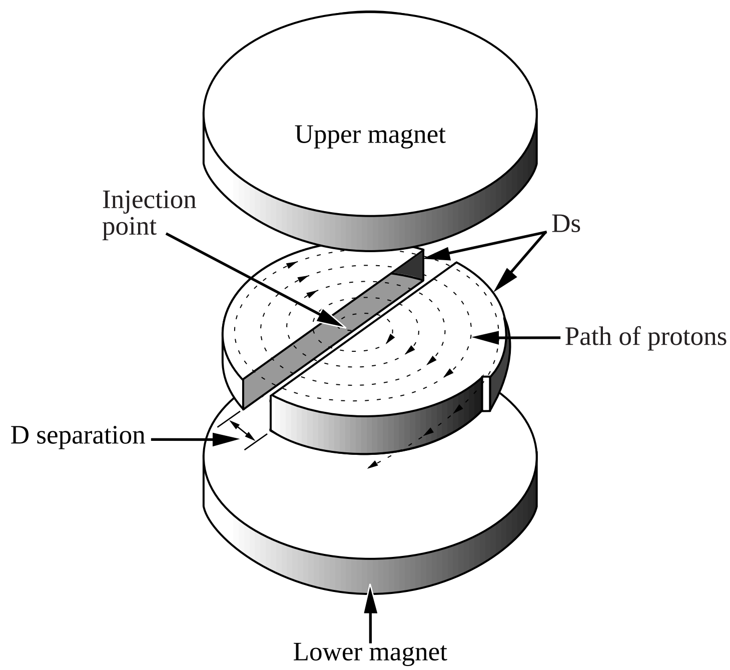
Note: Marks will be awarded for the physics principles used in your response and for the effective communication of your response.

Written-response question 2 begins on the next page.

Use the following information to answer the next question.

Cyclotron

A cyclotron is a particle accelerator that is constructed of two hollow metal shells shaped like Ds in a perpendicular magnetic field created by magnets, as shown below. The entire apparatus is placed in a vacuum. An alternating voltage is maintained across the D separation. Positively charged particles such as protons are injected near the centre of the Ds and travel in circular paths caused by the external perpendicular magnetic field. The frequency of the alternating voltage is adjusted to increase the speed of the particles each time they move across the Ds' separation.



Cyclotron Specifications

Magnetic field intensity	0.863 T
Maximum voltage across D separation	20 000 V
D separation	5.00 cm

Written Response — 15%

2.
- Determine the direction of the magnetic field needed to cause protons to circle in the direction shown. Justify your answer.
- Calculate the radius of the path of a proton travelling at 2.50×10^6 m/s.
- Calculate the speed of a proton after it passes once between the Ds, if it enters the space between the Ds at 2.50×10^6 m/s.

Use the following information to answer the remainder of this question.

The speed of a particle moving with circular motion and the time it takes the particle to complete one circular orbit are given by the formulas

$$v = \frac{2\pi R}{T} \text{ and } T = \frac{2\pi m}{qB_{\perp}}$$

- Beginning with force equations from the tear-out sheets, derive the formula for the period

$$T = \frac{2\pi m}{qB_{\perp}}$$

- Show that the units of $\frac{2\pi m}{qB_{\perp}}$ are equivalent to seconds.

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.

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** $9.81\ \text{N/kg}$
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	$c = 3.00 \times 10^{8}\ \text{m/s}$

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	$R_H = 1.10 \times 10^{7}\ \frac{1}{\text{m}}$

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^{+}

Trigonometry and Vectors

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

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

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

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

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

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

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

$$\vec{d} = \vec{v}_{\text{f}} t - \frac{1}{2}\vec{a}t^2$$

$$\vec{a} = \frac{\vec{v}_{\text{f}} - \vec{v}_{\text{i}}}{t}$$

$$\vec{d} = \left(\frac{\vec{v}_{\text{f}} + \vec{v}_{\text{i}}}{2}\right)t$$

$$\vec{d} = \vec{v}_{\text{i}} t + \frac{1}{2}\vec{a}t^2$$

$$v_{\text{f}}^2 = v_{\text{i}}^2 + 2ad$$

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

$$a_{\text{c}} = \frac{v^2}{r}$$

Dynamics

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

$$F_{\text{g}} = \frac{Gm_1m_2}{r^2}$$

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

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

$$\vec{F}_{\text{g}} = m\vec{g}$$

$$F_{\text{c}} = \frac{mv^2}{r}$$

$$F_{\text{f}} = \mu F_{\text{N}}$$

$$\vec{F}_{\text{s}} = -k\vec{x}$$

$$F_{\text{c}} = \frac{4\pi^2 mr}{T^2}$$

Momentum and Energy

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

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

$$W = Fd$$

$$E_{\text{p}} = mgh$$

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

$$E_{\text{p}} = \frac{1}{2}kx^2$$

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

Waves and Light

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

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

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

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

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

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

$$v = f\lambda$$

$$m = \frac{h_{\text{i}}}{h_0} = \frac{-d_{\text{i}}}{d_0}$$

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

$$\frac{1}{f} = \frac{1}{d_0} + \frac{1}{d_{\text{i}}}$$

Atomic Physics

$$hf = E_{\text{k}_{\text{max}}} + W$$

$$\frac{1}{\lambda} = R_{\text{H}}\left(\frac{1}{n_{\text{f}}^2} - \frac{1}{n_{\text{i}}^2}\right)$$

