January 1998

Physics 30

Grade 12 Diploma Examination

Alberta
EDUCATION

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Physics 30

Grade 12 Diploma Examination

Description

Time: 2.5 h. You may take an additional 0.5 h to complete the examination.

Total possible marks: 70

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, worth a total of 30% of the examination

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

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

The blank 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

- Fill in the information required on the answer sheet and the examination booklet as directed by the presiding examiner.
- You are expected to provide your own scientific calculator.
- Use only an HB pencil for the machine-scored answer sheet.
- If you wish to change an answer, erase **all** traces of your first answer.
- Consider all numbers used in the examination to be the result of a measurement or observation.
- Do not fold the answer sheet.
- The presiding examiner will collect your answer sheet and examination booklet and send them to Alberta Education.
- Read each question carefully.
- 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.

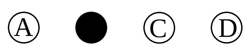
- Locate that question number on the separate answer sheet provided and fill in the circle that corresponds to your choice.

Example

This examination is for the subject of

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

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

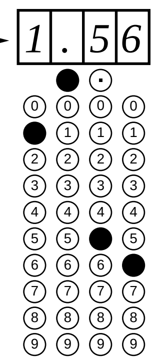
Calculation Question and Solution

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.
(Round and record your answer to three digits.)

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

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

Record 1.56 on the answer sheet →



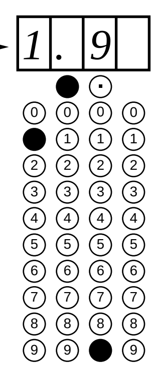
Calculation Question and Solution

A microwave of wavelength 16 cm has a frequency of $\boldsymbol{b} \times 10^{w}$ Hz.
The value of ***b*** is _________ .
(Round and record your answer to two digits.)

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

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

Record 1.9 on the answer sheet →



Correct-Order Question and Solution

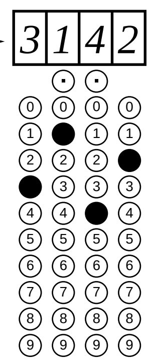
Place the following types of EMR in order of increasing energy:

1 blue light
2 gamma radiation
3 radio waves
4 ultraviolet radiation

(Record your answer as ☐☐☐☐ .)

Answer: 3142

Record 3142 on the answer sheet →



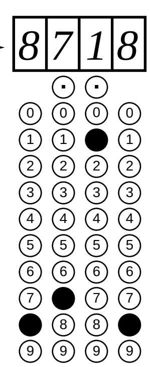
Scientific Notation Question and Solution

A hydrogen-like atom whose 3-2 transition emits light at 164 nm would have an E_1 value of $-\boldsymbol{a.b} \times 10^{-\boldsymbol{cd}}$ J. The values of ***a***, ***b***, ***c***, and ***d***, are ______.

(Record your answer as ***a*** ***b*** ***c*** ***d*** .)

Answer: $E_1 = -8.7 \times 10^{-18}$ J

Record 8718 on the answer sheet →

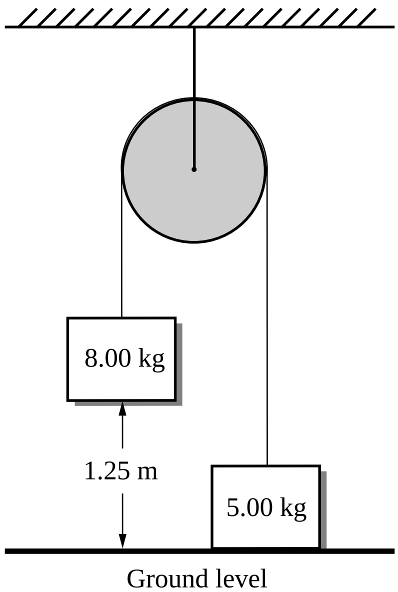


Written Response

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

Use the following information to answer the next three questions.

A physics student is investigating the conservation of mechanical energy in a system consisting of a massless, frictionless pulley and two blocks suspended by string. The student determines the potential energy with respect to ground level.



1. The initial total mechanical energy in this system is

A. 159 J

B. 98.1 J

C. 36.8 J

D. 0 J

2. Which of the following statements describes what happens when the blocks in the system are released?

A. The 8.00 kg block gains potential energy and loses kinetic energy.

B. The 8.00 kg block gains potential energy and gains kinetic energy.

C. The 5.00 kg block gains potential energy and loses kinetic energy.

D. The 5.00 kg block gains potential energy and gains kinetic energy.

3. While the blocks are moving, the total mechanical energy

A. increases
B. decreases
C. remains constant
D. varies, depending on the position of the blocks

Numerical Response

1. A goalie catches a 0.170 kg hockey puck travelling at a speed of 35.0 m/s. The maximum heat energy the impact could produce, expressed in scientific notation, is $\boldsymbol{b} \times 10^{w}$ J. The value of $\boldsymbol{b}$ is __________.

(Round and record your answer to three digits.)

Use the following information to answer the next two questions.

> A particle with a mass of 3.60×10^{-18} kg acquires 3.00×10^{5} eV of kinetic energy when it accelerates from rest through a potential difference of 1.00×10^{4} V.

4. The charge on the particle is

A. 4.80×10^{-18} C
B. 3.33×10^{-2} C
C. 3.00×10^{1} C
D. 2.08×10^{17} C

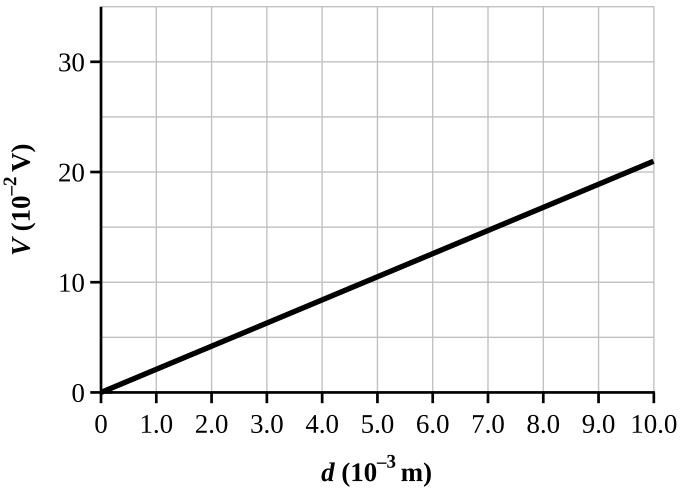
Numerical Response

2. The speed that the particle acquires, expressed in scientific notation, is $\boldsymbol{b} \times 10^{w}$ m/s. The value of $\boldsymbol{b}$ is __________ .

(Round and record your answer to three digits.)

Use the following information to answer the next three questions.

