June 1999

Physics 30

Grade 12 Diploma Examination

Alberta LEARNING

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Physics 30

Grade 12 Diploma Examination

Description

Time: 2.5 h. 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 and/or written-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 tearout 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

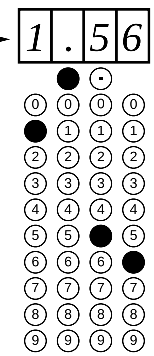
Calculation Question and Solution

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.)

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

$$a = \frac{121\ \text{N}}{77.7\ \text{kg}} = 1.5572716\ \text{m/s}^2$$

Record 1.56 on the answer sheet →



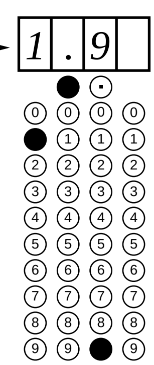
Calculation Question and Solution

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

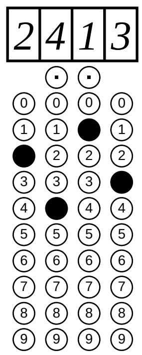
When the following subjects are arranged in alphabetical order, the order is ____, ____, ____, and ____ .

1 physics
2 biology
3 science
4 chemistry

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

Answer: 2413

Record 2413 on the answer sheet ⟶



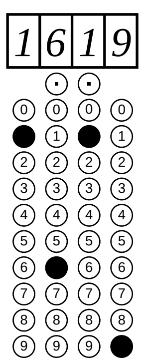
Scientific Notation Question and Solution

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

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

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

Record 1619 on the answer sheet ⟶



Written Response

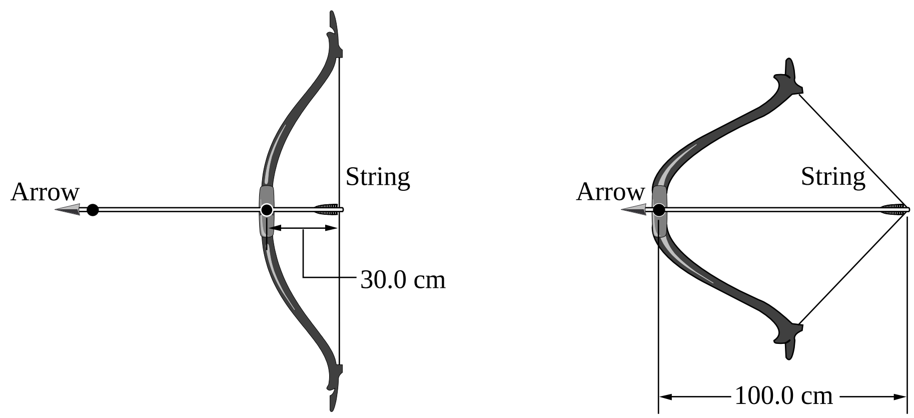
- Write your answers in the examination booklet as neatly as possible.
- For full marks, your answers must address **all** aspects of the question.
- Descriptions and/or explanations of concepts must be correct and include pertinent ideas, diagrams, calculations, and formulas.
- Your answers must be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

1. Which of the following quantities are scalar quantities?

A. Kinetic energy and potential energy
B. Kinetic energy and momentum
C. Potential energy and force
D. Momentum and force

Use the following information to answer the next two questions.

A "full draw" is the maximum distance that an archer can pull back an arrow. Using the "recurve bow" shown below, a particular archer requires an average force of 130 N to pull a full draw of 70.0 cm.



2. The maximum speed of a 20.6 g arrow leaving this bow from a full draw is

A. 66.5 m/s
B. 94.0 m/s
C. 4.42×10^3 m/s
D. 8.83×10^3 m/s

*Use your recorded answer for **Multiple Choice 2** to answer **Numerical Response 1.****

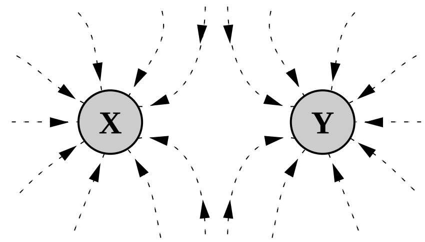
Numerical Response

1. When the archer releases the arrow from a full draw, the magnitude of the impulse that the bow gives to the arrow is __________ N·s.

(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.

Electric Field Lines Near Two Charged Spheres



3. The types of charge present on X and Y are, respectively,

A. negative and negative
B. negative and positive
C. positive and negative
D. positive and positive

Use the following information to answer the next four questions.

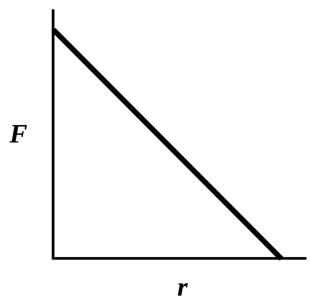
Charles Augustin de Coulomb performed a series of investigations on the quantitative nature of electrical forces. He was able to determine the effect of both distance and magnitude of charge on the electrostatic force between two charged metal spheres.

4. In order to determine the relationship between force and distance, Coulomb needed to

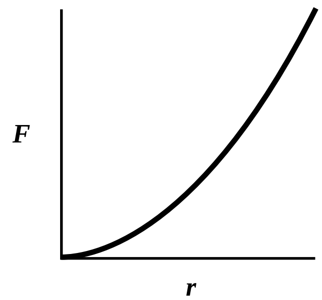
A. keep the magnitude of one charge constant
B. keep the magnitude of both charges constant
C. keep the distance between the charges constant
D. vary the magnitude of one charge while varying distance between the charges

5. Which of the following graphs represents the relationship that Coulomb determined between force and the distance between two charged metal spheres?

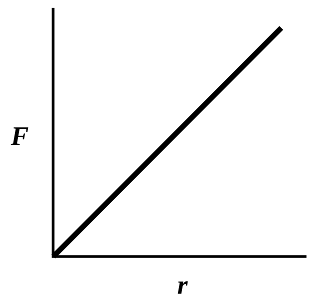
A.



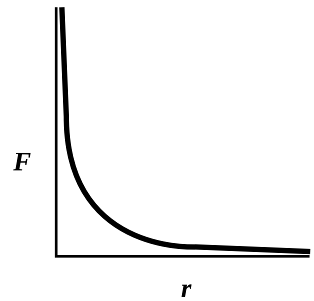
B.



C.



D.