$$W = hf_0$$

$$E_{\text{k}_{\text{max}}} = qV_{\text{stop}}$$

$$E_{\text{n}} = \frac{1}{n^2}E_1$$

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

$$r_{\text{n}} = n^2 r_1$$

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

Quantum Mechanics and Nuclear Physics

$$E = mc^2$$

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

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

Electricity and Magnetism

$$F_{\text{e}} = \frac{kq_1q_2}{r^2}$$

$$V = IR$$

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

$$P = IV$$

$$\vec{E} = \frac{\vec{F}_{\text{e}}}{q}$$

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

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

$$F_{\text{m}} = IlB_{\perp}$$

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

$$F_{\text{m}} = qvB_{\perp}$$

$$V = lvB_{\perp}$$

$$R = R_1 + R_2 + R_3$$

$$\frac{N_{\text{p}}}{N_{\text{s}}} = \frac{V_{\text{p}}}{V_{\text{s}}} = \frac{I_{\text{s}}}{I_{\text{p}}}$$

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

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

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

Fold and tear along perforation.

Periodic Table of the Elements

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									

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

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.

Fold and tear along perforation.

mm

10
20
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210

Physics 30 – January 2000

MULTIPLE-CHOICE KEY

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

NUMERICAL-RESPONSE KEY

1.	4.44
2.	2273
3.	15.9*
4.	9.60
5.	3.11
6.	7.83, 7.84
7.	2323
8.	1.46, 1.45
9.	2.55
10.	3.18
11.	1.79**
12.	4.56, 4.57, 4.58

Link:

If MC5 is A, then NR3 is 15.9
B, then NR3 is 63.4
C, then NR3 is 171
D, then NR3 is 685

** NR11 = (NR10 × 0.5625)

Holistic Scoring Guide

Reporting Category: Physics COMMUNICATION

<table>
<tr><td colspan="2">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.</td></tr>
<tr><th>Score</th><th>Criteria</th></tr>
<tr><td>3</td><td>In the response, the student
• provides a complete, well organized, and clear solution to the problem
• presents, in detail, a strategy in a logical manner
• demonstrates consistency of thought
• uses physics vocabulary appropriately and precisely
• presents an explicit relationship between the explanation and diagrams (if used)
• states formula(s) explicitly
• may make a mathematical error, however, the error does not hinder the understanding of either the strategy or the solution</td></tr>
<tr><td>2</td><td>In the response, the student
• provides an organized response; however, errors sometimes affect the clarity
• presents 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
• presents an implicit relationship between explanation and diagrams (if used)
• uses formula(s) that he/she likely inferred by analyzing the calculations
• likely makes mathematical errors that may hinder the understanding of either the strategy or the solution</td></tr>
<tr><td>1</td><td>In the response, the student
• lacks organization, and errors affect the clarity
• attempts to present 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
• presents 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
• makes mathematical errors that hinder the understanding of the strategy and/or the solution</td></tr>
<tr><td>0</td><td>In the response, the student
• writes very little and/or presents very little relevant information
• presents 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
• does not present a relationship between the explanation, if present, and diagrams (if used)
• may state a formula, but it does not contribute toward the solution</td></tr>
<tr><td>NR</td><td>No response given.</td></tr>
</table>

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 major concepts and/or laws, and indicates where they apply to the solution • 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 provides 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.

"Anaholistic" Scoring Guide

<table>
<tr><td colspan="2">Major Concepts: Direction of magnetic field; Circular motion; Effect of electric field on moving charges; Formula derivation and unit analysis.</td></tr>
<tr><th>Score</th><th>Criteria</th></tr>
<tr><td>NR</td><td>No response is given.</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>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>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, but the answer is consistent with calculated results</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>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, 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</td></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, 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</td></tr>
</table>

Sample Response

- Determine the direction of the magnetic field needed to cause protons to circle in the direction shown. Justify your answer.

  The direction of the magnetic field is from the lower magnet to the upper magnet. This direction is determined using the right hand rule for positively charged particles in a magnetic field. The thumb indicates the direction of the proton's velocity, $\vec{v}$. The palm (or bent finger) indicates the direction of the magnetic force, F_m. The fingers (or index finger) indicates the direction of the upward magnetic field, $\vec{B}$.

  or

  The fingers indicates the direction of the proton's velocity, $\vec{v}$. The thumb indicates the downward direction of the induced magnetic field, $\vec{B}$. Applying Lenz's Law, the induced magnetic field will oppose the deflecting magnetic field. Therefore, the deflecting magnetic field between the magnets is upward.