Potential Difference versus Plate Separation for Parallel Plates



5. The rate of change of potential difference with respect to the plate separation (d), in SI units, is

A. 0.048

B. 0.48

C. 2.1

D. 21

6. The proper SI units for the slope of the line on the graph are

A. J/m

B. V/m

C. V/s

D. N/s

7. The physical quantity that the slope represents is the electric

A. force

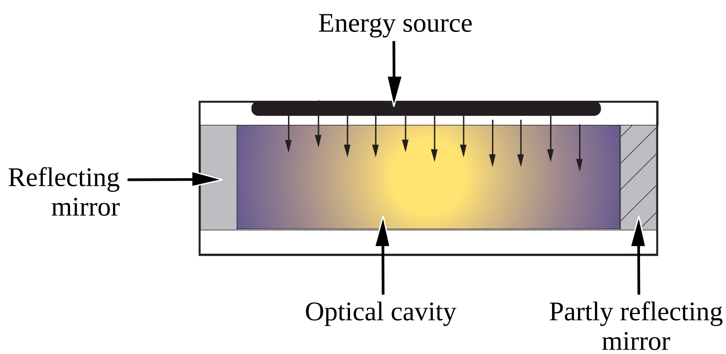
B. power

C. field strength

D. potential energy

Use the following information to answer the next three questions.

A survey team uses 25.0 W lasers to map terrain. The laser is composed of three main parts: an energy source, an active medium, and an optical cavity. The optical cavity encloses the active medium and two mirrors. The active medium in the laser is a low-density helium–neon gas mixture.



8. The 25.0 W laser is only 0.0200% efficient in converting electric energy into photon energy. The output power of the laser is

A. 5.00×10^{-3} W

B. 8.00×10^{-3} W

C. 1.25×10^{3} W

D. 3.14×10^{4} W

*Use your recorded answer from **Multiple Choice 8** to answer **Multiple Choice 9**.**

9. The beam of light from the laser has a wavelength of 633 nm. The number of photons per second emitted by the laser is

A. 9.99×10^{22}

B. 3.99×10^{21}

C. 2.55×10^{16}

D. 1.59×10^{16}

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

Numerical Response

3. In this laser, the mirrors are 17.0 cm apart. The time required for the photons to travel from one mirror to the other, expressed in scientific notation, is $\boldsymbol{b} \times 10^{-w}$ s. The value of $\boldsymbol{b}$ is __________.

(Round and record you answer to three digits.)

____

10. Scientists believe that chemical compounds found in far regions of space are the same as those found on Earth. Evidence for this has been provided in studies of

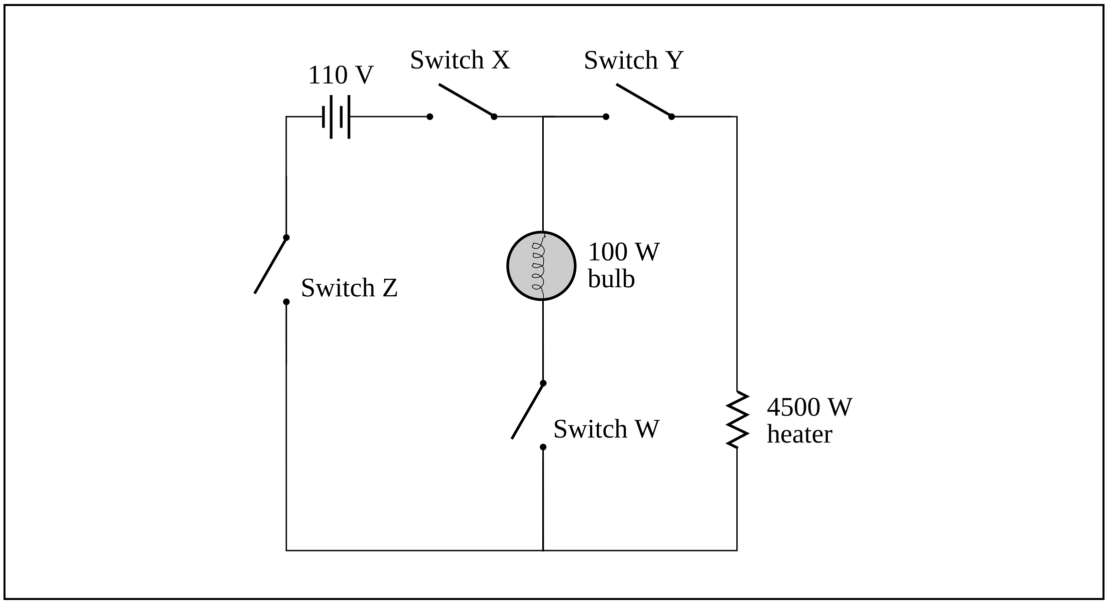
A. spectra

B. electricity

C. gravitation

D. magnetism

Use the following information to answer the next three questions.



11. An electric heater radiates energy at a rate of 4500 W when operated at a potential difference of 110 V. The resistance of the heater element is

A. $2.44 \times 10^{-2}\ \Omega$

B. $3.72 \times 10^{-1}\ \Omega$

C. $2.69\ \Omega$

D. $4.09 \times 10^{1}\ \Omega$

12. The switch that controls **only** the heater is labelled as

A. W

B. X

C. Y

D. Z

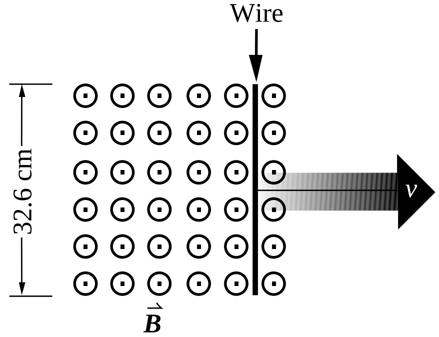
Numerical Response

4. When the 100 W bulb is lit, the current in the bulb, expressed in scientific notation, is $\boldsymbol{b} \times 10^{-w}$ A. The value of $\boldsymbol{b}$ is __________ .

(Round and record your answer to three digits.)

Use the following information to answer the next question.

A straight wire moves at a speed of 15.0 m/s at right angles to a magnetic field, as shown in the diagram. The wire is 32.6 cm long, and the magnitude of the magnetic field is 0.253 T.



Numerical Response

5. The potential difference between the ends of the wire is __________ V.

(Round and record your answer to three digits.)

