June 2001

Physics 30

Grade 12 Diploma Examination

Alberta
LEARNING

June 2001

Physics 30

Grade 12 Diploma Examination

Description

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

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

- 37 multiple-choice and 12 numerical-response questions, of equal value, worth 70% of the examination

- 2 written-response questions, of equal value, worth a total of 30% of the examination

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

A tear-out Physics Data Sheet is included near the back of this booklet. A Periodic Table of the Elements is also provided.

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

Instructions

- You are expected to provide your own calculator. You may use any scientific calculator or a graphing calculator approved by Alberta Learning. **NEW**

- You are expected to have cleared your calculator of all information that is stored in the programmable or parametric memory. **NEW**

- 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

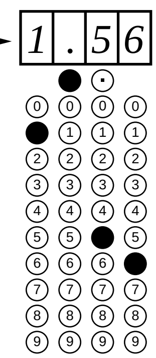
Calculation Question and Solution

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



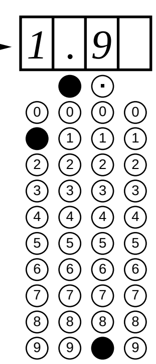
Calculation Question and Solution

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

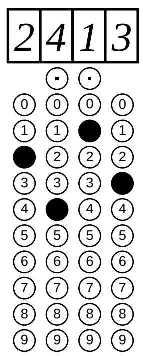
When the following subjects are arranged in alphabetical order, the order is ____, ____, ____, and ____ .

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 →



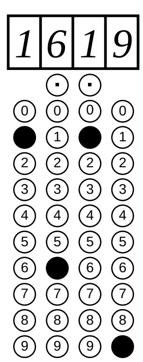
Scientific Notation Question and Solution

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

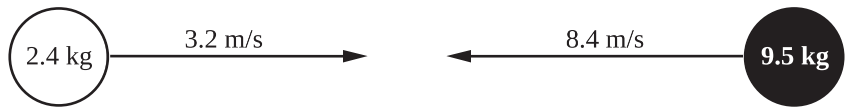
Record 1619 on the answer sheet →



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.

Use the following information to answer the first question.



The two objects shown above collide head-on. The velocity of the 9.5 kg object after collision is 5.4 m/s to the left.

1. The velocity of the 2.4 kg object after collision is

A. 15 m/s to the right
B. 8.7 m/s to the left
C. 8.0 m/s to the right
D. 6.2 m/s to the left

---

2. Two carts, each with a spring bumper, collide head-on. At one point during the collision, both carts are at rest for an instant. At that instant, the kinetic energy that the carts originally possessed is almost completely

A. lost to friction
B. transformed into heat and sound
C. converted into kinetic energy in the spring bumpers
D. converted into potential energy in the spring bumpers

Numerical Response

1. A 1 575 kg car, initially travelling at 10.0 m/s, collides with a stationary 2 250 kg car. The bumpers of the two cars become locked together. The speed of the combined cars immediately after impact is __________m/s.

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

3. A 115 g arrow travelling east at 20 m/s imbeds itself in a 57 g tennis ball moving north at 42 m/s. The direction of the ball-and-arrow combination after impact is

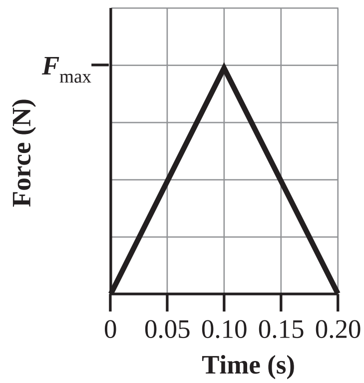
A. 46° N of E
B. 46° E of N
C. 25° E of N
D. 25° N of E

4. In an inelastic collision, the energy that appears to be missing is converted into

A. sound and momentum
B. force and momentum
C. sound and heat
D. heat and force

Use the following information to answer the next question.

Force–Time Graph



This graph shows the relationship between the force on a 0.801 kg football and the time a kicker's foot is in contact with the ball. As a result of the kick, the football, which was initially at rest, has a final speed of 28.5 m/s.

Numerical Response

2. The magnitude of the maximum force, F_{max}, exerted on the ball during the kicking process, expressed in scientific notation, is $\boldsymbol{a.b} \times 10^{\boldsymbol{c}}$ N. The values of ***a***, ***b***, and ***c*** are _____ , _____ , and _____.

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

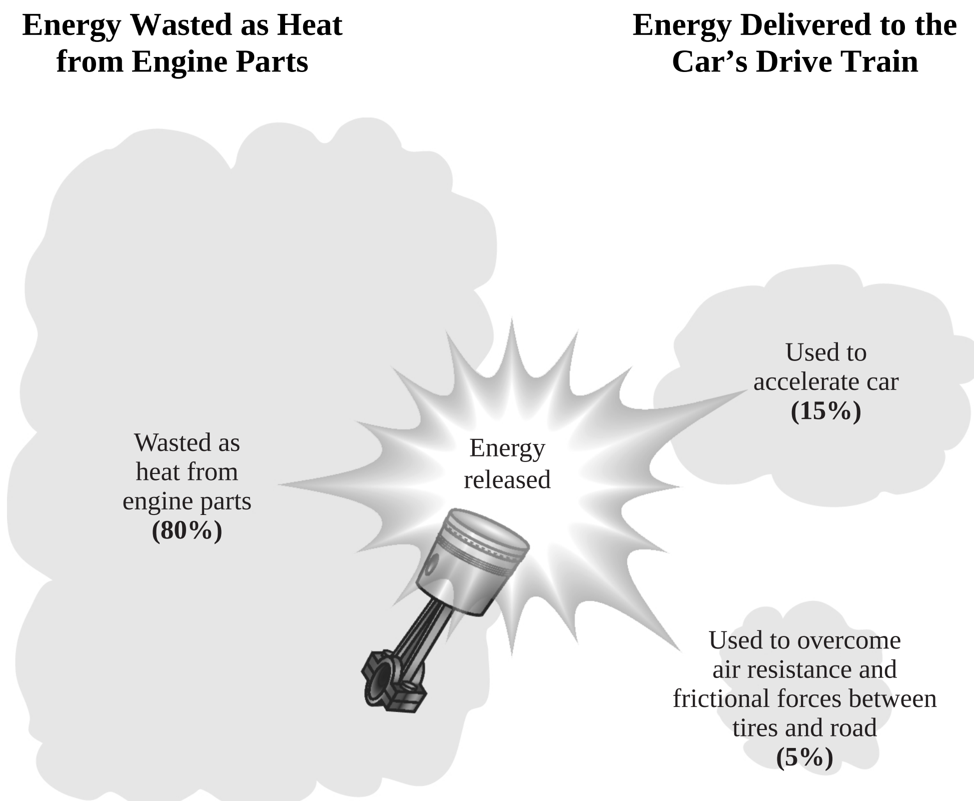
---

5. Which of the following units are correct units for momentum?

A. J·s
B. N·m
C. N·s
D. N/J

Use the following information to answer the next four questions.

The distribution of energy released during the burning of gasoline in a car is illustrated below.



Gasoline releases 30.2 MJ/L during burning. A particular car has a mass of 1.60×10^3 kg. In a test drive, the car accelerated from 3.00 m/s to 15.0 m/s over a distance of 115 m.