6. Coulomb started with two identically charged spheres separated by a distance r. The force between the spheres was F. If he changed the separation to $\frac{2}{3}r$, then the force between the spheres would have become

A. $\frac{4}{9}F$

B. $\frac{2}{3}F$

C. $\frac{3}{2}F$

D. $\frac{9}{4}F$

7. Coulomb again separated the identically charged spheres by distance r. The force between the spheres was F. Coulomb touched one of the spheres with a third, identical neutral sphere. The third sphere was then moved far away from the other spheres. If he then measured the force between the original spheres, the new force between the spheres would have been

A. $\frac{1}{2} F$

B. $\frac{1}{4} F$

C. $2F$

D. $4F$

---

8. A point charge of magnitude 6.9×10^{-5} C produces an electric field of 1.0×10^{3} N/C at point P. The distance from P to the charge is

A. 4.3×10^{-2} m

B. 2.1×10^{-1} m

C. 2.5×10^{1} m

D. 6.2×10^{2} m

9. During a lightning strike, 30 C of charge may move through a potential difference of 1.0×10^{8} V in 2.0×10^{-2} s. The total energy released by this lightning bolt is

A. 3.0×10^{9} J

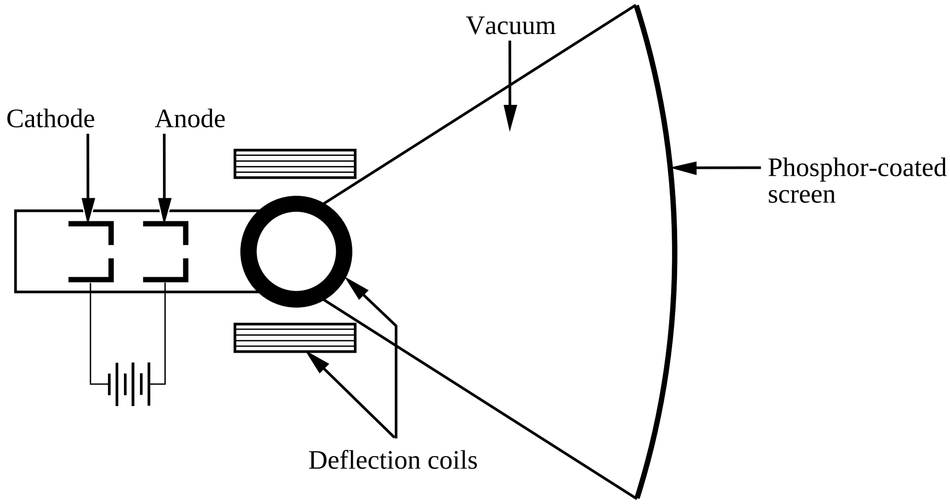
B. 6.0×10^{7} J

C. 3.3×10^{6} J

D. 1.5×10^{3} J

Use the following information to answer the next two questions.

Cathode-ray tubes (CRTs) are used for television and computer screens. They are set up as shown below.



Electrons are "boiled off" the surface of the cathode and are accelerated toward the anode. The cathode is 4.5 cm from the anode. A potential difference of 2.5×10^3 V exists between the cathode and the anode. The electrons are deflected both side to side and up and down by pairs of magnetic deflection coils mounted on the neck of the tube.

10. An electron hits the screen at a speed of

A. 1.0×10^7 m/s

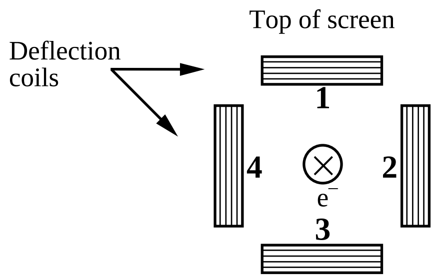
B. 1.5×10^7 m/s

C. 3.0×10^7 m/s

D. 8.8×10^{14} m/s

Use the following additional information to answer the next question.

An electron is travelling perpendicular to the magnetic deflection coils, into the page, as shown below.

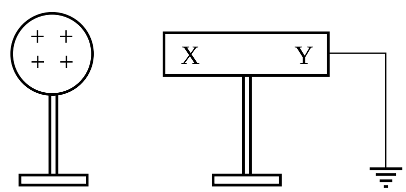


11. The coils that can produce a deflection toward the top of the screen are numbered

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

Use the following information to answer the next question.

A student places a positively charged sphere near a metal rod. Both are on insulated stands and the rod is grounded.

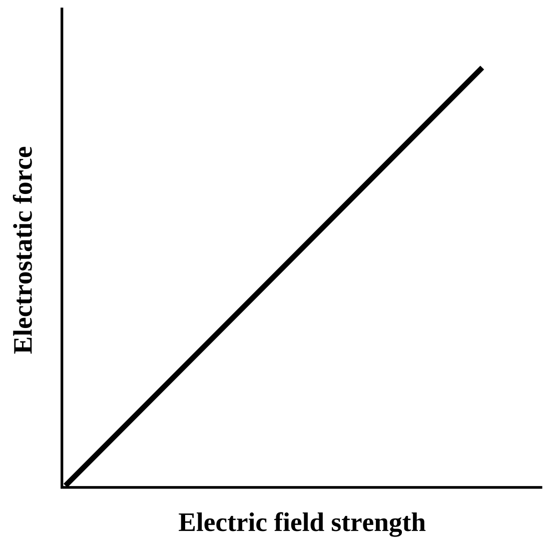


12. The distribution of charge on the rod is

A. positive at end X and electrons move off the rod into the ground
B. negative at end X and electrons move off the rod into the ground
C. positive at end X and electrons move onto the rod from the ground
D. negative at end X and electrons move onto the rod from the ground

Use the following information to answer the next question.

Force as a Function of Electric Field Strength



13. The slope of the graph represents

A. Coulomb’s Law

B. the distance between two parallel charged plates

C. the magnitude of the charge on a particle in an electric field

D. the potential difference between two points in an electric field

14. A photon exhibits properties of a particle because it has

A. mass

B. momentum

C. a constant speed

D. a fixed frequency

Numerical Response

2. Two microwave transmissions are sent at the same time on different routes to a receiving station. One route is 2 480 km longer than the other. The expected time between receiving the first transmission and receiving the second transmission, 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.)