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13. A transformer is used to change

A. alternating current to alternating current of a different magnitude
B. alternating current to constant direct current of the same magnitude
C. constant direct current to constant direct current of a different magnitude
D. constant direct current to alternating current of the same magnitude

14. Which of the following is an example of electromagnetic induction?

A. The forces two current-carrying wires exert on each other
B. The magnetic field produced by a constant current in a wire
C. The forces a magnet and a current-carrying wire exert on each other
D. The current produced in a wire loop by a changing magnetic field

15. A particle with a charge of 3.0×10^{-12} C moves with a speed of 2.0×10^{2} m/s at right angles to a magnetic field. The strength of the magnetic field is 0.400 T. The magnitude of the force acting on the particle due to the field is

A. 4.8×10^{-8} N

B. 2.4×10^{-10} N

C. 1.5×10^{-13} N

D. 1.3×10^{-17} N

16. An alpha particle passes without deflection through perpendicular electric and magnetic fields. The magnitude of the magnetic field is 2.20×10^{-2} T. The electric field is maintained by a 3.00×10^{2} V potential difference across plates that are 4.00 cm apart. The speed of the alpha particle is

A. 7.50×10^{3} m/s

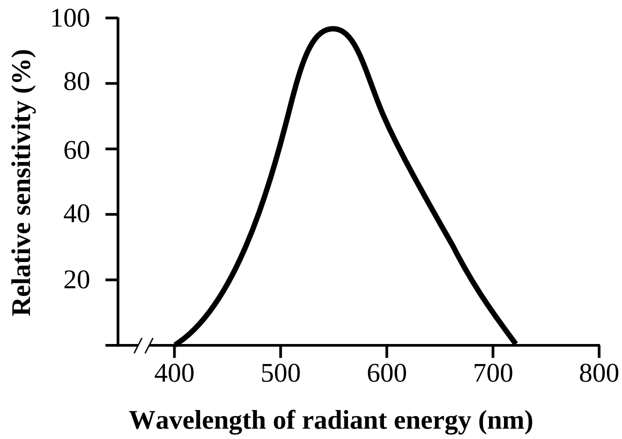
B. 1.36×10^{4} m/s

C. 1.20×10^{5} m/s

D. 3.41×10^{5} m/s

Use the following information to answer the next question.

The relative sensitivity of a normal human eye to radiant energy of fixed intensity is illustrated in the graph below.



17. The normal human eye shows the greatest sensitivity to

A. ultraviolet light
B. green light
C. violet light
D. red light

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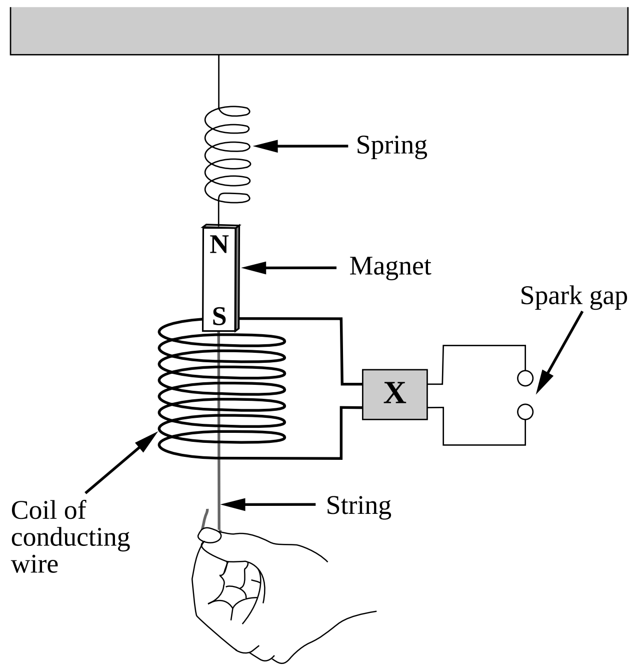
18. There is a relationship between the direction of propagation of an electromagnetic wave and the directions of its electric and magnetic fields. In this relationship, the electric and magnetic fields are

A. parallel to each other and parallel to the direction of propagation
B. parallel to each other and perpendicular to the direction of propagation
C. perpendicular to each other and parallel to the direction of propagation
D. perpendicular to each other and perpendicular to the direction of propagation

Use the following information to answer the next three questions.

Side View of an Electromagnetic Apparatus

During his studies of electromagnetism, a student proposes the following method of producing sparks.



The student pulls down on the string and then releases it, causing the magnet to oscillate. As the magnet moves downward and enters the coil from above, a current is induced in the coil.

19. To increase the voltage across the spark gap, which of the following components should be connected at **X**?

A. A resistor

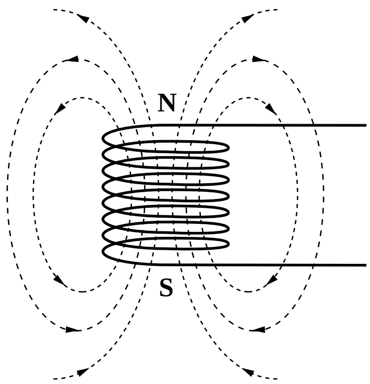
B. A transformer

C. A slip-ring commutator

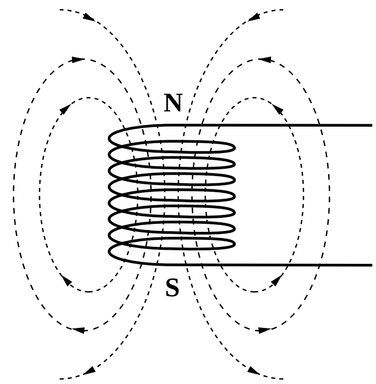
D. A split-ring commutator

20. Which of the following diagrams shows the direction of the magnetic field generated by the induced current in the coil as the magnet moves downward into the top of the coil?

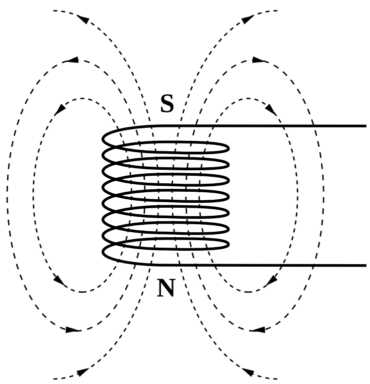
A.



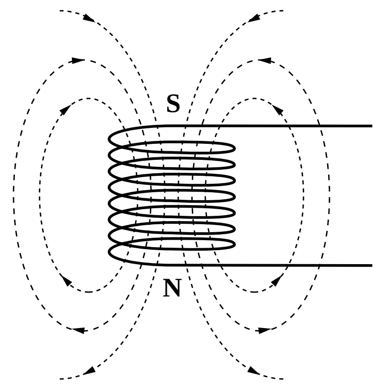
B.



C.



D.



21. If the effective voltage induced in the coil of conducting wire is 0.0500 V AC, the maximum induced voltage is

A. 0.0354 V

B. 0.0707 V

C. 0.100 V

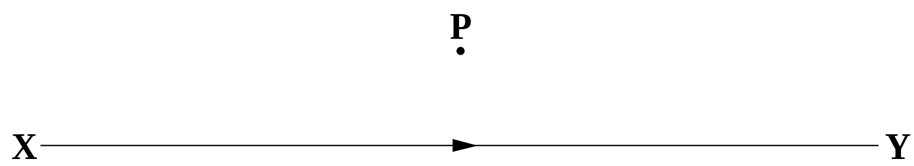
D. 0.0250 V

Use the following information to answer the next two questions.