6. The maximum amount of energy that would be delivered to the drive train when 65.0 L of gasoline is burned is

A. 1.51×10^2 MJ
B. 3.93×10^2 MJ
C. 1.96×10^3 MJ
D. 9.82×10^3 MJ

7. The change in the kinetic energy of the car during the test drive is

A. 9.60×10^3 J

B. 1.15×10^5 J

C. 1.73×10^5 J

D. 1.80×10^5 J

8. The magnitude of the impulse on the car during the test drive is

A. 4.80×10^3 kg·m/s

B. 1.92×10^4 kg·m/s

C. 2.40×10^4 kg·m/s

D. 2.88×10^4 kg·m/s

Use your recorded answer from ***Multiple Choice 8*** *to answer* ***Numerical Response 3.****

Numerical Response

3. The average net force on the car during the test drive, expressed in scientific notation, is $\boldsymbol{a.bc} \times 10^{\boldsymbol{d}}$ N. The values of ***a***, ***b***, ***c***, and ***d*** are ____, ____, ____, and ____.

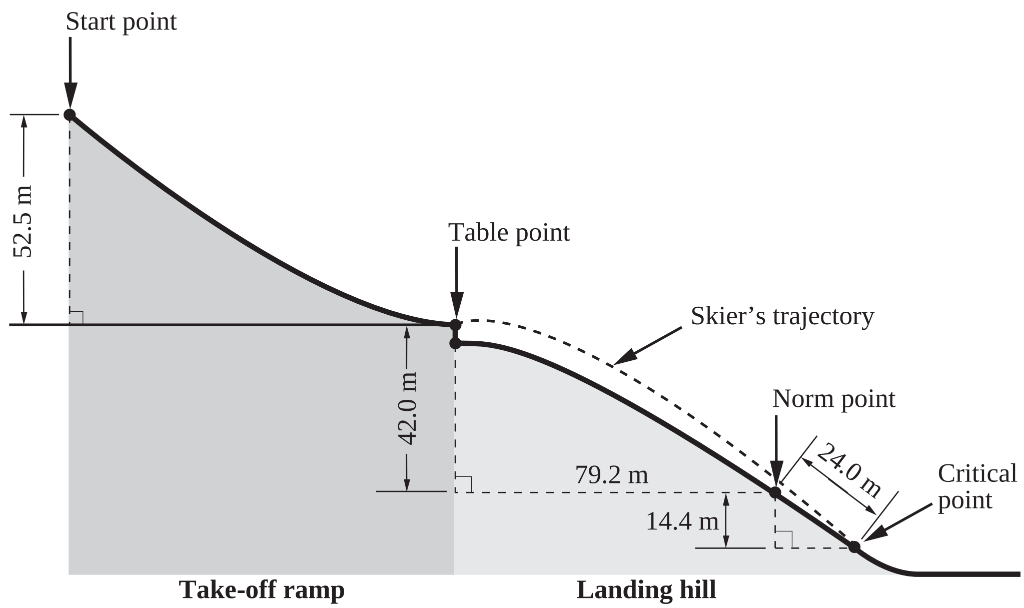
(Record all **four digits** of your answer in the numerical-response section on the answer sheet.)

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

Use the following information to answer the next three questions.

90 m Ski Jump

An elevation profile of the 90 m ski jump at Canada Olympic Park in Calgary is shown below. The skiers slide down a 111 m long ramp before taking off at the "table point." The distance from the table point to the "norm point" (the beginning of the steepest section of the landing hill) is 90 m, hence the name of the jump. Farther downhill, at the end of a straight section of 24.0 m, is the "critical point." If skiers fly past the critical point, it becomes dangerous to land because the landing hill starts to flatten out.



During a ski jumping competition, a skier's speed at the table point was 95 km/h, and she landed at the critical point with a speed of 85 km/h. The combined mass of the skier and her equipment was 60 kg.

9. The change in the skier's gravitational potential energy as she moved from the **table point** to the **critical point** was

A. -2.5×10^4 J

B. -3.3×10^4 J

C. -3.6×10^4 J

D. -6.7×10^4 J

10. Current ski jumping techniques actually slow down the ski jumpers on the way to the bottom of the hill. The skier's speed upon landing at the critical point was 85 km/h. What was the change in this skier's kinetic energy on her flight from the **table point** to the **critical point**?

A. -8.4×10^{1} J

B. -3.0×10^{2} J

C. -4.2×10^{3} J

D. -5.4×10^{4} J

11. The reduction in flight speed as a skier moves through the air is mainly due to the aerodynamic lift generated on the skier in "sailing position." The work done by this force acts to reduce the

A. kinetic energy of the skier

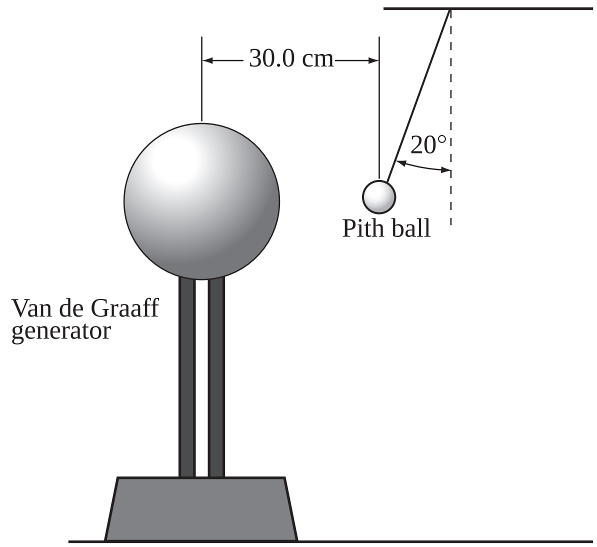
B. potential energy of the skier

C. time spent in the air by the skier

D. horizontal distance travelled by the skier

Use the following information to answer the next four questions.

To determine the electric force on a 2.5×10^{-4} kg neutral pith ball, a student charges a Van de Graaff generator and suspends the pith ball by an insulating thread.



12. When the neutral pith ball is placed near the charged Van de Graaff generator, the pithball is attracted to the generator as a result of

A. induction
B. grounding
C. conduction
D. induction and grounding

13. The direction of the electrical force on the pith ball is

A. $\rightarrow$
B. $\leftarrow$
C. $\uparrow$
D. $\downarrow$

14. The magnitude of the electrical force exerted on the pith ball by the charged Van de Graaff generator is

A. 2.5×10^{-3} N

B. 2.3×10^{-3} N

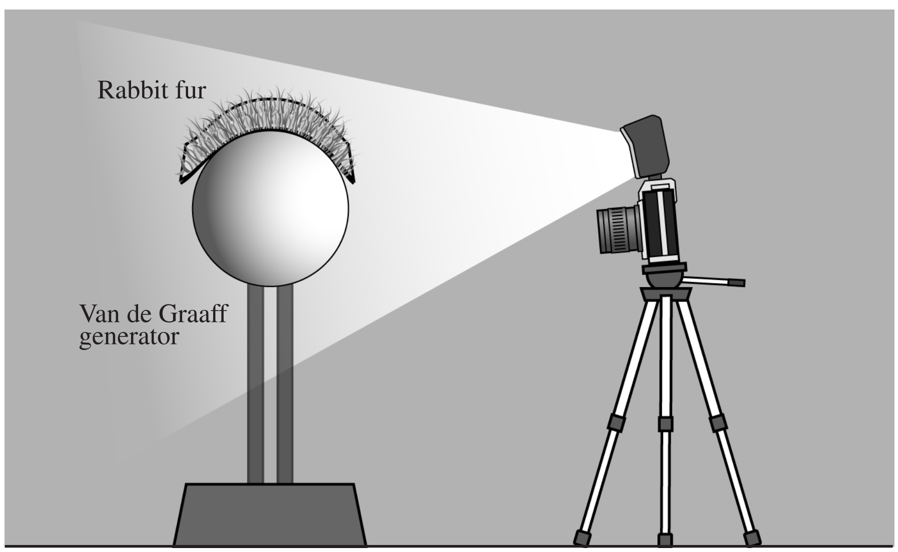
C. 8.9×10^{-4} N

D. 8.4×10^{-4} N

Use the following additional information to answer the next question.

