June 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

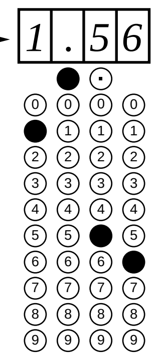
Calculation Question and Solution

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 →



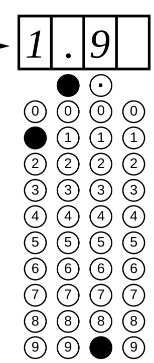
Calculation Question and Solution

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

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

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

Record 1.9 on the answer sheet →



Correct-Order Question and Solution

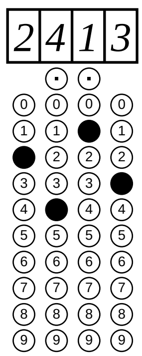
When the following subjects are arranged in alphabetical order, the order is ____, ____, ____, and ____ .

1 physics
2 biology
3 science
4 chemistry

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

Answer: 2413

Record 2413 on the answer sheet ⟶



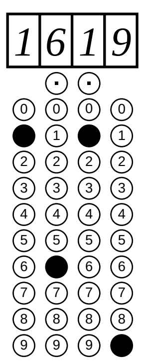
Scientific Notation Question and Solution

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

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

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

Record 1619 on the answer sheet ⟶



Written Response

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

1. The following statements all relate to a collision between any two objects on a horizontal frictionless surface. Which of these statements is **always true?**

- **A.** The kinetic energy of each object before and after the collision is the same.
- **B.** The momentum of each object before and after the collision is the same.
- **C.** The total momentum of the two objects before and after the collision is the same.
- **D.** With respect to the surface, the gravitational potential energy of each object before and after the collision increases.

2. A 500 g rock is thrown straight down from a bridge to the water 5.20 m below. If the rock strikes the water at a speed of 12.5 m/s, what was the initial speed of the rock?

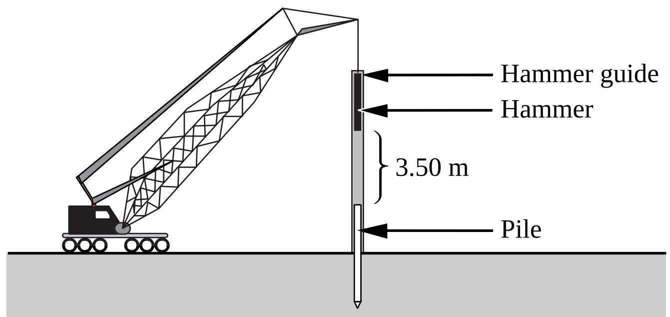
- **A.** 2.40 m/s
- **B.** 7.36 m/s
- **C.** 12.1 m/s
- **D.** 16.1 m/s

3. The concept of mechanical energy deals with the idea that

- **A.** mechanical energy is the amount of energy saved by a mechanical device
- **B.** mechanical energy is the sum of potential and kinetic energy
- **C.** potential energy and kinetic energy are always equal
- **D.** mechanical energy is a vector quantity

Use the following information to answer the next two questions.

Foundation piles for tall buildings are hammered into the ground using a "pile-driver." A pile-driver similar to the one shown below lifts a 900 kg hammer a distance of 3.50 m above the top of a pile, and then allows it to drop.



4. The magnitude of the impulse delivered by the hammer to the pile is

A. 61.8 kN·s
B. 30.9 kN·s
C. 7.46 kN·s
D. 3.73 kN·s

*Use your recorded answer for **Multiple Choice 4** to answer **Numerical Response 1.****

Numerical Response

1. The impulse is delivered by this pile-driver in 2.10×10^{-3} s. The magnitude of the force that the hammer exerts on the pile, expressed in scientific notation, is $\boldsymbol{b} \times 10^{w}$ N. The value of $\boldsymbol{b}$ is __________.

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

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

Use the following information to answer the next two questions.

A particular supertanker is fully loaded with oil and has a mass of 1.00×10^9 kg. The supertanker has a cruising speed of 20.0 km/h. One way to stop the ship is to reverse its engines. At maximum reverse thrust, the ship takes 32.0 min to stop.

Numerical Response

2. The momentum of the supertanker at cruising speed, expressed in scientific notation, is $\boldsymbol{b} \times 10^{w}$ kg·m/s. The value of $\boldsymbol{b}$ is __________.

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

Numerical Response

3. The kinetic energy of the supertanker at cruising speed, expressed in scientific notation, is $\boldsymbol{b} \times 10^{w}$ J. The value of $\boldsymbol{b}$ is __________.

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

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5. An empty freight car of mass m coasts along a track at 2.00 m/s until it couples to a stationary freight car of mass $2m$. The final speed of the two freight cars immediately after collision is

A. 1.50 m/s

B. 1.33 m/s

C. 1.15 m/s

D. 0.667 m/s

Use the following information to answer the next three questions.

On July 16, 1994, one of the fragments of comet Shoemaker-Levy 9 entered Jupiter's atmosphere travelling at 60.0 km/s.

As a comet fragment approaches a planet and before it enters the atmosphere, it gains kinetic energy according to the formula

$$\Delta E_{\mathrm{k}} = GM_{\mathrm{p}}m\left(\frac{1}{r_{\mathrm{f}}} - \frac{1}{r_{\mathrm{i}}}\right)$$

where G = gravitational constant
M_{p} = mass of the planet
m = mass of the fragment
r = distance from the centre of the planet to the fragment

As the fragment approached Jupiter's surface, the atmosphere became too dense for the fragment to push through. The fragment's tremendous kinetic energy was dissipated in an enormous explosion.