XY represents a section of a current-carrying wire. **Conventional current** is flowing in the direction of the arrow. The magnetic field at any point around the wire is found using the formula

$$B = \frac{\mu_o I}{2\pi R},$$

where μ_o is a constant and R is the distance from the wire.



22. The direction of the magnetic field produced by the current in *XY* at point P is

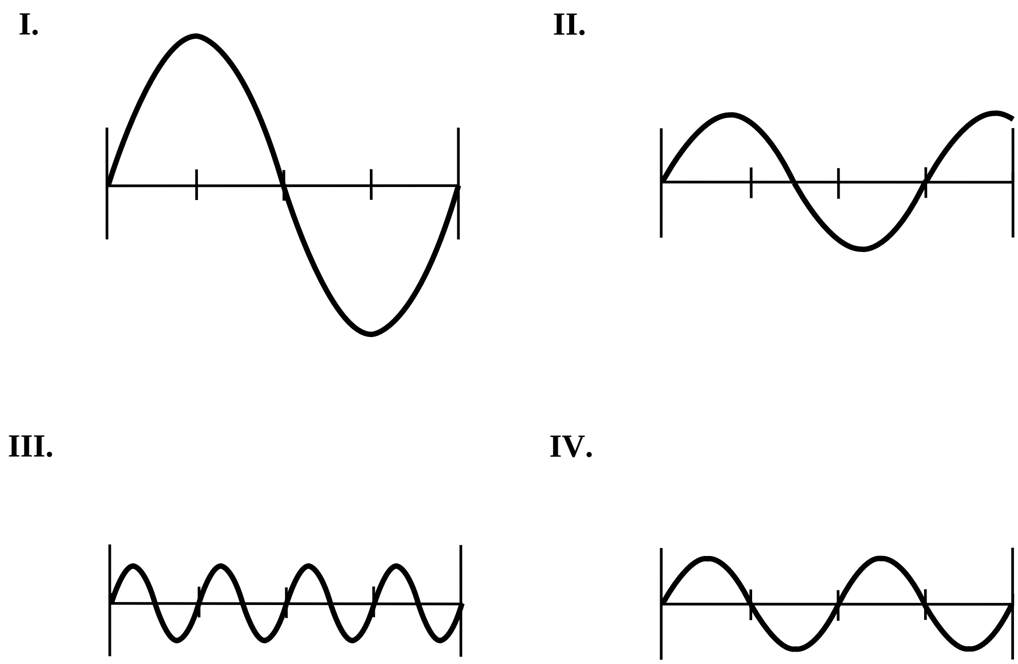
A. out of the page
B. to the right
C. into the page
D. to the left

23. If the current in conductor *XY* is doubled and all other variables remain constant, then the magnetic field strength at point P will

A. decrease to one-half of its present value
B. remain at its present value
C. increase to double its present value
D. increase to four times its present value

Use the following information to answer the next question.

Electromagnetic waves can be represented by the graphs of their electric fields. The following graphs represent the electric field of four electromagnetic waves over a fixed time interval.



24. According to quantum theory, the electromagnetic wave that has the greatest amount of energy per photon is represented by graph

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

Use the following information to answer the next three questions.

An experiment is designed to study the charge to mass ratio of hydrogen ions. Hydrogen ions, all moving in the same direction and with the same speed, *v*, are injected into a mass spectrometer. The magnitude of the magnetic field is varied, and the resulting radii of the path of the hydrogen ions are measured.

25. The equation that describes the radius of curvature of an ion's path is

A. $r = \frac{qB_{\perp}}{mv}$

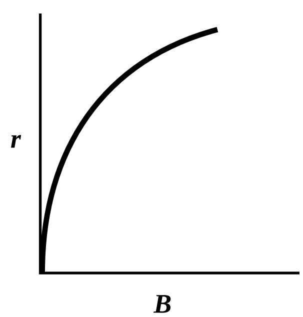
B. $r = \frac{mv}{qB_{\perp}}$

C. $r = \frac{qv}{mB_{\perp}}$

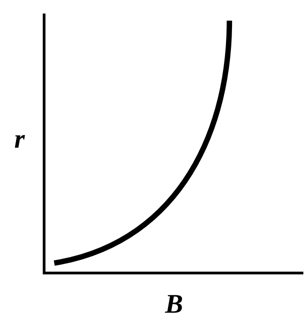
D. $r = \frac{mB_{\perp}}{qv}$

26. A graph that shows the relationship between the radius of curvature of a hydrogen ion's path and the strength of the magnetic field is graph

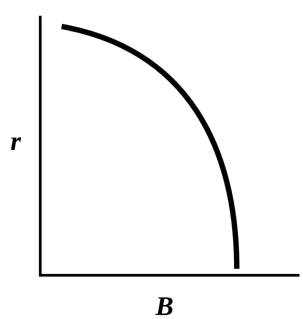
A.



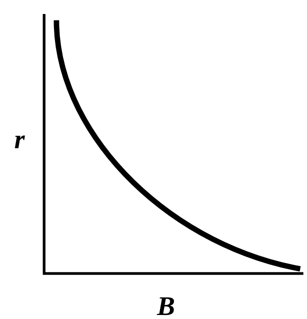
B.



C.

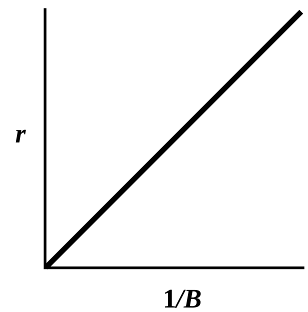


D.



Use the following additional information to answer the next question.

The manipulated variable in this experiment was modified in order to obtain the straight line graph shown below. The slope of this straight line graph can be used to determine the charge to mass ratio of a hydrogen ion.



27. Which of the following expressions gives the correct value for the charge to mass ratio?

A. Slope squared times speed

B. Slope divided by speed

C. Speed divided by slope

D. Speed times slope

Use the following information to answer the next question.

A student made the following statements with respect to infrared rays, microwaves, and ultraviolet light.

I. They all exhibit diffraction.
II. They all exhibit interference.
III. They all have the same frequency in a vacuum.
IV. They all have a speed of 3.00×10^8 m/s in a vacuum.

28. The statement made by the student that is **incorrect** is

A. I

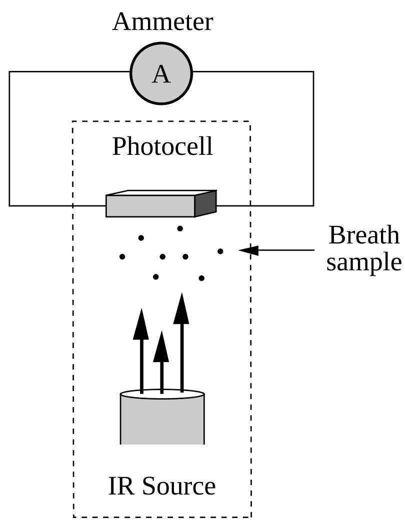
B. II

C. III

D. IV

Use the following information to answer the next three questions.