A student placed a piece of rabbit fur on the top of the sphere of the Van de Graaff generator. The generator was then turned on and the rabbit fur was repelled and formed an arc directly above the generator. When the generator was turned off, the fur remained in the same position.

Using a camera with a flash, a second student then took a picture of the apparatus. Immediately after the flash, the fur collapsed somewhat.



15. The concept that explains the collapse of the rabbit fur is

A. induction

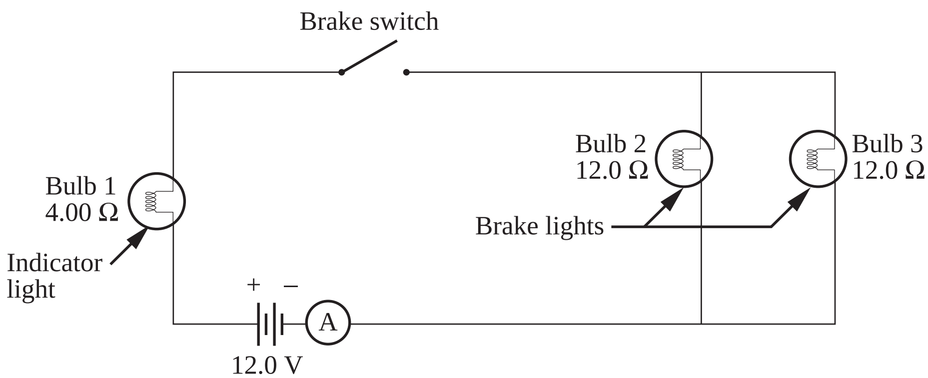
B. grounding

C. conduction

D. the photoelectric effect

Use the following information to answer the next four questions.

Brent rewired his brake light circuit so that every time he applies the brakes, an indicator light on the dashboard goes on. The circuit that Brent used is shown below.



16. Brent should **not** have wired the circuit as illustrated because both brake lights will fail to light if

A. bulb 1 fails

B. bulb 2 fails

C. bulb 3 fails

D. the brakes are applied

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

In Brent's circuit, all bulbs are working and the brake switch is closed.

Numerical Response

4. The reading on the ammeter is __________A.

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

Numerical Response

5. The voltage drop across one of the $12.0\ \Omega$ light bulbs is __________ V.

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

17. The electrical power dissipated by the $4.00\ \Omega$ bulb is

A. 5.76 W
B. 8.64 W
C. 14.4 W
D. 144 W

Numerical Response

6. The magnitude of the force between two charged particles that are a fixed distance apart is 3.80×10^{-4} N. If the distance between their centres is exactly doubled, then the magnitude of the force between the particles, expressed in scientific notation, is $\boldsymbol{a.bc} \times 10^{-\boldsymbol{d}}$ N. The values of ***a, b, c,*** and ***d*** are _____ , _____ , _____ , and _____.

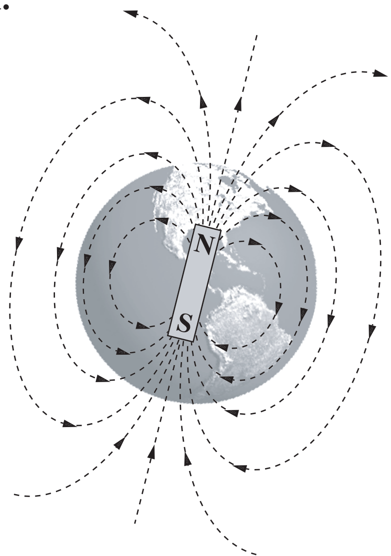
(Record all **four digits** of your answer in the numerical-response section on the answer sheet.)

18. The electric field strength 2.0×10^{-10} m from an alpha particle is

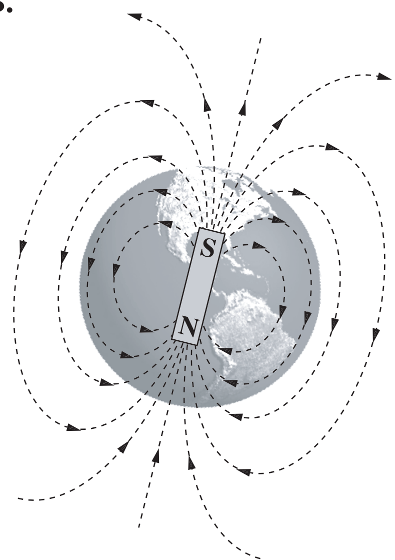
A. 7.2 N/C
B. 14 N/C
C. 3.4×10^{10} N/C
D. 7.2×10^{10} N/C

19. If the source of Earth's magnetic field were a bar magnet, then the **best** diagram to show this field would be

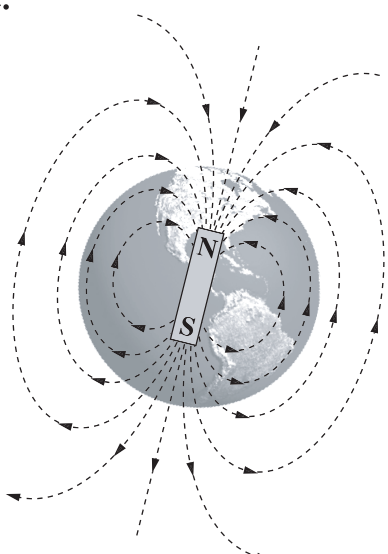
A.



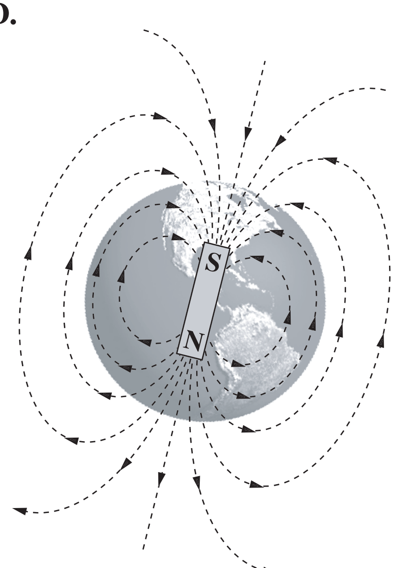
B.



C.



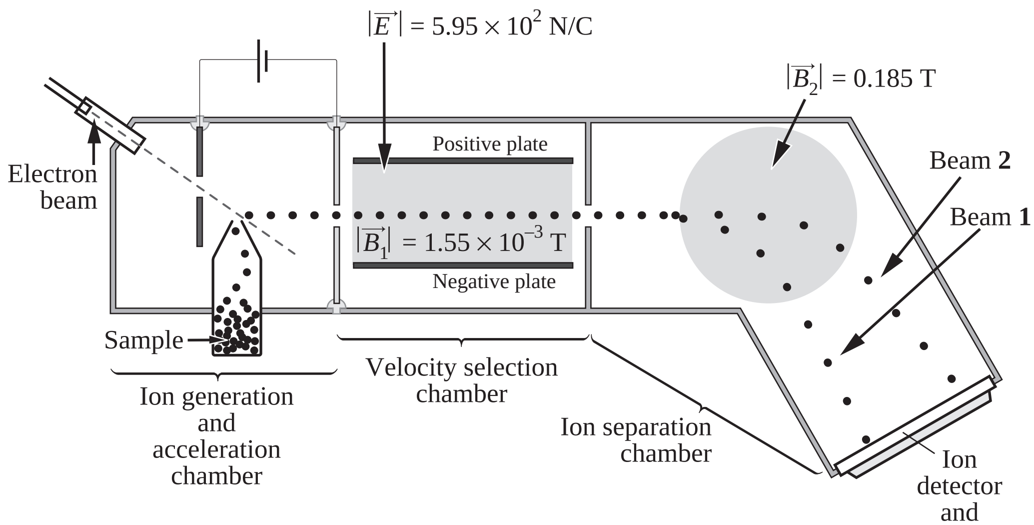
D.