The mass of Jupiter is 318 times the mass of Earth. The mass of the comet fragment was 6 000 kg.

6. The kinetic energy of the comet fragment as it entered into Jupiter's atmosphere was

A. 1.08×10^{7} J

B. 1.80×10^{8} J

C. 1.80×10^{11} J

D. 1.08×10^{13} J

Numerical Response

4. The increase in kinetic energy of the Shoemaker-Levy 9 comet fragment as it moved from 8.50×10^{9} m to 1.00×10^{8} m from the centre of Jupiter, expressed in scientific notation, was $\boldsymbol{b} \times 10^{w}$ J. The value of $\boldsymbol{b}$ is ___________.

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

7. When the comet fragment's kinetic energy was dissipated in the explosion, most of this energy was converted to

A. potential and kinetic energy

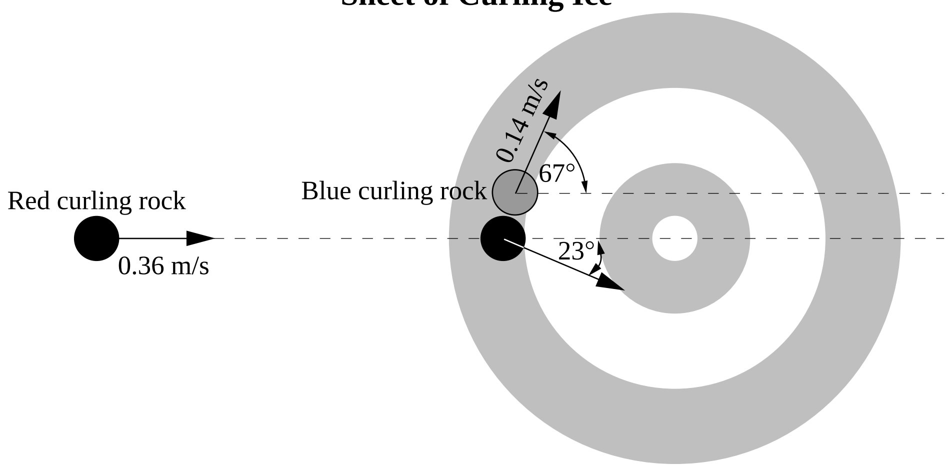
B. chemical energy only

C. light and heat

D. light only

Use the following information to answer the next question.

Sheet of Curling Ice



A red curling rock travelling straight down a sheet of ice at 0.36 m/s contacts a stationary blue curling rock. After contact, the blue rock moves at 0.14 m/s at an angle of 67° and the red rock moves at an angle of 23°, as illustrated. The mass of a curling rock is 18.8 kg.

8. The speed of the red rock, after contact, is

A. 0.15 m/s

B. 0.22 m/s

C. 0.33 m/s

D. 0.39 m/s

9. A rock climber falls and is saved from injuries by a climbing rope that is slightly elastic. The importance of the elasticity of the climbing rope can be understood in terms of impulse because elasticity results in

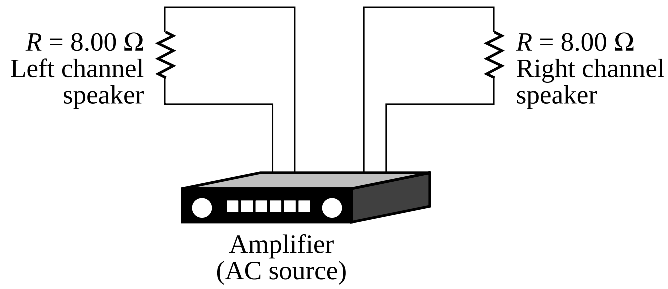
- **A.** decreased force during an increased time interval
- **B.** increased force during an increased time interval
- **C.** decreased force during a decreased time interval
- **D.** increased force during a decreased time interval

10. Two boys, Ted and Larry, initially at rest, push each other apart on a frictionless surface. Ted has a mass of 40 kg and Larry has a mass of 60 kg. After the boys push each other apart, Ted has a speed of 6 m/s. As the boys move apart, Larry has

- **A.** more momentum than Ted
- **B.** less momentum than Ted
- **C.** more kinetic energy than Ted
- **D.** less kinetic energy than Ted

Use the following information to answer the next two questions.

Speakers



At a particular volume setting, a stereo amplifier applies a maximum voltage of 30.0 V across each of two 8.00 Ω speakers.

11. The effective current in each speaker at this setting is

A. 1.88 A
B. 2.65 A
C. 3.75 A
D. 5.30 A

*Use your recorded answer for **Multiple Choice 11** to answer **Numerical Response 5.****