One type of breathalyzer involves illuminating a photocell (photoelectric surface) with infrared (IR) radiation of wavelength 9.50×10^{-6} m. Alcohol molecules absorb infrared radiation. A breathalyzer circuit is illustrated below.



The ammeter in the breathalyzer is calibrated to register a maximum reading with no alcohol sample between the detector and the IR source.

29. A breath sample containing alcohol is introduced into the analyzer. If it absorbs 50% of the radiation emitted by the infrared source, the current in the ammeter will be

A. halved

B. doubled

C. the same

D. quartered

Numerical Response

6. A current of 4.71×10^{-3} A passes through the ammeter for 30.2 s. The number of electrons that pass through the ammeter in that time, expressed in scientific notation, is $\boldsymbol{a.b} \times 10^{\boldsymbol{cd}}$. The values of ***a***, ***b***, ***c***, and ***d*** are __________.
(Record your answer as | *a* | *b* | *c* | *d* | .)

Numerical Response

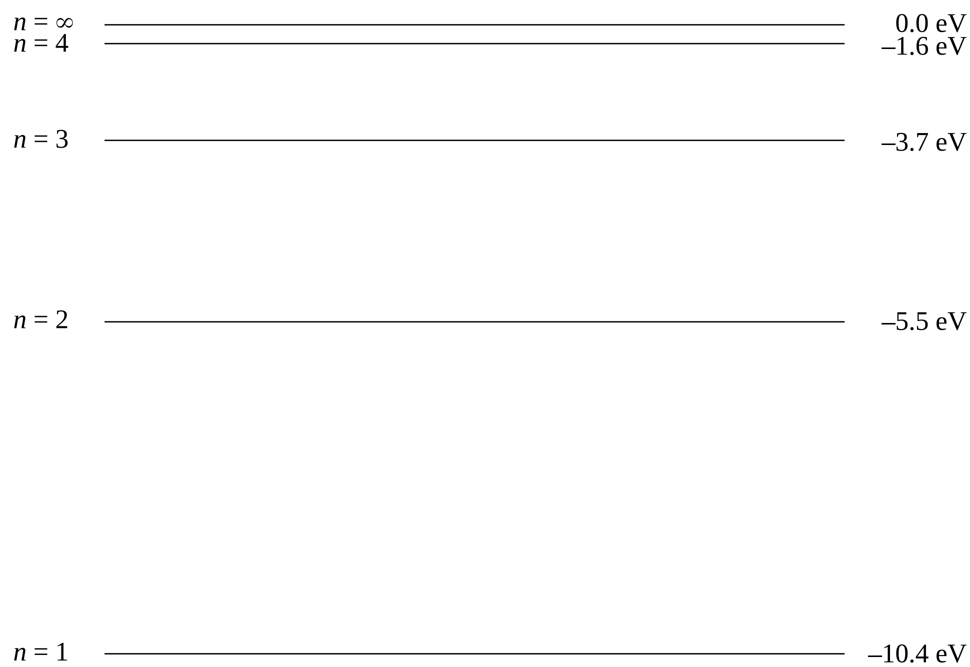
7. The energy of a photon of infrared radiation from this source, expressed in scientific notation, is $\boldsymbol{b} \times 10^{-w}$ J. The value of $\boldsymbol{b}$ is __________ .

(Round and record your answer to three digits.)

____

Use the following information to answer the next question.

Energy Levels of a Hypothetical Atom



Numerical Response

8. The energy required to ionize this atom when the electron is in the second energy level is __________ eV.

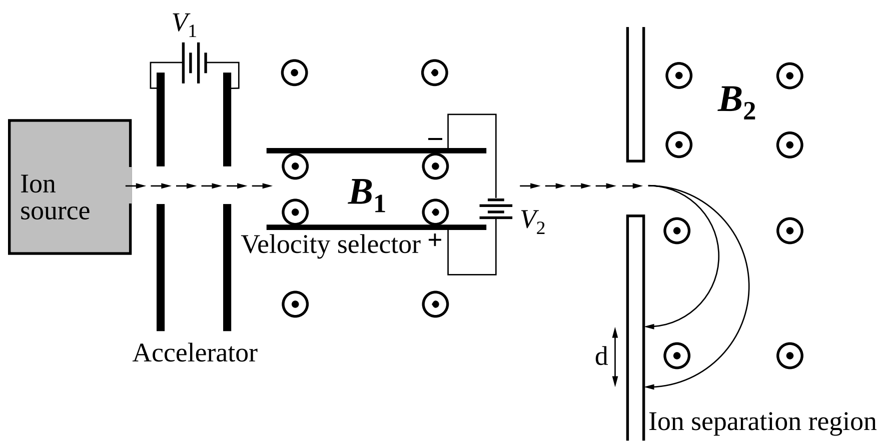
(Round and record your answer to two digits.)

Use the following information to answer the next three questions.

Carbon Dating Using a Mass Spectrometer

One method of determining the age of archeological remains is carbon dating. Of all carbon isotopes present in living tissue, 1.66×10^{-10}% are carbon-14. The radioactive half-life of carbon-14 is 5.73×10^{3} years. A mass spectrometer is a device that separates ions of different masses and can be used to determine the percentage of carbon-14 present in a sample.

In a mass spectrometer, a source produces gaseous ions that are accelerated by two vertical parallel plates that have a large potential difference between them. The beam of ions enters a velocity selector that allows only those ions with a specific velocity to pass through undeflected. Finally, the ions enter a magnetic field B_2 where the ions are separated according to their mass.



⊙ Indicates B_1 and B_2 directed perpendicularly out of the page.

A leather sandal from an archeological find is analyzed in order to determine the age of the sandal.

30. In the leather sandal, the mass spectrometer measures the carbon-14 content as 8.30×10^{-11}% of all carbon isotopes present. The approximate age of the sandal is

A. 1.43×10^{3} years

B. 5.73×10^{3} years

C. 1.15×10^{4} years

D. 2.29×10^{4} years

Numerical Response

9. The carbon atoms in the sandal are ionized by high-energy photons in the source chamber of the mass spectrometer. The ionization energy of carbon is 11.3 eV. The minimum frequency of radiation required in the source, expressed in scientific notation, is $\boldsymbol{b} \times 10^{w}$ Hz. The value of $\boldsymbol{b}$ is ___________ .

(Round and record your answer to three digits.)

31. The horizontal speed of the stream of carbon ions through the velocity selector is given by the expression

A. $\dfrac{|\vec{E}|}{B_1}$

B. $\dfrac{mg}{B_1 q}$

C. $\dfrac{mgd}{q}$

D. $\sqrt{\dfrac{F_e R}{m}}$

Use the following information to answer the next two questions.