15. An automobile's battery delivers a steady DC current to a headlight. The electric current in the wire produces a circular

A. electric field around the wire

B. magnetic field around the wire

C. gravitational field around the wire

D. electromagnetic field around the wire

Numerical Response

3. A wire that is 75.0 cm long carries a current of 6.00 A. The wire is at right angles to a uniform magnetic field and experiences a magnetic force of 0.350 N. The magnitude of the magnetic field, expressed in scientific notation, is $\boldsymbol{b} \times 10^{-w}$ T. The value of $\boldsymbol{b}$ is __________.

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

16. The effective voltage of an AC household outlet is 117 V. The maximum voltage across a lamp connected to the outlet is

A. 82.7 V

B. 117 V

C. 165 V

D. 330 V

17. Regions of the electromagnetic spectrum listed in order from largest to smallest wavelength are

A. X-ray, ultraviolet, visible, infrared, radio

B. X-ray, infrared, visible, ultraviolet, radio

C. radio, ultraviolet, visible, infrared, X-ray

D. radio, infrared, visible, ultraviolet, X-ray

18. Electromagnetic radiation is produced by charged particles that are moving

A. at the speed of light

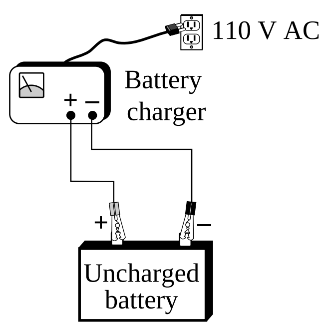
B. with zero acceleration

C. with a changing velocity

D. parallel to a fixed magnetic field

Use the following information to answer the next question.

In an automobile battery charger, 110 V of household voltage is converted to 14 V DC. The efficiency of the charger is 75%.



19. The initial direct current supplied to an uncharged battery by 0.70 A of household current is

A. 6.7×10^{-2} A

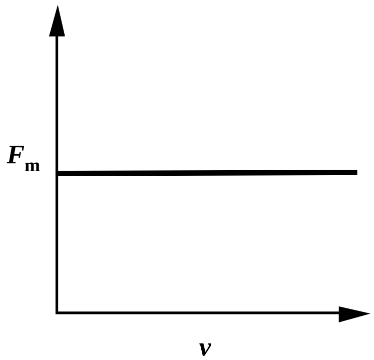
B. 8.9×10^{-2} A

C. 4.1 A

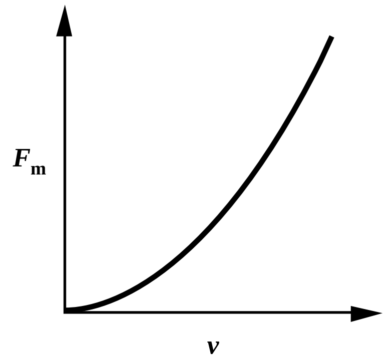
D. 5.5 A

20. In a certain experiment, the speed of a charged particle is made to increase as it moves at right angles to a uniform magnetic field. A graph that represents the relationship between magnetic force and speed is

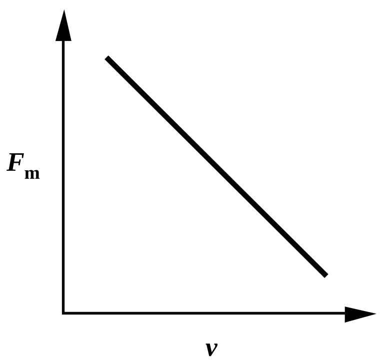
A.



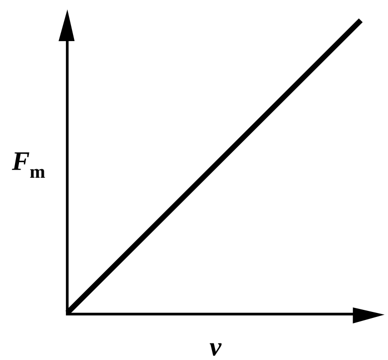
B.



C.



D.



Use the following information to answer the next question.

In 1991, the 18.0 GHz region of the electromagnetic spectrum was used to provide communication links in local area networks (LANs). This led to a dramatic expansion of this region's commercial use.

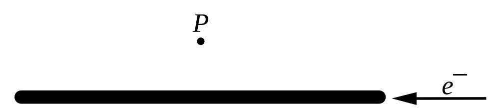
Numerical Response

4. The wavelength of an 18.0 GHz wave, expressed in scientific notation, is $\boldsymbol{b} \times 10^{-w}$ m. The value of $\boldsymbol{b}$ is __________.

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

Use the following information to answer the next question.

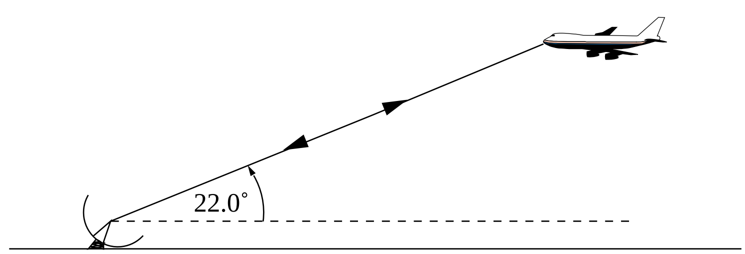
Electrons move through a wire as shown below.



21. What is the direction of the magnetic field at point *P*?

A. Into the page
B. Out of the page
C. Toward the top of the page
D. Toward the bottom of the page

Use the following information to answer the next question.



A radar pulse projected at an angle of elevation of $22.0°$ is reflected from an aircraft and returned. (Note: The diagram is not drawn to scale. The height of the radar transmitter/receiver can be ignored.)

Numerical Response

5. If the pulse takes 1.28×10^{-4} s to make the round trip, then the vertical height of the aircraft is __________ km.

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

Use the following information to answer the next three questions.

A proton with an energy of $894\ \text{eV}$ travels perpendicular to a magnetic field and moves in a circular path with a radius of 3.60×10^{-4} m.

22. The speed of the proton is

A. 4.14×10^{5} m/s
B. 1.77×10^{7} m/s
C. 1.71×10^{11} m/s
D. 3.14×10^{14} m/s

*Use your recorded answer from **Multiple Choice 22** to answer **Numerical Response 6**.**

Numerical Response

6. The strength of the magnetic field, expressed in scientific notation, is $\boldsymbol{a.bc} \times 10^{\boldsymbol{d}}$ T. The values of ***a, b, c,*** and ***d*** are _____ , _____ , _____ , and _____ .