Numerical Response

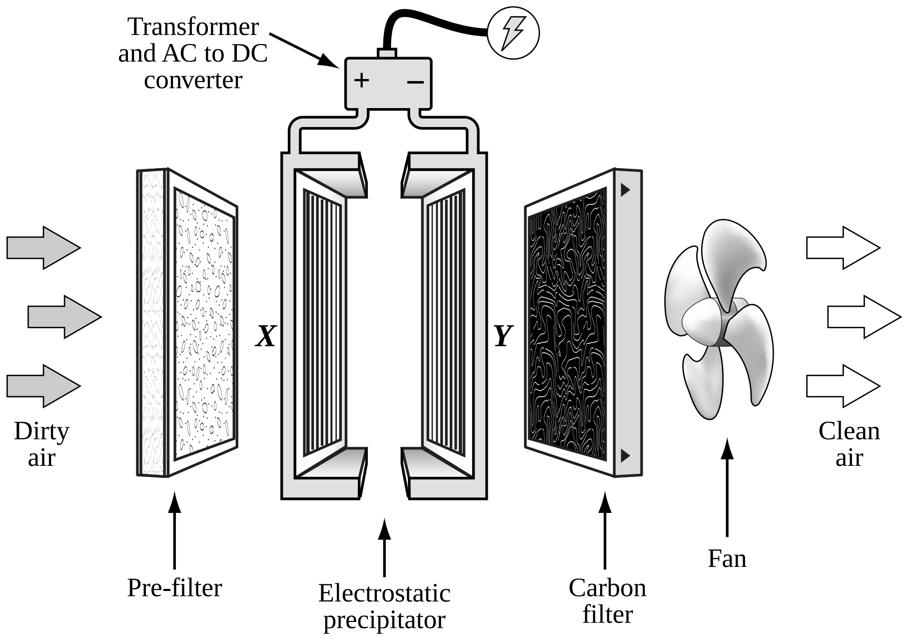
5. The average power dissipated in each speaker at this setting, expressed in scientific notation, is $\boldsymbol{b} \times 10^{w}$ W. The value of $\boldsymbol{b}$ is __________.

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

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

Use the following information to answer the next two questions.

Air Cleaner



One type of air cleaner uses a single-stage electrostatic precipitator to remove very fine particles, such as cigarette smoke and pollen, from the air in a room. The first grid, marked as ***X*** in the diagram, removes electrons from the particles through a combination of friction and electrostatic action. The particles pass through grid ***X*** and leave with a positive charge. The positively charged particles are then removed from the air stream by a negatively charged grid, marked as ***Y*** in the diagram. This cleaner also contains a pre-filter and a carbon filter to help remove dust and odours.

12. When particles are between grids ***X*** and ***Y***, they are repelled by

A. grid ***X*** and each other, but are attracted to grid ***Y***

B. grid ***Y*** and each other, but are attracted to grid ***X***

C. grid ***X*** but are attracted to each other and grid ***Y***

D. grid ***Y*** but are attracted to each other and grid ***X***

13. An electric field of magnitude 7.17×10^4 N/C is maintained between the grids of the electrostatic precipitator. The distance between grids ***X*** and ***Y*** is 5.60 cm. The potential difference across grids ***X*** and ***Y*** is

A. 1.28×10^6 V

B. 4.02×10^5 V

C. 1.28×10^4 V

D. 4.02×10^3 V

Use the following information to answer the next question.

Charged Spheres

The force exerted on sphere ***X*** by sphere ***Y*** has a magnitude of 6.0 N. A third sphere, ***Z***, with a charge –3.0 *Q* is introduced, as shown in the diagram.

14. The magnitude of the **net** force on sphere ***X***, due to spheres ***Y*** and ***Z***, is

A. 9.0 N

B. 12 N

C. 18 N

D. 24 N

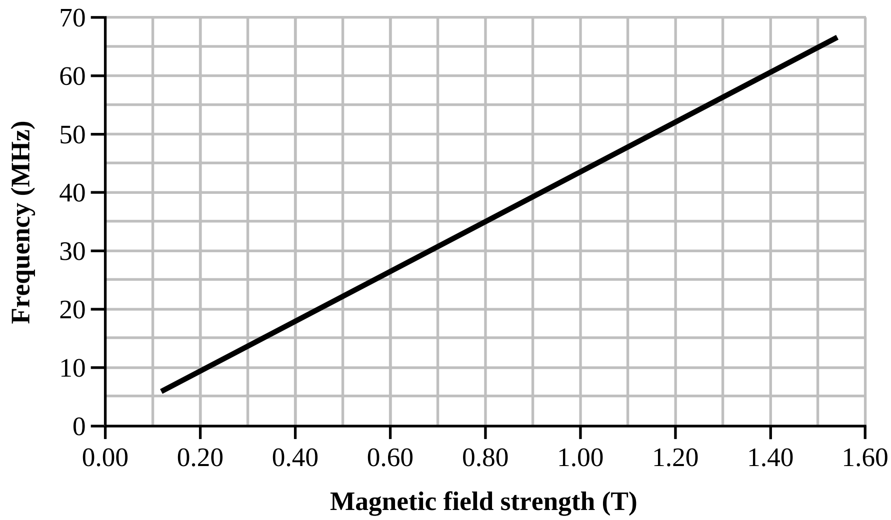
Use the following information to answer the next two questions.

Magnetic Resonance Imaging

Magnetic resonance imaging is used in medicine to produce images of a body's internal structures and tissues. This imaging technique relies on the interaction of nuclei with an external magnetic field.

When a hydrogen atom is placed in a magnetic field, it will absorb electromagnetic radiation (EMR) in the radio frequency range. The frequency absorbed varies as a function of the magnetic field strength.

Frequency as a Function of Magnetic Field Strength



The slope of the line in the graph above is called the gyromagnetic ratio.

15. The units of the gyromagnetic ratio will be

A. $\frac{\text{T}}{\text{MHz}}$

B. $\frac{\text{T}}{\text{s}}$

C. $\frac{1}{\text{T}\cdot\text{s}}$

D. T·MHz

Numerical Response

6. When a hydrogen atom is placed in a magnetic field with a strength of 0.80 T, the EMR wavelength absorbed is __________ m.