In an experiment, a researcher studied the decay of $^{210}_{84}Po$, which decays by alpha emission and releases a stable $^{206}_{82}Pb$ atom. The half-life of $^{210}_{84}Po$ is 138.4 days. The mass of the sample of $^{210}_{84}Po$ at the start of the experiment was 34.0 g.

Numerical Response

10. The amount of $^{210}_{84}Po$ remaining after 415.2 days was __________ g.

(Round and record your answer to three digits.)

Numerical Response

11. At the end of the experiment, the amount of $^{210}_{84}Po$ remaining was 1.06 g. The duration of the experiment was __________ days.

(Round and record your answer to three digits.)

32. The wavelength of the photon emitted when the electron of a hydrogen atom makes a transition from the third energy level to the first energy level is

A. 1.0×10^{-7} m

B. 2.5×10^{-7} m

C. 5.5×10^{-7} m

D. 8.3×10^{-7} m

33. Experiments with cathode ray tubes led to the discovery of the

A. photon

B. neutron

C. electron

D. alpha particle

34. An oil drop with a mass of 5.74×10^{-16} kg is suspended between two horizontal parallel plates. The magnitude of the electric field between the plates is 5.00×10^{3} N/C. The magnitude of the charge on the drop is

A. 8.00×10^{-16} C

B. 1.13×10^{-18} C

C. 1.60×10^{-19} C

D. 1.15×10^{-19} C

35. A metal has a work function of 4.6 eV. The corresponding threshold frequency is

A. 6.9×10^{33} Hz

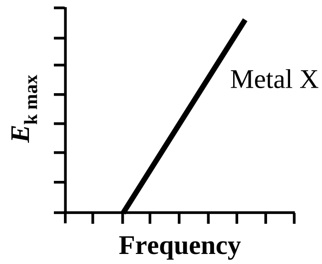
B. 1.1×10^{15} Hz

C. 9.0×10^{-16} Hz

D. 1.4×10^{-34} Hz

Use the following information to answer the next question.

Photoelectric Effect

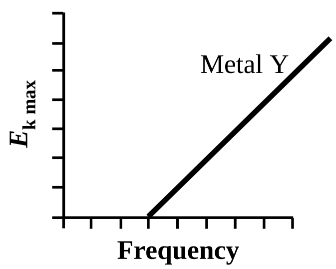


This graph shows the relationship between the maximum kinetic energy for emitted photoelectrons and the frequency of incident light for Metal X.

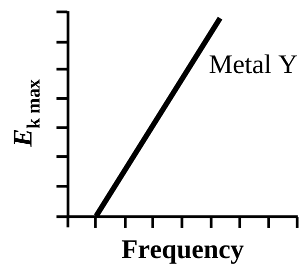
Note: The five graphs in this question are drawn to the same scale.

36. Metal Y has a different work function from Metal X. The graph that **could** represent the relationship between the maximum kinetic energy for emitted photoelectrons and the frequency of incident light for Metal Y is

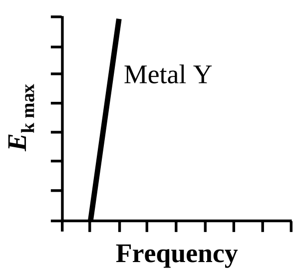
A.



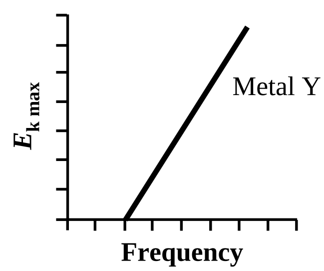
B.



C.



D.



37. The element $^{238}_{92}U$ undergoes radioactive decay until it attains a stable state as $^{206}_{82}Pb$. The first four stages of this decay series are

$$^{238}_{92}U \rightarrow {}^{234}_{90}Th \rightarrow {}^{234}_{91}Pa \rightarrow {}^{234}_{92}U \rightarrow {}^{230}_{90}Th.$$

The particles emitted in each of these steps are, respectively,

A. alpha, beta, beta, alpha
B. beta, alpha, alpha, beta
C. alpha, gamma, gamma, alpha
D. gamma, alpha, alpha, gamma

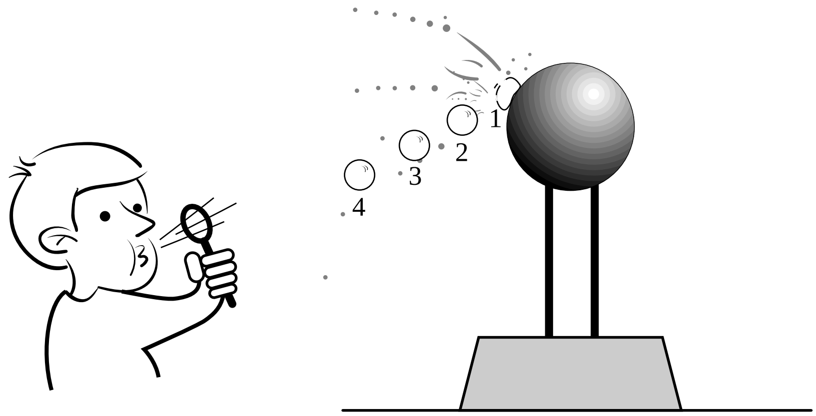
Numerical Response

12. The minimum potential difference through which an electron must be accelerated to produce an X-ray of energy 1.62×10^4 eV, expressed in scientific notation, is $\boldsymbol{b} \times 10^w$ V. The value of $\boldsymbol{b}$ is __________.

(Round and record your answer to three digits.)

Written-response question 1 begins on the next page.

Use the following information to answer the next question.



In a classroom demonstration, the dome of a Van de Graaff generator was initially charged negatively. A stream of closely spaced neutral soap bubbles was blown toward the dome of the generator. Much to the surprise of the teacher and the students, the following observations were made:

- the bubbles were initially attracted to the top of the dome of the generator until the first bubble hit the dome
- the first bubble hit the dome and splattered
- all the other bubbles then stopped in mid-air
- the other bubbles were then repelled from the dome of the generator and from each other

Written Response – 15%

1. Using the concepts of electrostatic forces and charge distribution, explain

- why the soap bubbles were initially attracted to the top of the generator
- why, after the first soap bubble splattered, the other bubbles were repelled from the generator and from each other

A diagram or diagrams may help to clearly communicate your ideas.

Note: A maximum of 8 marks will be awarded for the physics used to solve this problem. A maximum of 3 marks will be awarded for the effective communication of your response.

Written-response question 2 begins on the next page.

Written Response – 15%

2. A compact car with a mass of 1.0×10^3 kg is moving at 1.0×10^1 m/s north along a single-lane road. At the same time, a full-size car with a mass of 2.0×10^3 kg is moving at 8.0 m/s south along the same road. The two cars collide head-on. Immediately after the collision, the compact car has a velocity of 4.0 m/s south. The interaction lasted 8.0×10^{-2} s.