(Record your **four-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.**

23. An alpha particle and a proton enter a magnetic field at the same speed. The radius of the alpha particle's path is

A. half the radius of the proton's path
B. the same as the radius of the proton's path
C. twice the radius of the proton's path
D. four times the radius of the proton's path

24. Which of the following expressions that deal with electromagnetic waves has a constant value?

A. λ

B. f

C. $f\lambda$

D. f/λ

Use the following information to answer the next two questions.

> Mass spectrometers are used in archeological studies to help date ancient artifacts. The relative amounts of carbon-12 and carbon-14 isotopes in a sample of organic material may be used to determine the age of the sample. Carbon-14 is a radioactive isotope that undergoes beta decay and has a half-life of 5 730 years.

25. The product of the carbon-14 decay is

A. ${}^{14}_{7}\mathrm{N}$

B. ${}^{14}_{8}\mathrm{O}$

C. ${}^{10}_{4}\mathrm{Be}$

D. ${}^{12}_{6}\mathrm{C}$

26. An archeological sample is dated using the carbon-14 dating process and is found to be 2 865 years old. What percentage of the original carbon-14 remains?

A. 25.0%

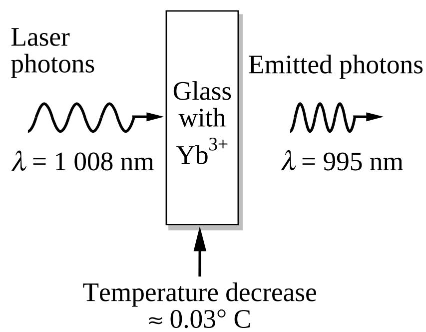
B. 29.3%

C. 70.7%

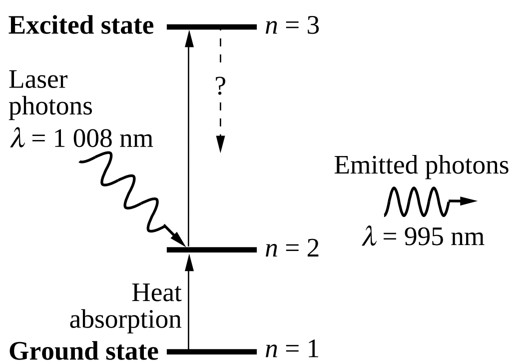
D. 75.0%

Use the following information to answer the next four questions.

Physicists have produced "optical cooling" by shining a laser onto glass that contains ytterbium ions (Yb^{3+}). The glass with ytterbium ions absorbs the laser photons and radiates photons with a shorter wavelength, as shown below. This process decreases the temperature of the glass with ytterbium ions.



One theory suggests that the cooling occurs because of electron movement between energy levels in the ytterbium ions, as shown below. If a ground state electron in an ytterbium ion absorbs a small amount of thermal energy, it moves to the second energy level ($n = 2$). The ion then absorbs the laser photon, which moves the electron to the excited state ($n = 3$). The cooling occurs when the ytterbium ion emits a photon.



27. When the glass cools, the ions lose both the thermal energy and the energy that was absorbed from the laser photons. The electron energy level transition that occurs is from energy level

A. $n = 3$ to $n = 2$

B. $n = 3$ to $n = 1$

C. $n = 2$ to $n = 1$

D. $n = 2$ to $n = 3$

Numerical Response

7. The frequency of the laser photons, expressed in scientific notation, is $\boldsymbol{a.b} \times 10^{\boldsymbol{cd}}$ Hz. The values of ***a, b, c***, and ***d*** are _____ , _____ , _____ , and _____ .

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

28. The energy difference between a laser photon and an emitted photon is

A. 2.00×10^{-19} J

B. 1.97×10^{-19} J

C. 2.58×10^{-21} J

D. 8.62×10^{-33} J

29. Visible light has frequencies that range between 4.3×10^{14} Hz (red) and 7.5×10^{14} Hz (violet). Which of the following statements **best** describes the absorbed laser photon and the emitted photon in the optical cooling experiment?

A. Both photons are in the infrared range.

B. Both photons are in the ultraviolet range.

C. Both photons are in the visible light range.

D. One photon is in the visible light range, and one is not in the visible light range.

30. In certain scattering experiments, alpha particles bounce backward from a thin metal target. This observation led to the hypothesis that

A. alpha particles carry electric charges

B. charge is uniformly distributed throughout the atom

C. alpha particles' kinetic energy cannot be converted to potential energy

D. the centre of the atom is very small, charged, and contains most of the atom's mass

Numerical Response

8. The work function of a metal with a threshold frequency of 1.1×10^{15} Hz, expressed in scientific notation, is $\boldsymbol{a.b} \times 10^{-\boldsymbol{cd}}$ J. The values of ***a, b, c,*** and ***d*** are _____ , _____ , _____ , and _____ .

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

31. When a neutral meson particle (π°) decays, it produces an electron (e^{-}). In this process, it is **most likely** that

A. nothing else is produced

B. a gamma ray is also produced

C. a negative particle is also produced

D. a positive particle is also produced

Use the following information to answer the next question.

Compton determined that the energy and momentum of a photon are related according to the formula $E = pc$.

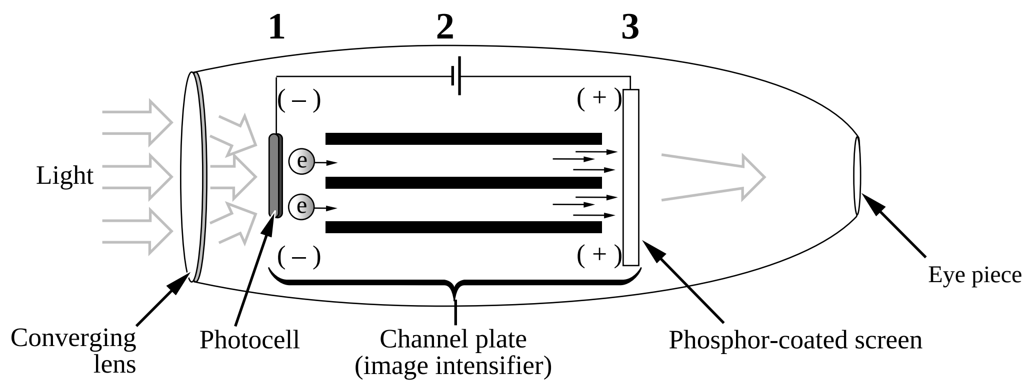
Numerical Response

9. A photon has a momentum of 4.0×10^{-23} N·s. The frequency of the photon, expressed in scientific notation, is $\boldsymbol{a.b} \times 10^{\boldsymbol{cd}}$ Hz. The values of ***a***, ***b***, ***c***, and ***d*** are _____ , _____ , _____ , and _____ .