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

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16. A proton and an alpha particle have identical circular orbits in a magnetic field. The proton has a speed of 4.4×10^5 m/s. The speed of the alpha particle is

A. 1.1×10^5 m/s

B. 2.2×10^5 m/s

C. 4.4×10^5 m/s

D. 8.8×10^5 m/s

17. Extra-high-voltage lines carrying 600 kV are used to transmit electrical energy. A transformer must be used to reduce the voltage to 120 kV for use in a factory. If there are 500 turns on the primary coil, the number of turns on the secondary coil **and** the type of transformer used are, respectively,

A. 100 turns, step up

B. 2 500 turns, step up

C. 100 turns, step down

D. 2 500 turns, step down

Numerical Response

7. A small object carrying a charge of $3.47\ \mu\text{C}$ experiences an electric force of 7.22×10^{-2} N when placed at a distance, d, from a second, identically charged object. The value of d is __________ m.

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

Numerical Response

8. The number of excess electrons on a ball that has a charge of -3.60×10^{-17} C, expressed in scientific notation, is $\boldsymbol{a.bc} \times 10^{\boldsymbol{d}}$. The values of $\boldsymbol{a}$, $\boldsymbol{b}$, $\boldsymbol{c}$, and $\boldsymbol{d}$ are _____ , _____ , _____ , and _____ .

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

18. An electron accelerates from rest across the gap between charged parallel plates and reaches a final speed of v. If the potential difference across the plates is tripled, the final speed of an electron accelerating from rest across the gap will be

A. $\frac{1}{3}v$

B. $\frac{1}{\sqrt{3}}v$

C. $\sqrt{3}v$

D. $9v$

19. X-rays are produced by

A. an alternating current of about 10^{18} Hz

B. firing gamma rays at a tungsten electrode

C. varying the speed of electrons in a magnetic field

D. collisions between high-speed electrons and a metal target

Use the following information to answer the next question.

In 1996, the space shuttle Columbia attempted to drag a conducting tether through Earth's magnetic field. The tether was 2.07×10^4 m long. The average magnitude of Earth's magnetic field perpendicular to the tether was 9.02×10^{-6} T. The speed of the shuttle and tether was 8.00×10^3 m/s, relative to Earth's magnetic field.

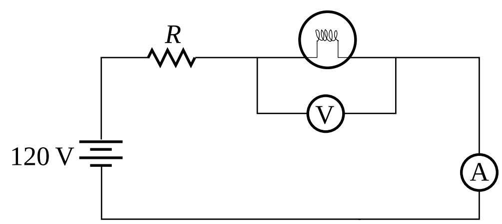
Numerical Response

9. The electric potential difference generated across the ends of the tether, expressed in scientific notation, was $\boldsymbol{a.bc} \times 10^{\boldsymbol{d}}$ V. The values of ***a***, ***b***, ***c***, and ***d*** are _____ , _____ , _____ , and _____ .

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

Use the following information to answer the next question.

Series Circuit



20. In the circuit above, the voltmeter reads 90 V and the ammeter reads 1.5 A. The value of the resistor, *R*, will be

A. 11 Ω

B. 20 Ω

C. 30 Ω

D. 80 Ω

Use the following information to answer the next two questions.

The following data were recorded from the back of a small microwave oven that has only one power setting.

Input	120 V (60 Hz AC)
Power Consumption	900 W
Frequency of Microwaves	2 450 MHz
Output Power	450 W

21. During its operation, the microwave oven draws a current of

A. 0.133 A
B. 0.267 A
C. 3.75 A
D. 7.50 A

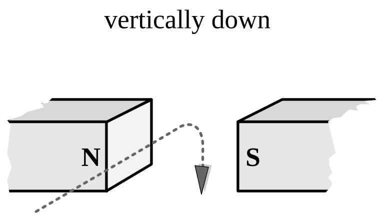
Numerical Response

10. The wavelength of the microwave radiation produced by the oven, expressed in scientific notation, is $\boldsymbol{a.bc} \times 10^{-\boldsymbol{d}}$ m. The values of $\boldsymbol{a}$, $\boldsymbol{b}$, $\boldsymbol{c}$, and $\boldsymbol{d}$ are _____ , _____ , _____ , and _____ .

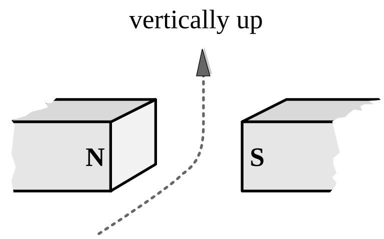
(Record all **four digits** of your answer in the numerical-response section on the answer sheet.)

22. The path followed by a moving proton in an external magnetic field is shown in

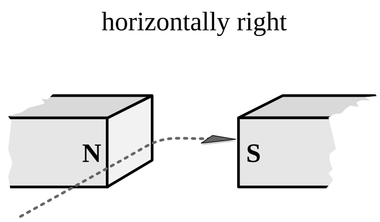
A.



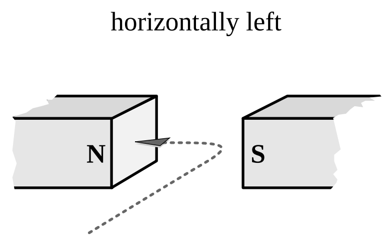
B.



C.



D.