- Calculate the radius of the path of a proton travelling at 2.50×10^6 m/s

$$\begin{aligned} F_\mathrm{m} &= F_\mathrm{c} \\ qvB_\perp &= \frac{mv^2}{r} \\ r &= \frac{mv}{qB_\perp} \end{aligned}$$

$$\begin{aligned} T &= T \\ \frac{2\pi m}{qB} &= \frac{2\pi r}{v} \\ r &= \frac{mv}{qB} \end{aligned}$$

$$r = \frac{(1.67 \times 10^{-27}\ \text{kg})(2.50 \times 10^{6}\ \text{m/s})}{(1.60 \times 10^{-19}\ \text{C})(0.863\ \text{T})}$$

$$r = 0.0302\ \text{m}$$

- Calculate the final speed of a proton after it passes once between the **D**'s, if its initial velocity entering the space between the **D**'s is 2.50×10^6 m/s.

Method I: Conservation of Energy

$$\begin{aligned}
\Delta E &= \Delta E_\text{k} \\
&= Vq = \tfrac{1}{2} m v_\text{f}^{\,2} - \tfrac{1}{2} m v_\text{i}^{\,2} \\
v_\text{f} &= \sqrt{\frac{2(Vq + \tfrac{1}{2} m v_\text{i}^{\,2})}{m}} \\
&= \sqrt{\frac{2[(20\,000\ \text{V})(1.60 \times 10^{-19}\ \text{C}) + \tfrac{1}{2}(1.67 \times 10^{-27}\ \text{kg})(2.50 \times 10^{6}\ \text{m/s})^2]}{1.67 \times 10^{-27}\ \text{kg}}} \\
v_\text{f} &= 3.18 \times 10^6\ \text{m/s}
\end{aligned}$$

Note: The incorrect solution $Vq = \tfrac{1}{2} m v_\text{f}^{\,2}$ gives a speed of 1.96×10^6 m/s

Method II: Dynamics and Kinematics

$$\begin{aligned}
\left|\vec{E}\right| &= \frac{F_\text{e}}{q} = \frac{V}{d} \\
F_\text{e} &= \left|\vec{E}\right| q = ma \\
\frac{V}{d} q &= ma \\
a &= \frac{Vq}{dm} \\
a &= \frac{(20\,000\ \text{V})(1.60 \times 10^{-19}\ \text{C})}{(5.00 \times 10^{-2}\ \text{m})(1.67 \times 10^{-27}\ \text{kg})} \\
a &= 3.832 \times 10^{13}\ \text{m/s}^2
\end{aligned}$$

$$\begin{aligned}
v_\text{f}^{\,2} &= v_\text{i}^{\,2} + 2ad \\
v_\text{f} &= \sqrt{(2.50 \times 10^{6}\ \text{m/s})^2 + 2(3.832 \times 10^{13}\ \text{m/s}^2)(5.00 \times 10^{-2}\ \text{m})} \\
v_\text{f} &= 3.18 \times 10^6\ \text{m/s}
\end{aligned}$$

- The speed of a particle moving with circular motion and the time it takes the particle to complete one circular orbit are given by the formulas

$$v = \frac{2\pi R}{T} \text{ and } T = \frac{2\pi m}{qB_\perp}$$

Beginning with force equations from the tearout Physics Data Sheet, derive the formula for the period,

$$T = \frac{2\pi m}{qB_\perp}$$

Method I

$$\begin{aligned} F_\mathrm{m} &= F_\mathrm{c} \\ qvB_\perp &= \frac{mv^2}{r} \\ qB_\perp &= m\left(\frac{2\pi R}{T}\right)\frac{1}{R} \\ T &= \frac{2\pi m}{qB_\perp} \end{aligned}$$

Method II

$$\begin{aligned} F_\mathrm{m} &= F_\mathrm{c} \\ qvB_\perp &= \frac{4\pi^2 mR}{T^2} \\ q\left(\frac{2\pi R}{T}\right)B_\perp &= \frac{4\pi^2 mR}{T^2} \\ T &= \frac{2\pi m}{qB_\perp} \end{aligned}$$

- Show that the units of $\frac{2\pi m}{qB_\perp}$ are equivalent to seconds.

$$\begin{aligned} T &= \frac{2\pi m}{qB_\perp} \\ \text{Unit of } T &= \frac{\mathrm{kg}}{(\mathrm{C})(\mathrm{T})} \\ &= \frac{\mathrm{kg}}{(\mathrm{C})\left(\frac{\mathrm{kg\cdot m/s^2}}{(\mathrm{C/s})(\mathrm{m})}\right)} \\ &= \frac{1}{\frac{1}{s}} \\ \text{Unit of } T &= s \end{aligned}$$