Use the following information to answer the next two questions.

A Mass Spectrometer

A particular lithium sample contains two isotopes. These isotopes are singly charged in an ion generation and acceleration chamber. Since individual atoms are ionized at different points in the acceleration chamber, their speeds vary when they enter the velocity selection chamber. In the velocity selection chamber, the electric field strength is 5.95×10^2 N/C and the magnetic field strength is 1.55×10^{-3} T. The velocity selection chamber allows ions of a certain speed to pass through undeflected. The beam of undeflected ions then enters the ion separation chamber where the magnetic field of 0.185 T splits the beam into two beams. Beam 1 curves through a radius of 0.131 m.



20. The speed of the undeflected ionized lithium ions, Li^+, as they leave the velocity selection chamber is

A. 4.25×10^4 m/s
B. 3.84×10^5 m/s
C. 8.63×10^6 m/s
D. 7.22×10^7 m/s

*Use your recorded answer from **Multiple Choice 20** to answer **Numerical Response 7.****

Numerical Response

7. The mass of a lithium ion in beam 1, expressed in scientific notation, is $\boldsymbol{b} \times 10^{-w}$ kg. The value of $\boldsymbol{b}$ is __________.

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

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

Use the following information to answer the next question.

Bill notices that the picture on his television screen is distorted when a strong magnet is placed near it.

Note: This distortion can be permanent.

21. This distortion occurs because of the magnetic force acting on the

A. visible wavelengths of EMR

B. television circuits

C. moving electrons

D. gamma radiation

Use the following information to answer the next two questions.

Radio Telescopes

Radio telescopes detect radio waves emitted by objects throughout the universe. They do not detect the visible light from stars and galaxies.

The Dominion Radio Astrophysical Observatory (DRAO), located in Penticton, BC, has a seven-antenna radio telescope. Using signals from this telescope, DRAO produces detailed wide-angle pictures of the radio sky.

One of the radio waves that this telescope can detect has a frequency of 1 420 MHz, and comes from an arm of the Milky Way Galaxy that is 7.00×10^{18} km away.

22. The amount of time, in days, that it takes the radio waves detected by the telescope to reach Earth is

A. 2.7×10^{8} days

B. 6.5×10^{9} days

C. 2.3×10^{13} days

D. 2.0×10^{18} days

23. DRAO is located in a basin surrounded by mountains, which shield it from manmade radio waves that interfere with astronomical signals. Manmade radio waves are produced by

A. radioactive decay

B. electron transitions in atoms

C. oscillating charges in a linear antenna

D. high speed electrons stopped suddenly by a metal surface

Use the following information to answer the next question.

A proton enters a magnetic field at a right angle to the field. An alpha particle enters the same field at the same angle but with **twice** the speed. Once in the magnetic field, both particles move in a circular path.

24. The ratio of radius of the alpha particle's path to the radius of the proton's path is

A. 1 : 1
B. 2 : 1
C. 4 : 1
D. 8 : 1

---

25. Which of the following forms of electromagnetic radiation has photons of lowest energy?

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

Numerical Response

8. If certain X-rays have a frequency of 2.15×10^{20} Hz, then the period of these X-rays, expressed in scientific notation, is $\boldsymbol{b} \times 10^{-w}$ s. The value of $\boldsymbol{b}$ is **__________**.

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

26. Maxwell's work contained the new idea that

A. an electric current in a wire produces a magnetic field that circles the wire

B. a current is induced in a conductor that moves across a magnetic field

C. an electric field that changes with time generates a magnetic field

D. two parallel, current-carrying wires exert a force on each other

27. Evidence of the wave-like properties of matter can be found in the

A. refraction of light

B. diffraction of electrons

C. Compton scattering of X-ray photons

D. conservation of momentum of photons

28. Which of the following types of radiation can be deflected by both electric fields and magnetic fields?

A. X-rays

B. Cathode rays

C. Photon beams

D. Electromagnetic waves

Use the following information to answer the next question.

When a certain metal is struck by a photon with a frequency of 8.23×10^{14} Hz, the metal emits an electron with a maximum speed of 2.45×10^{5} m/s.

Numerical Response

9. The work function for this metal is __________ eV.

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

---

29. In his explanation of the photoelectric effect, Einstein **proposed** that

A. the speed of light is constant

B. light energy is concentrated in distinct “packets”

C. light energy is evenly distributed over the entire wave front

D. metallic surfaces emit electrons when illuminated with short-wavelength light

Use the following information to answer the next question.

Data Recorded in a Photoelectric Effect Experiment

I The number of photoelectrons emitted each second
II The maximum kinetic energy of the emitted photoelectrons
III The charge on each of the emitted photoelectrons

30. The intensity of a light source that causes photoelectric emission is increased while the frequency of the light source is kept constant. This increase will result in an increase in

A. I only

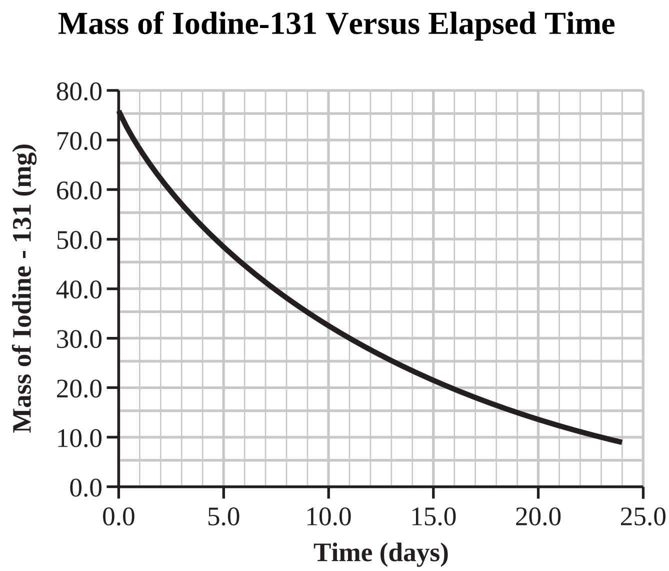
B. II only

C. I and II only

D. II and III only

Use the following information to answer the next six questions.

A sample of iodine-131 has an initial mass of 76.0 mg. The activity of the sample is measured and the amount of iodine-131 remaining in the sample is determined. The following graph was obtained.



A particular nucleus of iodine-131 decays by emitting a beta particle that travels at 2.34×10^{5} m/s and gamma radiation that has a wavelength of 5.36×10^{-12} m. Extra momentum and kinetic energy are carried off by a neutrino.

31. The half-life of iodine-131 is

A. 8.0 days
B. 12.0 days
C. 16.0 days
D. 24.0 days

*Use your recorded answer from **Multiple Choice 31** to answer **Numerical Response 10.****

Numerical Response

10. After 48.0 days the amount of iodine-131 that remains in the sample is __________ mg.

(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.**

32. The energy emitted as gamma radiation during the transmutation of an iodine-131 nucleus is

A. 3.55×10^{-45} J

B. 2.68×10^{-27} J

C. 1.24×10^{-22} J

D. 3.71×10^{-14} J

Use the following additional information to answer the next question.