23. A result that emerged from Einstein's work is the expression $E = pc$, where p is the magnitude of the momentum of a photon. The magnitude of the momentum of a 1.30×10^{2} eV photon is

A. 6.93×10^{-26} kg·m/s

B. 2.08×10^{-17} kg·m/s

C. 8.20×10^{-14} kg·m/s

D. 4.33×10^{-7} kg·m/s

24. The magnitude of the magnetic force exerted on a charged particle in a magnetic field will be doubled by doubling **any one** of

- **A.** the charge of the particle, or the speed of the particle, or the mass of the particle
- **B.** the magnitude of the field or the angle of entry of the particle
- **C.** the speed of the particle, or the mass of the particle, or the magnitude of the field
- **D.** the charge of the particle, or the speed of the particle, or the magnitude of the field

25. One $\frac{\text{N}\cdot\text{C}\cdot\text{m}}{\text{A}\cdot\text{m}\cdot\text{s}}$ is the same as

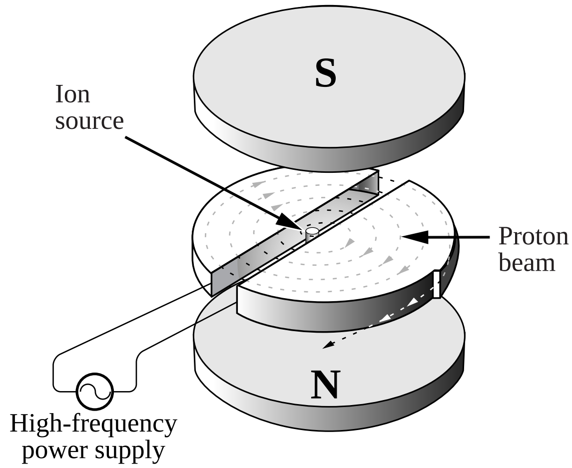
- **A.** 1 A
- **B.** 1 N
- **C.** 1 C
- **D.** 1 J

26. The particle nature of X-ray radiation is **best** demonstrated by the observation that X-rays

- **A.** exhibit the Compton effect
- **B.** have great penetrating ability
- **C.** are diffracted by pure crystals
- **D.** are not deflected by magnetic fields

Use the following information to answer the next two questions.

A cyclotron uses a magnetic field to move charged particles in a circular path. It also uses a high frequency power supply to repeatedly accelerate the particles.



Ernest Lawrence was the first person to use a cyclotron. His cyclotron accelerated protons to a maximum energy of 8.0×10^4 eV. With this energy, the protons moved in a circular path with a radius of 6.5×10^{-2} m.

27. The maximum speed of the protons in Lawrence's cyclotron was

A. 1.5×10^{13} m/s

B. 1.7×10^{8} m/s

C. 3.9×10^{6} m/s

D. 9.8×10^{15} m/s

*Use your recorded answer for **Multiple Choice 27** to answer **Multiple Choice 28.****

28. The magnitude of the magnetic field used by Lawrence was

A. 6.3×10^{-1} T

B. 2.7×10^{1} T

C. 2.4×10^{6} T

D. 1.6×10^{9} T

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

Use the following information to answer the next question.

Sources of Electromagnetic Radiation

1 Movement of outer electrons to lower orbitals
2 Deceleration of high-speed electrons
3 Decay of radioactive nuclei
4 Rotation of an armature in a generator

Numerical Response

11. Match each of the sources of electromagnetic radiation with the type of electromagnetic radiation it produces given below. Use each number only once.

Process:	__________	__________	__________	__________
Type:	**Gamma rays**	**Visible light**	**X-rays**	**Extremely low frequency wave (AC)**

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

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29. An ice rink is lit by a bluish light with a wavelength of 500 nm. The period of the light is

A. 1.67×10^{-15} s

B. 8.33×10^{-13} s

C. 6.00×10^{5} s

D. 6.00×10^{14} s

Numerical Response

12. The Compton Gamma Ray Observatory is a satellite that is able to detect electromagnetic radiation from throughout the universe. The Compton Observatory can detect photons ranging from 4.00×10^4 eV to 3.00×10^{10} eV. The highest frequency that can be detected, 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.)

30. Two scientists who conducted experiments that led to the determination of the mass of an electron were

A. Planck and Einstein
B. Rutherford and Bohr
C. Thomson and Millikan
D. Compton and de Broglie

31. In the photoelectric equation, the symbol W represents the

A. energy gain of the target metal
B. wavelength of the incident radiation
C. maximum wavelength of an emitted electron
D. minimum energy required to release an electron from a metal

32. Violet light striking the negative electrode in a phototube causes a current to flow in the tube. Under the same conditions, another form of light that will always cause a current to flow is

A. blue
B. green
C. infrared
D. ultraviolet

33. A photon of UV-B light with a wavelength of 2.90×10^{-7} m strikes an electron in a hydrogen atom in its ground state. As a result, the electron will