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

Use the following information to answer the next three questions.

Night vision devices operate by taking available ambient light, such as starlight, and converting it into an electrical signal that is then amplified within a channel plate (image intensifier). The electrical signal is then focused on a phosphor-coated screen that emits a green image.



32. When light falls on the device at position **1** in the diagram,

A. the Compton effect occurs
B. the photoelectric effect occurs
C. light refraction and diffraction occurs
D. light diffraction and interference occurs

33. Night vision devices have a built-in brightness protection circuit to protect both the device and the viewer from unexpected bright light. The circuit is activated when the

A. photoelectric current increases
B. photoelectric current decreases
C. kinetic energy of photoelectrons increases
D. kinetic energy of photoelectrons decreases

Numerical Response

10. Green light with a wavelength of 545 nm reaches the observer's eyes. The energy of a photon of this green light is __________ eV.

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

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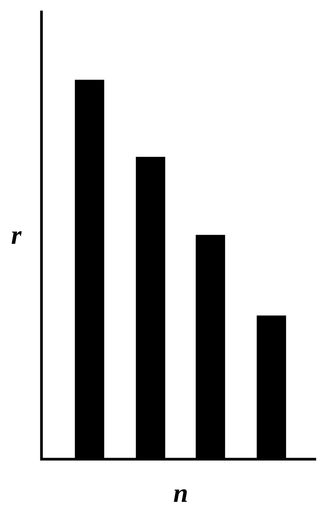
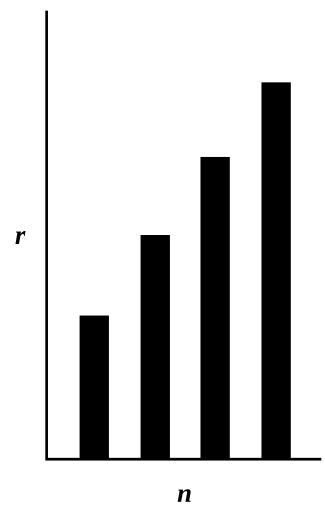
34. The graph below that shows the relationship between the radius of a hydrogen atom (r) and the energy level (n) of its electron is

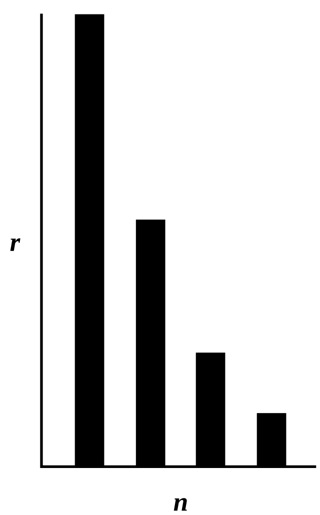
A.



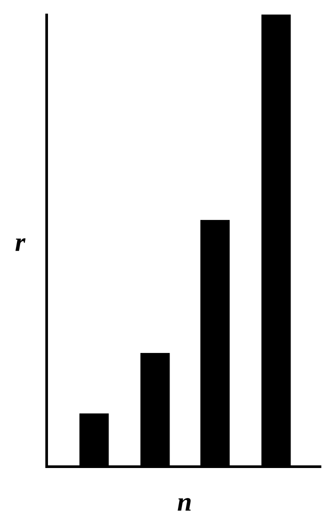
B.



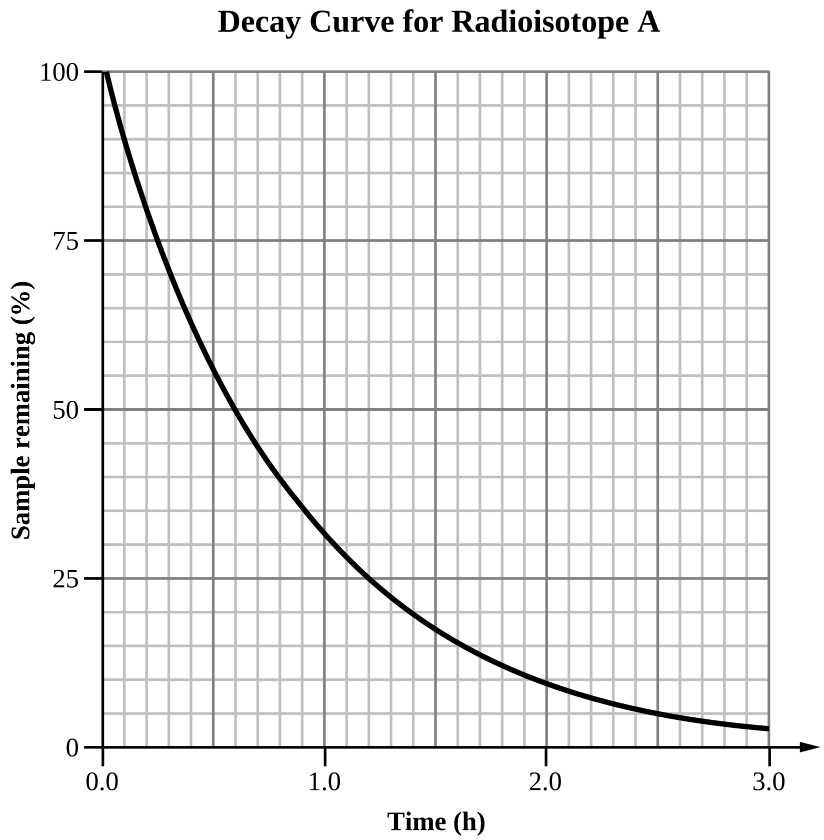
C.



D.



Use the following information to answer the next question.