The momentum of the gamma ray photon and the beta particle can be calculated. The momentum of a gamma ray photon *(γ)* is determined by the equation

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

33. For the decay of iodine-131, the relationship between the magnitude of the momentum of the gamma ray photon (p_γ) and the magnitude of the momentum of the beta particle (p_β) can be represented by the equation

A. $p_\gamma = -p_\beta$

B. $p_\gamma = p_\beta$

C. $p_\gamma = (1.72 \times 10^{-3}) \times p_\beta$

D. $p_\gamma = (5.80 \times 10^{2}) \times p_\beta$

34. The equation for this radioactive decay is

A. ${}^{131}_{53}\text{I} \rightarrow {}^{127}_{51}\text{Sb}$ + beta + gamma + neutrino

B. ${}^{131}_{53}\text{I} \rightarrow {}^{132}_{54}\text{Xe}$ + beta + gamma + neutrino

C. ${}^{131}_{53}\text{I} \rightarrow {}^{132}_{53}\text{I}$ + beta + gamma + neturino

D. ${}^{131}_{53}\text{I} \rightarrow {}^{131}_{54}\text{Xe}$ + beta + gamma + neutrino

35. To protect lab technicians from harmful radiation, the equipment used in this experiment should be shielded with

A. lead to stop the γ radiation
B. paper to stop the β particles
C. an electric field to stop the γ radiation
D. a magnetic field to stop the β particles

Numerical Response

11. An X-ray tube operates at an electrical potential difference of 1.00×10^5 V. The minimum wavelength of the X-ray radiation it produces, expressed in scientific notation, is $\boldsymbol{b} \times 10^{-w}$ m. The value of $\boldsymbol{b}$ is __________.

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

Numerical Response

12. The voltage required to stop an alpha particle with an initial speed of 5.34×10^4 m/s is __________ V.

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

Use the following information to answer the next two questions.

An electron in a hydrogen atom makes a transition from the third energy level to the ground state.

36. The frequency of light emitted when the electron drops from energy level $n = 3$ to $n = 1$ is

A. 2.2×10^{-8} Hz
B. 1.0×10^{7} Hz
C. 5.5×10^{14} Hz
D. 2.9×10^{15} Hz

37. In a hydrogen atom, the ratio of the radius of the third orbital to the radius of the first orbital is

A. 9 : 1
B. 6 : 1
C. 3 : 1
D. $\sqrt{3} : 1$

The written response questions follow on the next page.

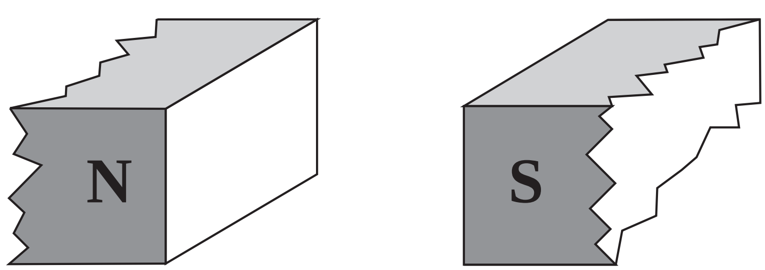
Written Response — 15%

1. You have been given a large permanent magnet with a uniform magnetic field between its poles. In a preliminary experiment, the magnetic field of the permanent magnet was found to be at least 100 times the strength of Earth's magnetic field. Using concepts discussed in the Physics 30 course, design a procedure to measure the magnitude of the magnetic field. Assume that the space between the poles is large enough to insert any necessary equipment.

The description of your procedure must include

- a label indicating the direction of the magnetic field between the poles of the magnet below
- a list of the materials required
- a labelled diagram showing your experimental design
- a description of how to obtain the measurements required to calculate the magnitude of the magnetic field
- a derivation of the formula used to determine the magnitude of the magnetic field

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.

In a modified Millikan apparatus, a small, charged object that has a mass of 3.8×10^{-15} kg is suspended by the electric field that is between charged parallel plates. The table below shows how the balancing voltage depends on the distance between the plates.

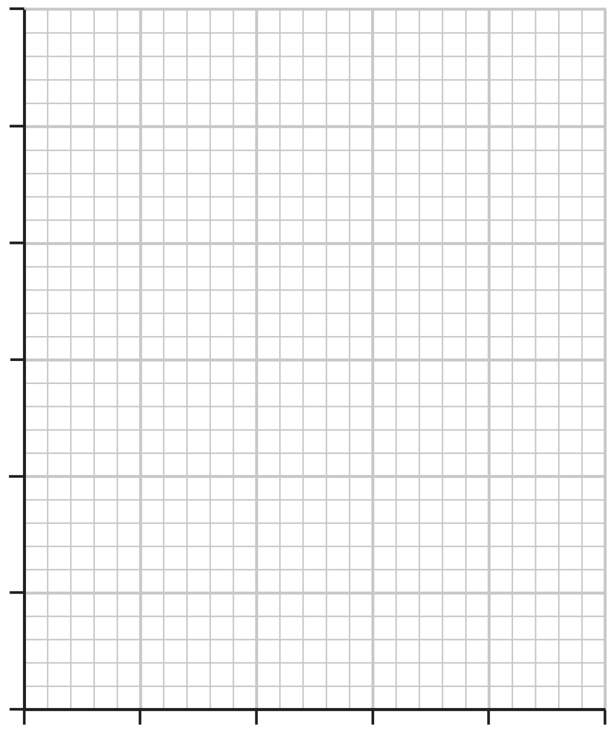
Plate separation (mm)	**Balancing voltage (10^3 V)**
11.1	1.39
20.0	2.21
24.0	2.78
28.1	3.11
35.1	4.22
50.0	?

Written Response — 15%

2.
- Provide a graph of the balancing voltage as a function of the plate separation, with the manipulated variable on the horizontal axis.
- Calculate the slope of the graph, and describe the physical quantity or quantities that this slope represents.
- Using the slope, or another suitable averaging technique, determine the magnitude of the charge on the suspended mass.
- Determine the balancing voltage required when the plates are separated by 50.0 mm.

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

(title)



You may continue your answer on the next page.

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

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

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	$G = 6.67 \times 10^{-11}\ \text{N}\cdot\text{m}^2/\text{kg}^2$
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	$k = 8.99 \times 10^{9}\ \text{N}\cdot\text{m}^2/\text{C}^2$
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	$h = 6.63 \times 10^{-34}\ \text{J}\cdot\text{s}$ **or** $4.14 \times 10^{-15}\ \text{eV}\cdot\text{s}$
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 $\vec{R}$

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

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

$$R_x = R\cos\theta$$

$$R_y = R\sin\theta$$

Graphing Calculator Window Format

x: $[x_{\text{min}}, x_{\text{max}}, x_{\text{scl}}]$

y: $[y_{\text{min}}, y_{\text{max}}, y_{\text{scl}}]$

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}

Fold and tear along perforation.