- Determine the speed and direction of the full-size car immediately after the collision.
- Show that the collision was **not** elastic.
- Determine the magnitudes and the directions of the average forces of impact on the compact car and on the full-size car.

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 SHEETS

CONSTANTS

Gravity, Electricity, and Magnetism

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

Atomic Physics

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

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

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

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

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

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

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

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

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

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

Dynamics

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

$F_{\text{g}} = \frac{Gm_1 m_2}{r^2}$

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

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

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

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

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

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

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

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

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

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

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

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

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

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

$v = f\lambda$

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

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

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

Atomic Physics

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

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

$W = hf_0$

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

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

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

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

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

Quantum Mechanics and Nuclear Physics

$E = mc^2$

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

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

Electricity and Magnetism

$F_{\text{e}} = \frac{kq_1 q_2}{r^2}$

$V = IR$

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

$P = IV$

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

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

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

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

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

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

$V = lvB_{\perp}$

$R = R_1 + R_2 + R_3$

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

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

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

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

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

Key

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

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

( ) Indicates mass of the most stable isotope

Tear-out Page

Fold and tear along perforation.

Tear-out Page

Fold and tear along perforation.

Tear-out Page

PHYSICS 30

DIPLOMA EXAMINATION

JANUARY 1998

Multiple Choice
and
Numerical Response
Key

Draft
Written Response
Scoring Guide

Physics 30 – January 1998

MULTIPLE-CHOICE KEY

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

* if MC8 is A, then MC9 is D
B, then MC9 is C
C, then MC9 is B
D, then MC9 is A

NUMERICAL-RESPONSE KEY

1.	1.04
2.	1.63
3.	5.67
4.	9.09
5.	1.24
6.	8917
7.	2.09
8.	5.5
9.	2.73
10.	4.25
11.	692
12.	1.62

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>The response:
• is complete, well organized and clear
• demonstrates in detail a strategy in a logical manner
• demonstrates consistency of thought
• uses physics vocabulary appropriately and precisely
• demonstrates an explicit relationship between the explanation and diagrams (if used)
• explicitly states formula(s)
• may have a mathematical error present, but it does not hinder the understanding of either the strategy or the solution</td></tr>
<tr><td>2</td><td>The response:
• is organized, however, errors sometimes affect the clarity
• demonstrates a strategy but details are general and/or sometimes lacking
• demonstrates consistency of thought most of the time, however, some gaps in logic leave it somewhat open to interpretation
• uses physics vocabulary, however, it may not be precise
• demonstrates an implicit relationship between explanation and diagrams (if used)
• uses formula(s) that are likely inferred by analyzing the calculations
• likely has mathematical errors present that may hinder the understanding of either the strategy or the solution</td></tr>
<tr><td>1</td><td>The response:
• lacks organization and errors affect the clarity
• attempts to demonstrate a strategy but provides little or no detail
• demonstrates a lack of consistency of thought and it is difficult to interpret
• uses physics vocabulary, however, it is often misused
• demonstrates a weak relationship between the explanation and diagrams (if used)
• may not state formula(s), however, it is possible that they can be deciphered by analyzing the calculations
• has mathematical errors that hinder the understanding of the strategy and/or the solution</td></tr>
<tr><td>0</td><td>The response:
• has very little written and/or contains very little relevant information
• is not organized, and is confusing and/or frustrating to the reader
• does not demonstrate a strategy to solve the problem
• uses little or no physics vocabulary, however, if present, it is misused
• demonstrates no relationship between the explanation, if present, and diagrams (if used)
• may state formula but it does not contribute towards the solution</td></tr>
<tr><td>NR</td><td>No response given.</td></tr>
</table>

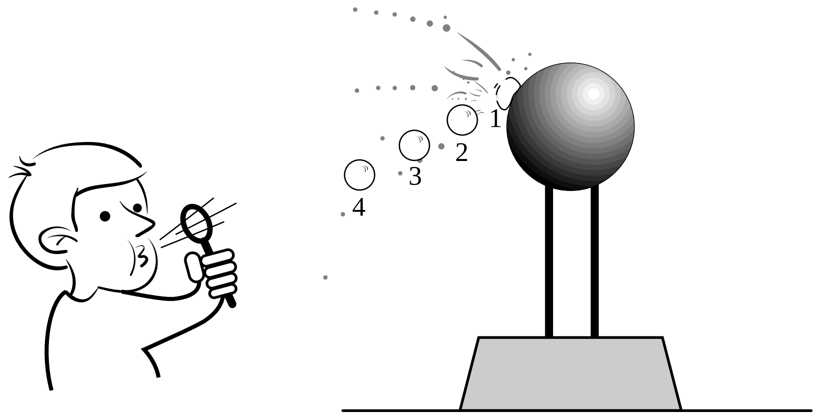
Holistic Scoring Guide

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	The response: • uses an appropriate method that reflects a **thorough understanding** of electrostatic principles including induction, attractive forces, conduction, and repulsive forces • provides a complete description of how these principles apply to the given observations • has, if used, diagrams and/or sketches that are appropriate, correct, and complete • has no major omissions or inconsistencies
3	The response: • uses an appropriate method that reflects a **good understanding** of electrostatic principles • provides a description of how these principles apply to the given observations • has, if used, diagrams and/or sketches 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	The response: • uses a method that reflects a **basic understanding** of electrostatic principles • provides a description that attempts to apply these principles to the given observations • has, if used, diagrams and/or sketches that may be appropriate, although some aspect is incorrect or incomplete • has inconsistencies or a major omission
1	The response: • uses a method that reflects a **poor understanding** of electrostatic principles • provides a description that restates the observations and makes reference to charges and forces • may have formula, however, the application is incorrect or inappropriate • has, if present, diagrams and/or sketches that are inappropriate, incorrect, and/or incomplete • has minor and major inconsistencies and/or omissions
0	The response: • uses a method that reflects little or no understanding of electrostatic principles • provides a description that is inappropriate • may have formula and substitution but they do not address the question • has, if present, diagrams and/or sketches that are incorrect, inappropriate, and incomplete • has major omissions
NR	No response is given.

Use the following information to answer the next question.



In a classroom demonstration, the dome of a Van de Graaff generator was initially charged negatively. A stream of closely spaced neutral soap bubbles was blown toward the dome of the generator. Much to the surprise of the teacher and the students, the following observations were made:

- the bubbles were attracted to the top of the dome of the generator until the first bubble hit the dome
- the first bubble splattered
- the other bubbles then stopped in mid-air
- the other bubbles were then repelled from the dome of the generator and from each other

Written Response – 15%

1. Using the concepts of electrostatic forces and charge distribution, explain

- why the soap bubbles were initially attracted to the top of the generator
- why, after the first soap bubble splattered, the other bubbles were repelled from the generator and from each other

A diagram or diagrams may help to clearly communicate your ideas.