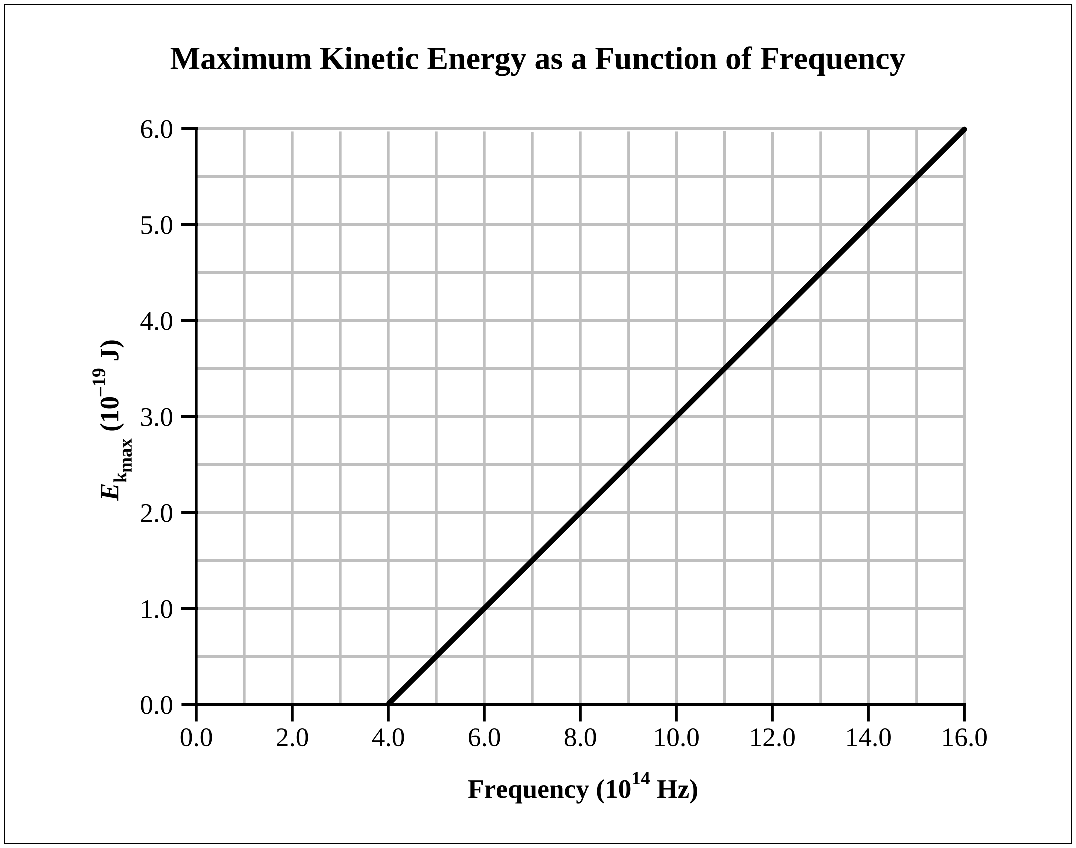
The graph illustrates the decay of a radioactive isotope.

Numerical Response

11. The time required for a 40.0 g sample to decay to 1.25 g is __________ h.

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

Use the following information to answer the next question.



35. Based on the graph above, Planck's constant has a value of

A. 6.6×10^{-34} J·s
B. 5.0×10^{-34} J·s
C. 3.6×10^{-34} J·s
D. 3.0×10^{-34} J·s

Use the following information to answer the next three questions.

A particular nuclear fission reaction of uranium-235 is represented by

$${}^{235}_{92}\mathrm{U} + {}^{1}_{0}\mathrm{n} \rightarrow {}^{141}_{55}\mathrm{Cs} + {}^{\boldsymbol{ab}}_{\boldsymbol{cd}}\boldsymbol{X} + 3\,{}^{1}_{0}\mathrm{n},$$

where element ***X*** is unknown.

36. The value of ***cd*** in the above reaction can be identified using the Law of Conservation of

A. Mass
B. Energy
C. Charge
D. Momentum

Numerical Response

12. The fission product in this reaction is represented by ${}^{\boldsymbol{ab}}_{\boldsymbol{cd}}\boldsymbol{X}$.
The values of ***a, b, c,*** and ***d*** are _____ , _____ , _____ , and _____ .

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

37. In the above fission reaction, the mass of the reactants is 236.05 atomic mass units, and the mass of the products is 235.86 atomic mass units. Which of the following explanations **best** describes the change in mass that occurs in this nuclear fission reaction?

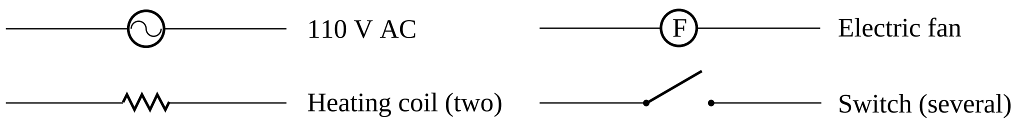
A. Mass and energy are equivalent, and energy has been converted into mass in this reaction.
B. Mass and energy are equivalent, and mass has been converted into energy in this reaction.
C. Mass and energy are equivalent, and the missing mass is due to inaccurate laboratory measuring equipment.
D. Neutrinos that are given off in the fission reaction are undetectable, which accounts for the differences in mass of the detectable components of the reaction.

Written-response question 1 begins on page 22.

Use the following information to answer the next question.

You have the following components: an electric fan, two heating coils, several switches, and connecting wires. These components are to be used to construct a hair dryer.

Schematics of Hair Dryer Components



The design requirements for your hair dryer are that the fan is always on when the hair dryer is on and that it has two heat settings: high and low.

Written Response — 15%

1. • Draw a schematic diagram of a hair dryer circuit that meets the design requirements.

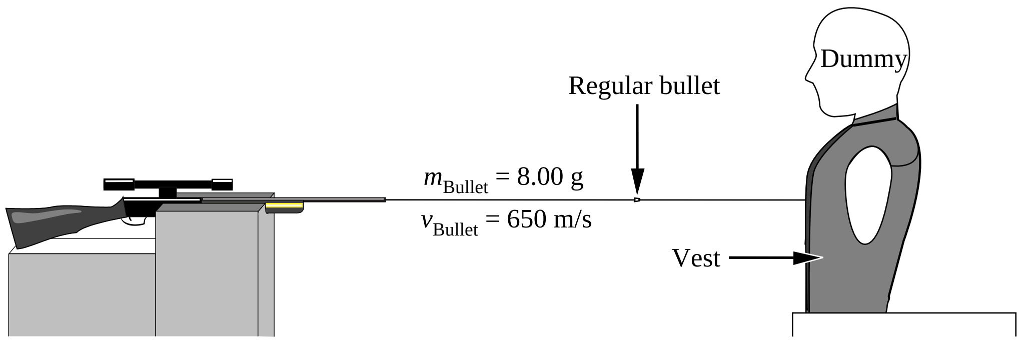
• Based on the circuit diagram you have drawn, analyze the operation of the hair dryer. In your response, explain how the switch settings and their locations in the circuit control the low and high heat settings. Also, explain why the hair dryer should be designed so that the fan is on whenever the hair dryer is on.