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

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

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

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

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

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

$R = R_1 + R_2 + R_3$

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

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

$V = IR$

$P = IV$

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

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

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

$V = lvB_{\perp}$

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

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

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

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

PHYSICS 30

DIPLOMA EXAMINATION

JUNE 2001

Multiple Choice
and
Numerical Response
Key

Written Response
Scoring Guide

Physics 30 June 2001 Diploma Examination
Multiple-Choice and Numerical-Response Keys
Multiple Choice

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

Numerical Response

1.	4.12	**7.**	1.01
2.	232	**8.**	4.65
3.	1503 *	**9.**	3.24
4.	1.20	**10.**	1.19
5.	7.20	**11.**	1.24
6.	9505	**12.**	29.6 or 29.8

If MC 8 is	A, the NR 3 is 3752, 3762
	B, the NR 3 is 1503
	C, then NR 3 is 1883
	D, then NR 3 is 2252
If MC 20 is	A, the NR 7 is 9.12
	B, the NR 7 is 1.01
	C, then NR 7 is 4.49
	D, then NR 7 is 5.37
If MC 31 is	A, the NR 10 is 1.19
	B, the NR 10 is 4.75
	C, then NR 10 is 9.50
	D, then NR 10 is 19.0

Physics 30 — Holistic Scoring Guide

Major Concepts: Magnetic field direction; Effect of an external magnetic field on moving charges; Experimental design	
Score	**Criteria**
5 **Excellent**	• The student provides a complete solution that covers the full scope of the question. – The reader has no difficulty following the strategy or solution presented by the student. – Statements made in the response are supported explicitly but may contain minor errors or have minor omissions. *In the response, the student uses major generalizations of physics such as balanced or unbalanced forces and conservation laws. The student applies knowledge from one area of physics to another.*
4 **Good**	• The student provides a solution to the significant parts of the question. – The reader may have some difficulty following the strategy or solution presented by the student. – Statements made in the response are supported implicitly and may contain errors. *In the response, the student uses major generalizations of physics. The response is mostly complete, mostly correct, and contains some application of physics knowledge.*
3 **Satisfactory**	• The student provides a solution in which he/she has made significant progress toward answering the question. – The reader has difficulty following the strategy or solution presented by the student. – Statements made in the response may be open to interpretation and may lack support. *In the response, the student uses item-specific methods that reflect a knowledge-based approach, but the student does not apply them to the question.*
2 **Limited**	• The student provides a solution in which he/she has made some progress toward answering the question. – Statements made in the response lack support. *In the response, the student uses an item-specific method.*
1 **Poor**	• The student provides a solution that contains a relevant statement that begins to answer the question.
0 **Insufficient**	• The student provides a solution that is invalid for the question.
NR	No response is given.

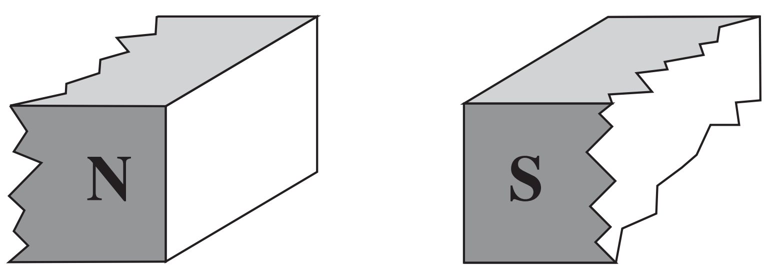
Written Response — 15%

1. You have been given a large permanent magnet with a uniform magnetic field between its poles. In a preliminary experiment, the magnetic field of the permanent magnet was found to be at least 100 times the strength of Earth's magnetic field. Using concepts discussed in the Physics 30 course, design a procedure to measure the magnitude of the magnetic field. Assume that the space between the poles is large enough to insert any necessary equipment.

The description of your procedure must include

- a label indicating the direction of the magnetic field between the poles of the magnet below
- a list of the materials required
- a labelled diagram showing your experimental design
- a description of how to obtain the measurements required to calculate the magnitude of the magnetic field
- a derivation of the formula used to determine the magnitude of the magnetic field

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

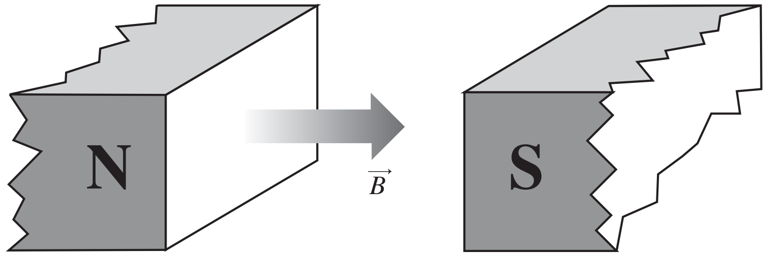


A complete response should include the following content. The clarity of the response is considered in assigning a mark.

Expected Content

- Magnetic field direction
- Effect of External Magnetic field on a moving charge
- Experimental Design

Sample Solution

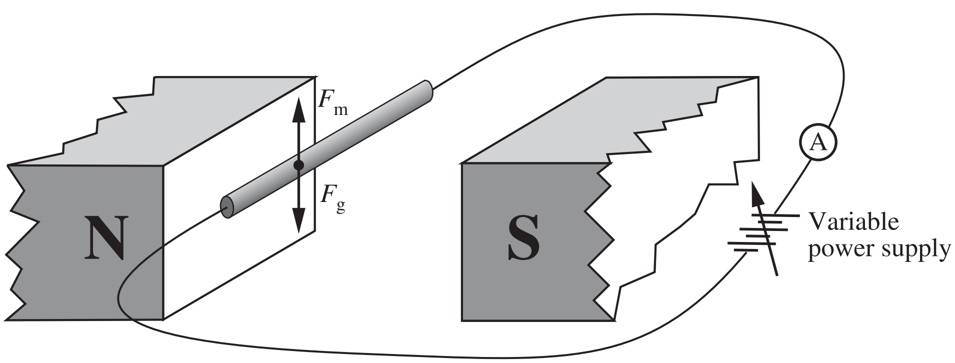


Experimental Design

Method 1 – Current balance 1

List:
- ammeter
- balance
- variable power supply
- wires
- metal rod
- meter stick

Procedure
- measure mass of metal rod
- measure perpendicular length of magnetic field (This is the length of conductor in the magnetic field.)
- Complete a circuit with the variable power supply, the metal rod and the ammeter all in series
- Place the rod perpendicular to the magnetic field
- Adjust the current until the metal rod is suspended in the magnetic field
- Record current



Analysis:

$$F_m = F_g$$

$$BIl = mg$$

$$B = \frac{mg}{Il}$$

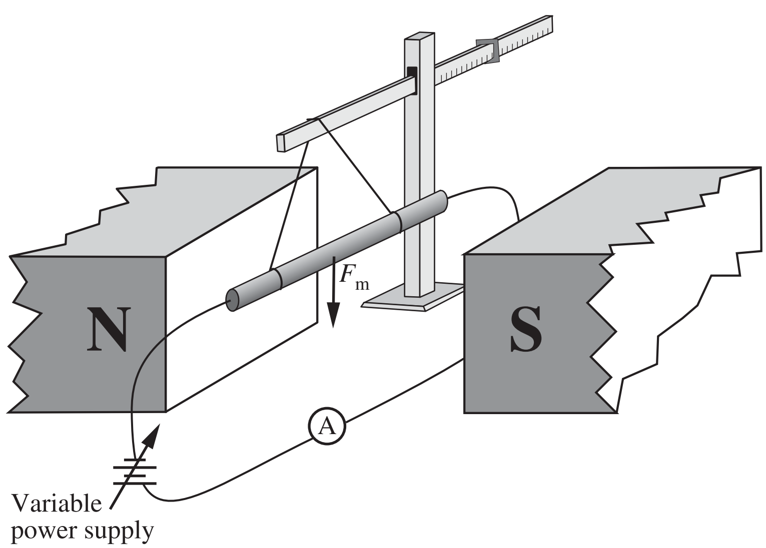
Special Notes: Method 1

- The length of the rod in the magnetic field must be measured
- The rod must be perpendicular to the magnetic field
- the direction of F_m must be opposite gravity and consistent with the polarity of the power supply

Method 2 – Current Balance 2

List:
ammeter
balance
metal rod
metre stick
variable power supply
string

Procedure
- measure mass of metal rod
- measure perpendicular length of magnetic field (This is the length of conductor in the magnetic field.)
- suspend the rod from one arm of the balance
- connect wires, rod, power supply and ammeter in series
- zero the balance
- adjust the current, record current
- read the change in mass measured by the balance