Note: A maximum of 8 marks will be awarded for the physics used to solve this problem. A maximum of 3 marks will be awarded for the effective communication of your response.

The marks are arrived at in the following manner.
Take the level the response is at from the ***Holistic Scoring Guide Physics CONTENT*** and multiply by two $(4 \times 2 = 8)$.

Add the score from the ***Holistic Scoring Guide Physics COMMUNICATION*** $(8 + 3 = 11)$.

“Anaholistic” Scoring Guide

Major Concepts: Vector Analysis; Conservation of Momentum; Inelastic Collisions; Force	
Level	**Criteria**
NR	No response is given.
0	The response: • identifies an area of physics that does not apply to the major concepts • uses inappropriate formulas, diagrams, and/or explanations
1	The response: • attempts at least two of the major concepts **or** uses an appropriate method that reflects a good understanding of one of the major concepts • errors in the formulas, diagrams, and/or explanations are present and the answer is not consistent with calculated results
2	The response: • uses an appropriate method that reflects a basic understanding of three of the four major concepts **or** a good understanding of two of the major concepts • has formulas and/or diagrams that are implicitly correct, but the applications of these are not made to the final solution **or** errors in application of equations are present but the answer is consistent with calculated results
3	The response: • uses an appropriate method that reflects a basic understanding of all four of the major concepts **or** a good understanding of three of the major concepts • uses an appropriate method that reflects an excellent understanding of two of the major concepts **and** a basic understanding of one of the two remaining concepts • formulas and/or diagrams may be implicit, but are applied correctly; errors in calculations and/or substitutions are present which hinder the understanding of the physics content • explanations are correct but lack detail • has a major omission or inconsistency
4	The response: • uses an appropriate method that reflects a good understanding of all of the major concepts **or** an excellent understanding of three of the major concepts • explanations are correct and detailed • most formulas are explicit and are applied correctly • has minor errors, omissions, or inconsistencies in calculations and/or substitutions but these do not hinder the understanding of the physics content • most diagrams are appropriate, correct, and complete • may have errors in units, significant digits, rounding or graphing
5	The response: • uses an appropriate method that reflects an excellent understanding of all the major concepts • provides a complete description of the method used and shows a complete solution to the problem • explicitly states formulas • may have a minor error, or omission, or inconsistency, but it does not hinder the understanding of the physics content • diagrams are appropriate, correct and complete • may have an error in significant digits or rounding

Written Response – 15%

2. A compact car with a mass of 1.0×10^3 kg is moving at 1.0×10^1 m/s north along a single-lane road. At the same time, a full-size car with a mass of 2.0×10^3 kg is moving at 8.0 m/s south along the same road. The two cars collide head-on. Immediately after the collision, the compact car has a velocity of 4.0 m/s south. The interaction lasted for 8.0×10^{-2} s.

- Determine the speed and direction of the full-size car immediately after the collision.
- Show that the collision was **not** elastic.
- Determine the magnitudes and the directions of the average forces of impact on the compact car and on the full-size car.

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

- Determine the speed and direction of the full-size car immediately after the collision.

Momentum before collision must equal momentum after collision.

$\sum \vec{p}_i = \sum \vec{p}_f$: one dimensional problem N + S –

$$m_1\vec{v}_{1i} + m_2\vec{v}_{2i} = m_1\vec{v}_{1f} + m_2\vec{v}_{2f}$$

$$\vec{v}_{2f} = \frac{m_1\vec{v}_{1i} + m_2\vec{v}_{2i} - m_1\vec{v}_{1f}}{m_2}$$

$$\vec{v}_{2f} = \frac{(1.0 \times 10^3 \text{ kg})(1.0 \times 10^1 \text{ m/s}) + (2.0 \times 10^3 \text{ kg})(-8.0 \text{ m/s}) - (1.0 \times 10^3 \text{ kg})(-4.0 \text{ m/s})}{2.0 \times 10^3 \text{ kg}}$$

$$\vec{v}_{2f} = -1.0 \text{ m/s}$$

The velocity of the full-size car is 1.0 m/s south.

- Show that the collision was **not** elastic.

If the collision is elastic then kinetic energy is conserved.

$$\sum E_{k\,\mathrm{i}} = \sum E_{k\,\mathrm{f}} \quad \text{if the collision is elastic}$$

$$\sum E_{k\,\mathrm{i}} = \frac{1}{2}m_1 v_{1\mathrm{i}}{}^2 + \frac{1}{2}m_2 v_{2\mathrm{i}}{}^2$$

$$\sum E_{k\,\mathrm{i}} = \frac{1}{2}(1.0 \times 10^3\ \mathrm{kg})(1.0 \times 10^1\ \mathrm{m/s})^2 + \frac{1}{2}(2.0 \times 10^3\ \mathrm{kg})(8.0\ \mathrm{m/s})^2$$

$$\sum E_{k\,\mathrm{i}} = 1.14 \times 10^5\ \mathrm{J}$$

$$\sum E_{k\,\mathrm{i}} = 1.1 \times 10^5\ \mathrm{J}$$

$$\sum E_{k\,\mathrm{f}} = \frac{1}{2}m_1 v_{1\mathrm{f}}{}^2 + \frac{1}{2}m_2 v_{2\mathrm{f}}{}^2$$

$$\sum E_{k\,\mathrm{f}} = \frac{1}{2}(1.0 \times 10^3\ \mathrm{kg})(4.0\ \mathrm{m/s})^2 + \frac{1}{2}(2.0 \times 10^3\ \mathrm{kg})(1.0\ \mathrm{m/s})^2$$

$$\sum E_{k\,\mathrm{f}} = 9.0 \times 10^3\ \mathrm{J}$$

Since $\sum E_{k\,\mathrm{i}} > \sum E_{k\,\mathrm{f}}$, the collision was inelastic.

- Determine the magnitudes and the directions of the average forces of impact on the compact car and on the full-size car.

The force on the compact car is given by

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

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

$$= \frac{m(\vec{v}_{1\mathrm{f}} - \vec{v}_{1\mathrm{i}})}{\Delta t}$$

$$= \frac{(1.0 \times 10^3\ \mathrm{kg})(-4.0\ \mathrm{m/s}\ - 1.0 \times 10^1\ \mathrm{m/s})}{8.0 \times 10^{-2}\ \mathrm{s}}$$

$$F = -1.8 \times 10^5\ \mathrm{N}$$

The force on the full-size car is given by

$$\vec{F} = \frac{(2.0 \times 10^3\ \mathrm{kg})(-1.0\ \mathrm{m/s}\ - (-8.0\ \mathrm{m/s}))}{8.0 \times 10^{-2}\ \mathrm{s}}$$

$$F = 1.8 \times 10^5\ \mathrm{N}$$

The magnitude of the force on the compact car is 1.8×10^5 N and the direction is south. Since the forces on the compact car and the full-size car are an action–reaction pair, the magnitude of the force on the full-size car is 1.8×10^5 N and its direction is north.