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.

Several Canadian companies are redesigning and testing bulletproof vests. One company does a test that involves firing a target rifle at a crash test dummy wearing a vest.



The company is testing the vests with both regular bullets and armour-piercing bullets. The armour-piercing bullet travels 1.20 times faster and has 1.20 times the mass of the regular bullet shown above.

Written Response — 15%

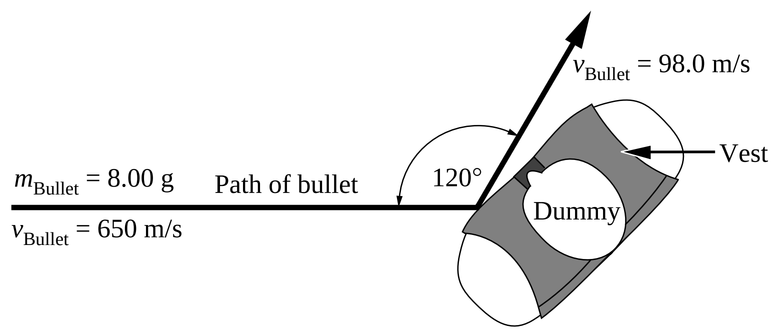
2. • Quantitatively compare the kinetic energy of the armour-piercing bullet with the kinetic energy of the regular bullet.

• How much energy is released by the explosion of the gunpowder if the transfer of energy from the explosion to the regular bullet is 90.0% efficient?

• The regular bullet is in the rifle barrel for 1.42×10^{-3} s. What is the average force exerted on the regular bullet by the expanding gases?

Use this additional information to answer the next part of the question.

A second test performed by the company has the regular bullet strike the vest at a glancing angle. The mass of the vest and the dummy is 56.0 kg. The bullet–vest collision is inelastic.



- Determine the resultant **speed** of the vest and the dummy following the glancing collision shown above.

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

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

Fold and tear along perforation.

PHYSICS DATA SHEET

CONSTANTS

Gravity, Electricity, and Magnetism

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

Atomic Physics

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

Particles

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

Trigonometry and Vectors

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

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

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

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

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

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

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

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

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

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

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

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

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

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

Dynamics

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

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

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

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

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

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

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

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

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

Momentum and Energy

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

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

$W = Fd$

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

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

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

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

Waves and Light

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

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

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

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

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

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

$v = f\lambda$

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

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

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

Atomic Physics

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

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

$W = hf_0$

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

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

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

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

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

Quantum Mechanics and Nuclear Physics

$E = mc^2$

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

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

Electricity and Magnetism

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

$V = IR$

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

$P = IV$

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

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

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

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

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

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

$V = lvB_{\perp}$

$R = R_1 + R_2 + R_3$

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

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

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

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

Fold and tear along perforation.

Periodic Table of the Elements

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
IA	IIA	IIIB	IVB	VB	VIB	VIIB		VIIIB	VIIIB	IB	IIB	IIIA	IVA	VA	VIA	VIIA	VIIIA or O
1 H 1.01 hydrogen																	2 He 4.00 helium
3 Li 6.94 lithium	4 Be 9.01 beryllium											5 B 10.81 boron	6 C 12.01 carbon	7 N 14.01 nitrogen	8 O 16.00 oxygen	9 F 19.00 fluorine	10 Ne 20.17 neon
11 Na 22.99 sodium	12 Mg 24.31 magnesium											13 Al 26.98 aluminum	14 Si 28.09 silicon	15 P 30.97 phosphorus	16 S 32.06 sulphur	17 Cl 35.45 chlorine	18 Ar 39.95 argon
19 K 39.10 potassium	20 Ca 40.08 calcium	21 Sc 44.96 scandium	22 Ti 47.90 titanium	23 V 50.94 vanadium	24 Cr 52.00 chromium	25 Mn 54.94 manganese	26 Fe 55.85 iron	27 Co 58.93 cobalt	28 Ni 58.71 nickel	29 Cu 63.55 copper	30 Zn 65.38 zinc	31 Ga 69.72 gallium	32 Ge 72.59 germanium	33 As 74.92 arsenic	34 Se 78.96 selenium	35 Br 79.90 bromine	36 Kr 83.80 krypton
37 Rb 85.47 rubidium	38 Sr 87.62 strontium	39 Y 88.91 yttrium	40 Zr 91.22 zirconium	41 Nb 92.91 niobium	42 Mo 95.94 molybdenum	43 Tc (98.91) technetium	44 Ru 101.07 ruthenium	45 Rh 102.91 rhodium	46 Pd 106.40 palladium	47 Ag 107.87 silver	48 Cd 112.41 cadmium	49 In 114.82 indium	50 Sn 118.69 tin	51 Sb 121.75 antimony	52 Te 127.60 tellurium	53 I 126.90 iodine	54 Xe 131.30 xenon
55 Cs 132.91 cesium	56 Ba 137.33 barium	57-71	72 Hf 178.49 hafnium	73 Ta 180.95 tantalum	74 W 183.85 tungsten	75 Re 186.21 rhenium	76 Os 190.20 osmium	77 Ir 192.22 iridium	78 Pt 195.09 platinum	79 Au 196.97 gold	80 Hg 200.59 mercury	81 Tl 204.37 thallium	82 Pb 207.19 lead	83 Bi 208.98 bismuth	84 Po (208.98) polonium	85 At (209.98) astatine	86 Rn (222.02) radon
87 Fr (223.02) francium	88 Ra (226.03) radium	89-103	104 Unq (266.11) unnilquadium	105 Unp (262.11) unnilpentium	106 Unh (263.12) unnilhexium	107 Uns (262.12) unnilseptium	108 Uno (265) unniloctium	109 Une (266) unnilennium									

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

Key

Atomic number → 3 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

Tear-out Page

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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 1999

Multiple Choice
and
Numerical Response
Key

Written Response
Scoring Guide

Physics 30 – June 1999

MULTIPLE-CHOICE KEY

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

NUMERICAL-RESPONSE KEY

1.	1.94*	**7.**	3014
2.	8.27	**8.**	7319
3.	7.78	**9.**	1819
4.	1.67	**10.**	2.28
5.	7.19	**11.**	3.0
6.	1201**	**12.**	9237

Links:

*If MC 2 is A, then NR 1 is 1.37
B, then NR 1 is 1.94
C, then NR 1 is 91.0 or 91.1
D, then NR 1 is 182