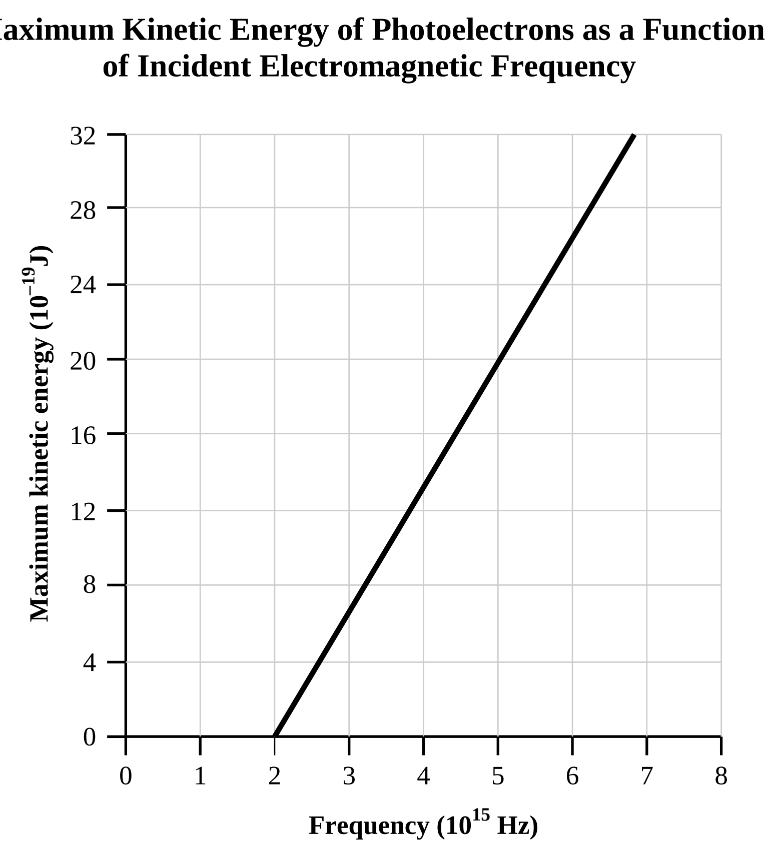
A. be raised to energy level 2

B. be raised to energy level 3

C. be raised to energy level 5

D. not be raised to a higher energy level

Use the following information to answer the next question.



34. The work function of the material emitting the photoelectrons is

A. 2.0×10^{15} J

B. 1.3×10^{-18} J

C. 6.6×10^{-34} J

D. 0.0 J

Use the following information to answer the next three questions.

Some smoke detectors use the radioactive source americium-243 to ionize the air between two electric plates in a detection chamber. A 9.0 V battery in the detector causes a continuous current to flow between the plates. When smoke particles enter the chamber, they neutralize the ionized air molecules, which decreases the current and triggers an alarm.

35. Typically, the 9.0 V battery used in this type of detector will transfer 200 C of charge in 1.0 years. The resistance of the circuit in the detector is

A. $1.4 \times 10^{6}\ \Omega$

B. $5.9 \times 10^{4}\ \Omega$

C. $3.9 \times 10^{3}\ \Omega$

D. $7.0 \times 10^{-7}\ \Omega$

36. If the air is ionized by alpha particles produced by the americium-243, what immediate byproduct would one expect to find?

A. Curium-243

B. Plutonium-243

C. Berkelium-247

D. Neptunium-239

37. Americium-243 has a half-life of approximately 7 000 years. If a detector containing 20 mg of this isotope were discarded and then rediscovered 70 years later, approximately how much americium-243 would remain?

A. 20 mg

B. 0.20 mg

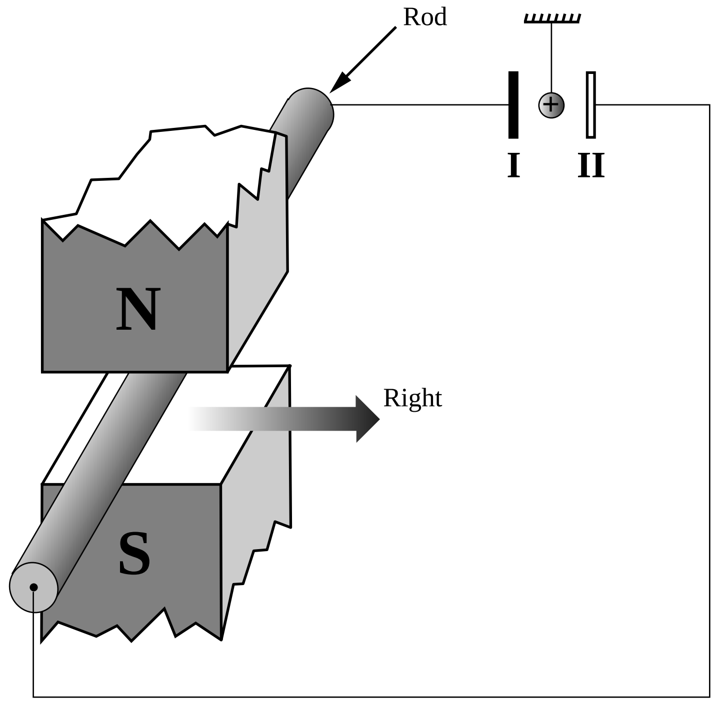
C. 2.0×10^{-7} mg

D. No measurable amount would remain.

The written-response questions follow on the next page.

Use the following information to answer the next question.

A positively charged sphere is suspended by an insulating thread between two neutral parallel plates, I and II. The plates are connected by wire to a copper rod.



A student moves the copper rod to the right in an external magnetic field. The motion of the rod through the magnetic field causes electrons to move in the rod and induces a potential difference across the plates. The charged sphere moves toward one of the plates but does not come in contact with it.

Written Response — 15%

1. Explain the motion of the charged sphere. In your answer,

- describe and explain the movement of the electrons in terms of the direction of the motion of the copper rod through the magnetic field
- describe and explain the motion of the charged sphere in terms of the charges on it and on plates I and II
- describe a change to the apparatus or procedure that would cause the charged sphere to have a larger deflection toward the metal plate

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.

The supernova known as SN1987A reached it maximum brightness, or luminosity (energy release per second), in mid-May 1987. After that, its luminosity decreased.