Analysis:

$$\Delta\ weight = F_m$$

$$\Delta\ m * g = BIl$$

$$B = \frac{mg}{Il}$$

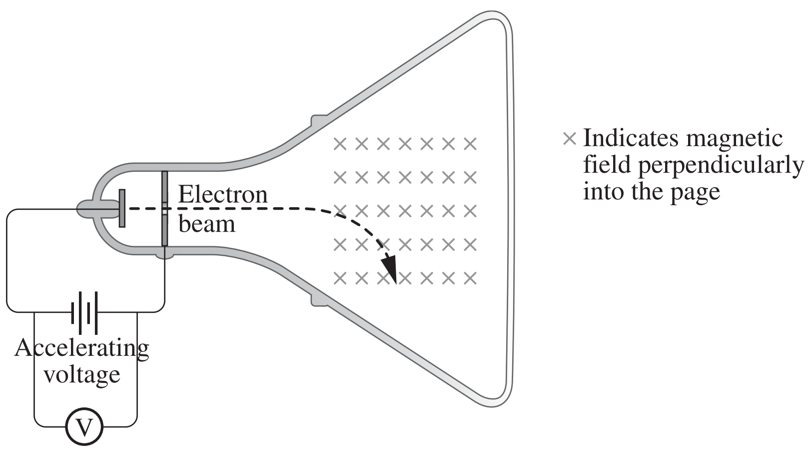
Special Notes: Method 2

- The length of the rod <u>in</u> the magnetic field must be measured
- The rod must be perpendicular to the magnetic field
- Direction of forces do not matter. If F_m is given, it must be consistent with the polarity of the power supply

Method 3 – Circular Motion

List: volt meter
meter stick
power supply
cathode ray tube

Procedure
- place the cathode ray tube so that the electron beam is perpendicular to the magnetic field
- connect the power supply to the cathode ray tube
- connect a volt meter in parallel to the power supply, record potential difference
- use a meter stick to measure the radius of curvature of the electron beam in the magnetic field



Analysis: by conservation of energy

$$E_{p_{electric}} = E_{k_{electron}}$$

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

$$v = \sqrt{\frac{2Vq}{m}}$$

the magnetic force causes circular motion

$$F_{\mathrm{m}} = F_{\mathrm{e}}$$

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

$$B = \frac{mv}{qr}$$

Special Notes: Method 3

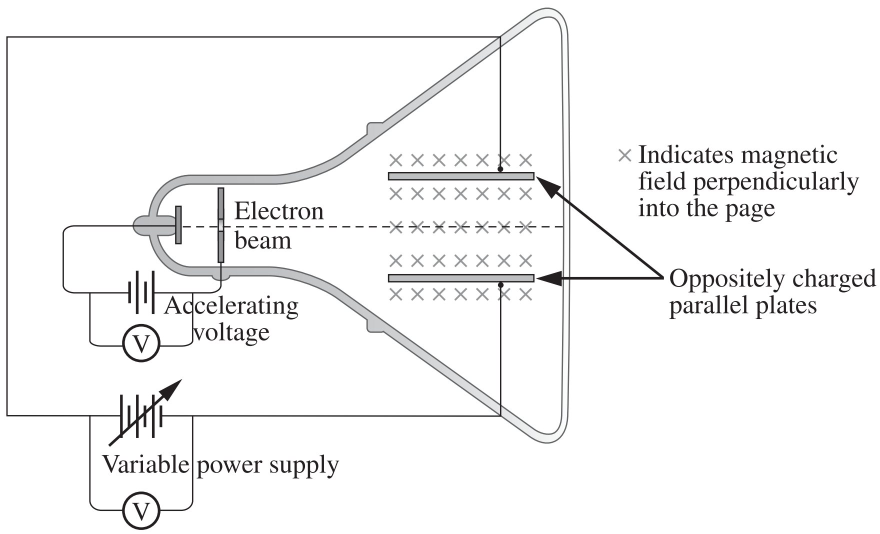
- The method of determining the speed of the electrons must be explicit
- The method of measuring *r* must be explicit (but does not need to be practical)
- The electron path and magnetic field must be perpendicular
- The direction of the magnetic field and path deflection must be consistent
- It is not necessary for the student to explicitly identify how the electron path will be observed

Method 4 – Velocity Selector

List: metre stick
2 volt meter
power supply
variable power supply
cathode ray tube with metal plates inside

Procedure

- set up the cathode ray tube away from the magnetic field so that the electron beam is undeflected. Mark the position of the beam
- Record the voltage V_1
- place cathode ray tube so that the electron beam is perpendicular
- adjust the variable power supply on the plates inside the CRTuntil the electron beam returns to its original path
- record the voltage V_2
- measure the distance between the plates in the cathode ray tube.



Analysis: Conservation of Energy

$$E_{p_{electric}} = E_{k_{electron}}$$

$$V_1 q = \frac{1}{2}mv^2$$

$$v = \sqrt{\frac{2V_1 q}{m}}$$

balanced forces

$$F_e = F_m$$

$$|\vec{E}|q = Bvq, |\vec{E}| = \frac{V_2}{d}$$

$$B = \frac{V_2}{dv}$$

Special Notes: Method 4

- The method of determining the speed of the electrons must be explicit
- The electron path and magnetic field must be perpendicular
- The polarity on the power supplies must be consistent to accelerate the electrons and to produce an electric force in the opposite direction to the magnetic force
- The direction of F_m, F_e and B must be consistent

Scoring Guide for Anaholistic Questions

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

Use the following information to answer the next question.

In a modified Millikan apparatus, a small, charged object that has a mass of 3.8×10^{-15} kg is suspended by the electric field that is between charged parallel plates. The table below shows how the balancing voltage depends on the distance between the plates.

Plate separation (mm)	**Balancing voltage (10^3 V)**
11.1	1.39
20.0	2.21
24.0	2.78
28.1	3.11
35.1	4.22
50.0	?

Written Response — 15%

2.

- Provide a graph of the balancing voltage as a function of the plate separation, with the manipulated variable on the horizontal axis.
- Calculate the slope of the graph, and describe the physical quantity or quantities that this slope represents.
- Using the slope, or another suitable averaging technique, determine the magnitude of the charge on the suspended mass.
- Determine the balancing voltage required when the plates are separated by 50.0 mm.

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.

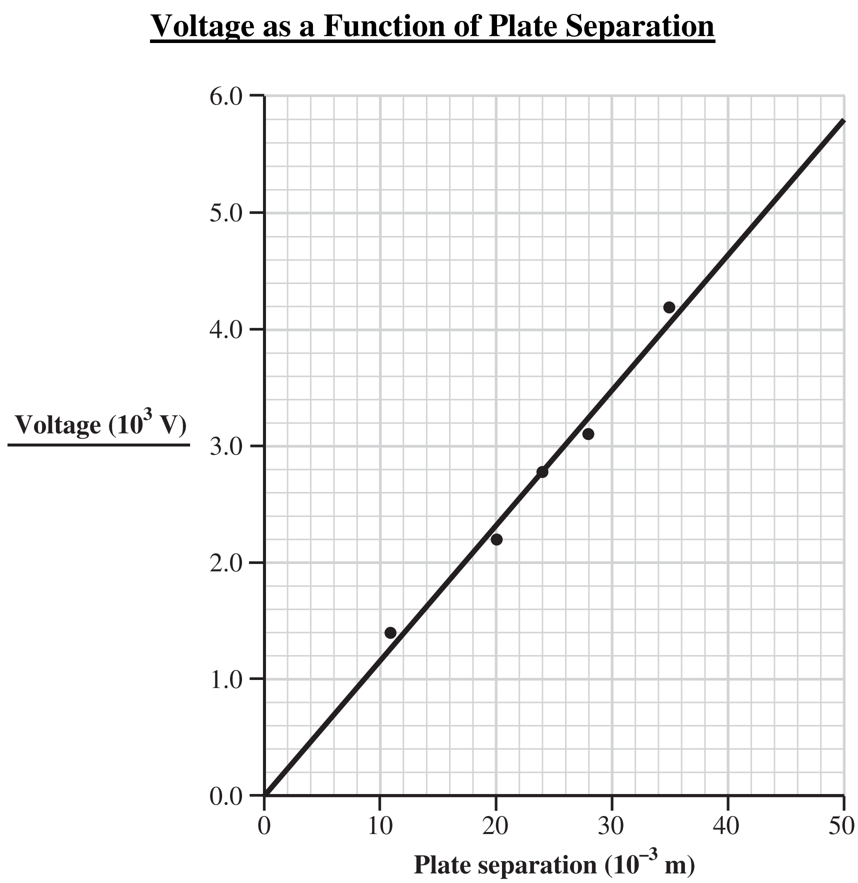
Use the following information to answer the next question.