Decline in Luminosity in Supernova SN1987A

Time (Days)	**Luminosity (10^{35} W)**
0	1.000
50	0.638
100	0.407
150	0.260
200	0.166
250	0.106
300	0.067
350	0.043

The most likely reason that the luminosity decreased is that luminosity depends on the radioactive decay of isotopes created in the explosion. One source of the luminosity could be the gamma rays that result from any one of the decay chains listed in the following table.

Radioactive Decay Chains
(Showing Half-Life and Gamma Ray Energy)

$$^{56}\mathrm{Ni} \xrightarrow[\text{0.158 MeV}]{\text{6.1 day}} {}^{56}\mathrm{Co} \xrightarrow[\text{1.238 MeV}]{\text{77.3 day}} {}^{56}\mathrm{Fe}$$

$$^{57}\mathrm{Co} \xrightarrow[\text{0.122 MeV}]{\text{272 day}} {}^{57}\mathrm{Fe}$$

$$^{22}\mathrm{Na} \xrightarrow[\text{1.275 MeV}]{\text{2.605 year}} {}^{22}\mathrm{Ne}$$

$$^{44}\mathrm{Ti} \xrightarrow[\text{0.0783 MeV}]{\text{67 year}} {}^{44}\mathrm{Sc} \xrightarrow[\text{0.2712 MeV}]{\text{2.44 day}} {}^{44}\mathrm{Ca}$$

$$^{60}\mathrm{Fe} \xrightarrow[\text{0.0586 MeV}]{1.5 \times 10^{6}\text{ year}} {}^{60}\mathrm{Co} \xrightarrow[\text{1.173 MeV}]{\text{5.27 year}} {}^{60}\mathrm{Ni}$$

$$^{26}\mathrm{Al} \xrightarrow[\text{1.809 MeV}]{7.1 \times 10^{5}\text{ year}} {}^{26}\mathrm{Mg}$$

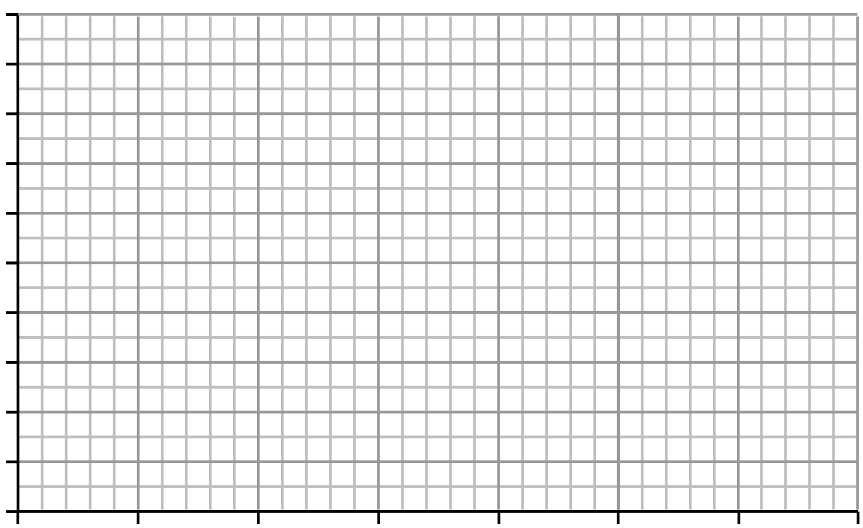
NOTE: The time provided above the arrow in each decay is the half-life. The energy provided below the arrow in each decay is the gamma ray energy.

Written Response — 15%

2.
- Plot a graph of luminosity versus time.
- Determine the half-life of the luminosity, and identify the single decay believed to be responsible for most of the energy released by the supernova.
- The amount of radioactive nickel-56 predicted to have been created in the supernova is about 1.49×10^{29} kg. How many days would it take for the mass of nickel-56 to be reduced to 1.86×10^{28} kg?
- The decay chain $^{60}\text{Fe} \rightarrow {}^{60}\text{Co} \rightarrow {}^{60}\text{Ni}$ shows two radioactive decays. Write the nuclear decay equation for iron-60. Provide the name of the particle emitted.
- Identify the decay chain in the table that releases gamma rays with the shortest wavelength. Explain why you identified this decay chain, and calculate the shortest gamma wavelength.

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

________________________________(Title)



You 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

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

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

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

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

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

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

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

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

Dynamics

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

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

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

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

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

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

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

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

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

Momentum and Energy

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

$$W = Fd$$

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

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

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

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

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

Waves and Light

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

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

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

$$v = f\lambda$$

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

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

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

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

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

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

Atomic Physics

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

$$W = hf_0$$

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

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

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

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

$$r_n = n^2r_1$$

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

Quantum Mechanics and Nuclear Physics

$$E = mc^2$$

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

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

Electricity and Magnetism

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

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

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

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

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

$$R = R_1 + R_2 + R_3$$

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

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

$$V = IR$$

$$P = IV$$

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

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

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

$$V = lvB_{\perp}$$

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

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

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 Li ← Symbol
Atomic molar mass → 6.94
Name → lithium

Based on $^{12}_{6}C$
( ) Indicates mass of the most stable isotope

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 30 40 50 60 70 80 90 100 110 120 130 140 150 160 170 180 190 200 210

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

Physics 30 June 2000 Diploma Examination
Multiple Choice and Numerical Response Keys

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

1. 3.55
2. 5.56
3. 1.54
4. 7.52
5. 5.62 or 5.63
6. 8.6
7. 1.22
8. 2252
9. 1493
10. 1221
11 3124
12 7.24 or 7.25

NR1 is linked to MC4: MC4 A —2.94, B—1.47, C—3.55, D—1.78
NR5 is linked to MC11: A—2.83 or 5.64, B—5.62 or 7.95, C—1.13, D—2.25 or 1.59
MC28 is linked to MC27: 27A—C, B—B, C—A, D—D

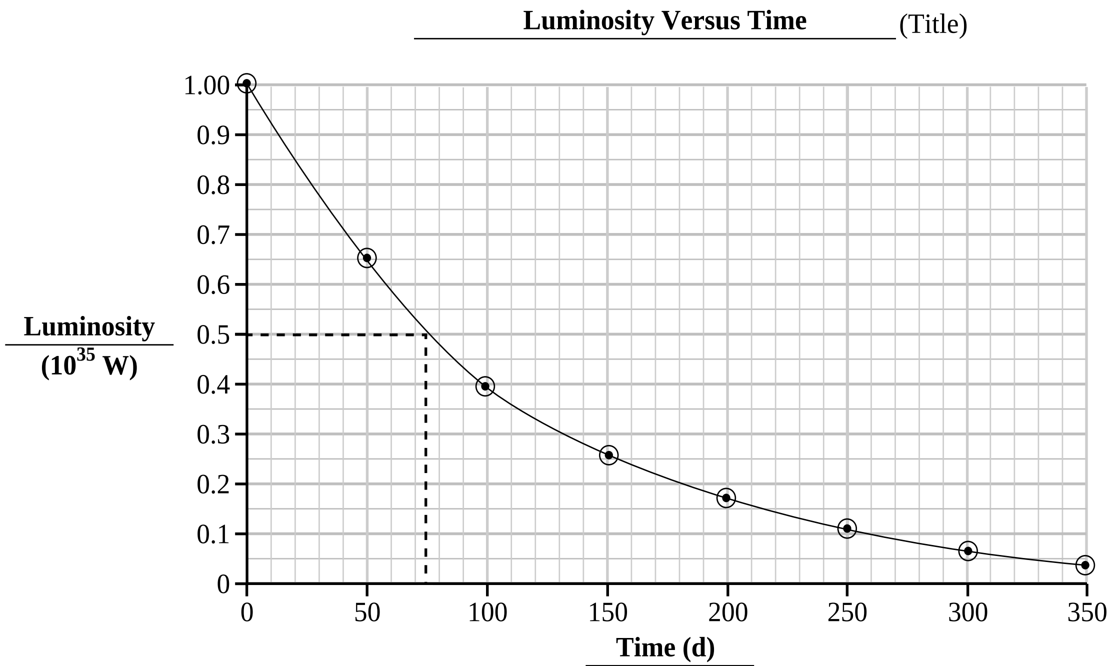
Physics 30 June 2000 Diploma Examination
Multiple Choice and Numerical Response Keys

Question	Key	Skill	STS	GLE
1	C			2
2	B			2
3	B			2
4	C		*	2
NR1	3.55		*	2
NR2	5.56		*	2
NR3	1.54		*	2
5	D	*		2
6	D		*	2
NR4	7.52	*	*	2
7	C		*	2
8	C	*	*	2
9	A		*	2
10	D			2
11	B		*	3
NR5	5.62 or 5.63		*	3
12	A		*	2
13	D		*	
14	C	*		2
15	C	*	*	3
NR6	8.6		*	4
16	B	*		2
17	C		*	3
NR7	1.22	*		2
NR8	2252			2
18	C	*		2
19	D			3
NR9	1493		*	3
20	B	*		3
21	D		*	3
NR10	1221		*	4
22	A	*		1
23	A			2
24	D			1
25	B	*		3
26	A			4
27	C		*	2
28	A		*	2
NR11	3124		*	4
29	A			4
NR12	7.24 or 7.25		*	4
30	C			2

31	D			4
32	D			4
33	D			4
34	B	*		4
35	A		*	3
36	D		*	4
37	A		*	4

WR1	Skill 5%	GLE1 5%	GLE2 10%
WR2	Skill 7%	STS 15%	GLE4 15%

Sample Solution for Written Response Question Two



- Decay
  Based on the lines drawn above at 0.5 and down to 75 days, the half-life of the luminosity is 75 days. The closest half-life in the table is the decay of cobalt-56 into iron-56 with a half-life of 77.3 days.

- $N_o = 1.49 \times 10^{29}$ kg
  $N = 1.86 \times 10^{28}$ kg
  $t_{1/2} = 6.1$ days

$1.49 \times 10^{29} \div 2 \div 2 \div 2 = 1.86 \times 10^{28}$ kg

Therefor 3 half-lives have expired.

Total time = 3×6.1 d = 18 days

- ${}^{60}_{26}\text{Fe} \rightarrow {}^{60}_{27}\text{Co} + {}^{0}_{-1}\text{e}$
  A beta particle is emitted.

- Photons with the shortest wavelength have the highest energy.
  So, the decay chain, ${}^{26}\text{Al} \xrightarrow{7.1\times10^{5}\text{ y}} {}^{26}\text{Mg}$ gives the shortest wavelengths.

$$E = 1.809 \text{ MeV} = 2.894 \times 10^{-13} \text{ J}$$

$$\lambda = \frac{hc}{E} = \frac{(6.63 \times 10^{-34} \text{ J•s})(3.00 \times 10^{8} \text{ m/s})}{2.894 \times 10^{-13} \text{ J}}$$

$$\lambda = 6.87 \times 10^{-13} \text{ m}$$