In a modified Millikan apparatus, a small, charged object that has a mass of 3.8×10^{-15} kg is suspended by the electric field between charged parallel plates. The table below shows how the balancing voltage depends on the distance between the plates.

Sample Solution

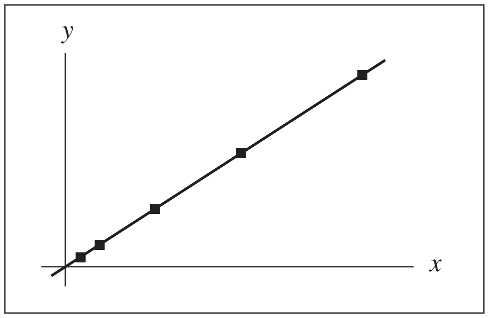
2. • Provide a graph of the balancing voltage as a function of the plate separation, with the manipulated variable on the horizontal axis.

Method 1



Method 2: Graphing Calculator

Balancing Voltage as a Function of Plate Separation



x-axis is plate separation in mm (or m)
y-axis is balancing voltage in 10^3 V

- Calculate the slope of the graph and describe the physical quantity or quantities this slope represents.

Method 1

slope = rise/run

$$= \frac{(4.4 \times 10^3 - 1.4 \times 10^3)\ \text{V}}{(38 \times 10^{-3} - 12 \times 10^{-3})\ \text{m}}$$

$= 1.15 \times 10^5$ V/m or consistent with graph

or

Method 2

L1 = plate separation, d, in mm (or m)
L2 = balancing voltage, V, in 10^3 V

Using the linear regression function on the calculator
($ax + b$) L1, L2, Y
gives slope = 1.16×10^5 V/m

Notes on Method 2:

- the definition (and units) of L1 and L2 and the order they are used in the linear regression must be consistent
- a power of 10 of 2 comes from missing the power of 10 of 3 on the units of y-axis.
- The slope is the electric field between the plates

OR

- The slope is the gravitational force (weight) of the mass divided by the charge on the mass
- Using the slope, or another suitable averaging technique, determine the magnitude of the charge on the suspended mass.

Method 1 (using slope)

$$
\begin{aligned}
F_{\mathrm{g}} &= mg \\
F_e &= q\left|\vec{E}\right| \\
\left|\vec{E}\right| &= \frac{V}{d} \\
F_{\mathrm{g}} &= F_{\mathrm{e}} \\
mg &= \frac{qV}{d} \\
q &= mg\,\frac{d}{V} \\
&= \frac{mg}{\text{slope}} \\
q &= \frac{(3.8\times10^{-15}\ \text{kg})(9.81\ \text{m/s})^2}{(1.15\times10^{5}\ \text{V/m}} \\
q &= 3.2\times10^{-19}\ \text{C}
\end{aligned}
$$

Method 2 (extrapolate for graph)

Find average change using values for *q, V* pairs with this formula, then average.

$$q = mg\times\frac{d}{V}$$

$$q_1 = (3.8\times10^{-15}\ \text{kg})(9.81\ \text{m/s}^2)\times\frac{11.1\times10^{-3}\ \text{m}}{1.39\times10^{3}\ V} = 2.98\times10^{-19}\text{C}$$

$$q_2 = (3.8\times10^{-15}\ \text{kg})(9.81\,\text{m/s}^2)\times\frac{20\times10^{-3}\text{m}}{2.21\times10^{3}\ \text{V}} = 3.37\times10^{-19}\text{C}$$

$$q_3 = (3.8\times10^{-15}\ \text{kg})(9.81\,\text{m/s}^2)\times\frac{24\times10^{-3}\text{m}}{2.78\times10^{3}\ \text{V}} = 3.22\times10^{-19}\text{C}$$

$$q_4 = (3.8\times10^{-15}\ \text{kg})(9.81\,\text{m/s}^2)\times\frac{2.81\times10^{-3}\text{m}}{3.11\times10^{3}\ \text{V}} = 3.37\times10^{-19}\text{C}$$

$$q_5 = (3.8\times10^{-15}\ \text{kg})(9.81\,\text{m/s}^2)\times\frac{3.51\times10^{-3}\text{m}}{4.22\times10^{3}\ \text{V}} = 3.10\times10^{-19}\text{C}$$

$$\bar{q} = \frac{\Sigma q}{n} = \frac{1.604\times10^{-18}\ \text{C}}{5}$$

$$\bar{q} = 3.2\times10^{-19}\ \text{C}$$

- Determine the balancing voltage required when the plates are separated by 50.0 mm.

Method 1

$$
\begin{aligned}
V &= \left|\vec{E}\right| d \\
&= (1.16 \times 10^{5}\ \mathrm{V/m})(5.0 \times 10^{-2}\ \mathrm{m}) \\
&= 5.8 \times 10^{3}\ \mathrm{V}
\end{aligned}
$$

answer: 5.8×10^{3} V

Method 2: Graphing Calculator: by extending window to include $x = 50.0$ mm and then using the trace function, the balancing voltage is 5.8×10^{3} V.

Anaholistic Grid

Major Concept	Graphing Data	Calculation of slope and identifying quantity	Balancing Forces	Data Analysis
Excellent	• allow one minor graphing error	• uses points on the line • explicitly states formula • showing “change in” • correctly identifies the quantity (physical)	• starting with $F_e = F_g$ to derive $\frac{V}{d}q = mg$, $q = mgd / V$	• explicitly communicates methods • finds q from use of slope or proper averaging • extrapolates to 50.0 mm
Good	• may have variables on wrong axis **or** • may have two omissions	• forgets power of 10 in slope calculation • relates slope to a physical quantity • average 5 calculated $\lvert\vec{E}\rvert$	• incorrect/incomplete multiplication **or** • starts with $\frac{V}{d}q = mg$	• makes significant progress toward both extrapolation and finding q **or** • completes one and begins the other
Basic	• dot-to-dot graph **or** • non best fit line	• uses non-linear data points • only determines value of slope • implies substitution of origin	• starts with $q = \frac{mdg}{V}$	• Begins both the extrapolation and finding q **or** • makes significant progress on one
Attempt	• dot-to-dot with wrong axis	• data point off line • single $\lvert\vec{E}\rvert$ calculation off line	• states or implies $\lvert\vec{E}\rvert = \vec{g}$	• Begins one of extrapolation or finding q

Do a final check for SD and units.

	5	**4**	**3**	**2**	**1**	**0**
Excellent	4+	3	2+ basic	2	1	
Good		4	3	2	1	
Basic			4	3	2	
Attempt					2	1

Note: only penalize forgetting the power of 10 one the potential difference **once**