**If MC 22 is A, then NR 6 is 1201
B, then NR 6 is 5132
C, then NR 6 is 4966
D, then NR 6 is 9109

Holistic Scoring Guide

Reporting Category: Physics COMMUNICATION

When marking **COMMUNICATION**, the marker should consider how effectively the response **describes in detail the method, procedure, or strategy used to provide a solution to the problem.**	
Score	**Criteria**
3	In the response, the student • provides a complete, well organized, and clear solution to the problem • provides, in detail, a strategy in a logical manner • demonstrates consistency of thought • uses physics vocabulary appropriately and precisely • provides an explicit relationship between the explanation and diagrams (if used) • states formula(s) explicitly • may have a mathematical error that does not hinder the understanding of either the strategy or the solution
2	In the response, the student • provides an organized response, however, errors sometimes affect the clarity • provides a strategy, but details are general and/or sometimes lacking • demonstrates consistency of thought most of the time, however, some gaps in logic leave the response somewhat open to interpretation • uses physics vocabulary, however, it may not be precise • provides an implicit relationship between explanation and diagrams (if used) • uses formula(s) that are likely inferred by analyzing the calculations • likely has mathematical errors that may hinder the understanding of either the strategy or the solution
1	In the response, the student • lacks organization, and errors affect the clarity • attempts to provides a strategy with little or no detail • demonstrates a lack of consistency of thought, and the response is difficult to interpret • uses physics vocabulary, however, it is often misused • provides a weak relationship between the explanation and diagrams (if used) • may not state formula(s), however, it is possible that the formula(s) can be deciphered by analyzing the calculations • has mathematical errors that hinder the understanding of the strategy and/or the solution
0	In the response, the student • writes very little and/or presents very little relevant information • provides a response that is not organized, and is confusing and/or frustrating to the reader • does not provide a strategy to solve the problem • uses little or no physics vocabulary, however, if present, it is misused • provides no relationship between the explanation, if present, and diagrams (if used) • may state a formula but it does not contribute toward the solution
NR	No response given.

Holistic Scoring Guide

Reporting Category: Physics CONTENT

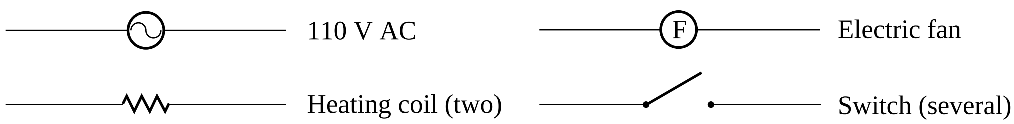
When marking **CONTENT**, the marker should consider how effectively the response **uses physics concepts, knowledge, and skills to provide a solution to the problem**.

Score	Criteria
4	In the response, the student • uses an appropriate method that reflects a **thorough understanding** of the major concepts and/or laws, and indicates where they apply to the solution • provides a complete description of the method used **and** shows how to solve the problem • correctly uses formula(s) and although minor errors in substitution and/or calculation may be present they do not hinder the understanding of the physics content • has drawn diagrams and/or sketches, if applicable, that are appropriate, correct, and complete • has no major omissions or inconsistencies
3	In the response, the student • uses an appropriate method that reflects a **good understanding** of the main concepts and/or laws, and indicates where they apply to the solution • provides a description of the method used **and/or** shows how to solve the problem • correctly uses formula(s) however, errors in substitution and/or calculation may hinder the understanding of the physics content • has drawn diagrams and/or sketches, if applicable, that are appropriate, although some aspect may be incorrect or incomplete • may have several minor inconsistencies or perhaps one major inconsistency, however, there is little doubt that the understanding of physics content is good
2	In the response, the student • uses a method that reflects a **basic understanding** of the major concepts and/or laws but experiences some difficulty indicating where they apply to the solution • provides either a description of the method used **or** shows how to solve the problem • uses formula(s), however, errors and inconsistencies in substitution and/or calculation hinder the understanding of the physics content presented • has drawn diagrams and/or sketches, if applicable, that may be appropriate, although some aspect is incorrect or incomplete • has inconsistencies or a major omission
1	In the response, the student • uses a method that reflects a **poor understanding** of the major concepts and/or laws, and experiences difficulty indicating where they apply to the solution • provides a description of the method used, or a solution, that is incomplete • may use formula(s) however, the application is incorrect or inappropriate • has drawn diagrams and/or sketches, if applicable, that are inappropriate, incorrect, and/or incomplete • has minor and major inconsistencies and/or omissions
0	In the response, the student • uses a method that reflects little or no understanding of the major concepts and/or laws • does not provide a description of the method used • may use formula(s) and substitution, but they do not address the question • has drawn diagrams and/or sketches, if applicable, that are incorrect, inappropriate, and incomplete • has major omissions
NR	No response is given.

Use the following information to answer the next question.

You have the following components: an electric fan, two heating coils, several switches, and connecting wires. These components are to be used to construct a hair dryer.

Schematics of Hair Dryer Components



The design requirements for your hair dryer are that the fan is always on when the hair dryer is on and that it has two heat settings: high and low.

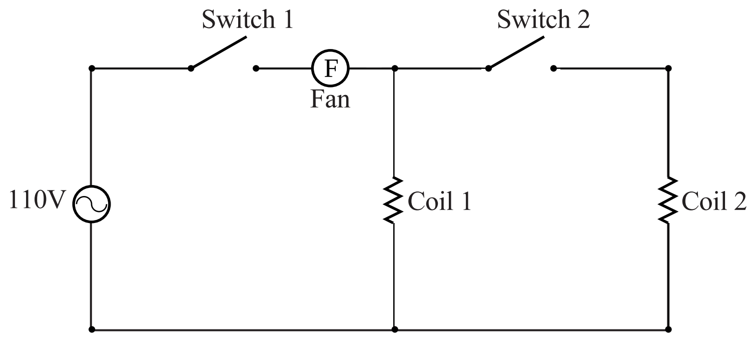
Written Response — 15%

1. • Draw a schematic diagram of a hair dryer circuit that meets the design requirements.

• Based on the circuit diagram you have drawn, analyze the operation of the hair dryer. In your response, explain how the switch settings and their locations in the circuit control the low and high heat settings. Also, explain why the hair dryer should be designed so that the fan is on whenever the hair dryer is on.

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

Sample Solution



Closing switch one, with the hair dryer plugged in, will turn on coil 1 and the fan, resulting in a low heat mode of operation. When the switches are both closed both coil 1 and coil 2, as well as the fan, are turned on resulting in the high heat mode of operation.

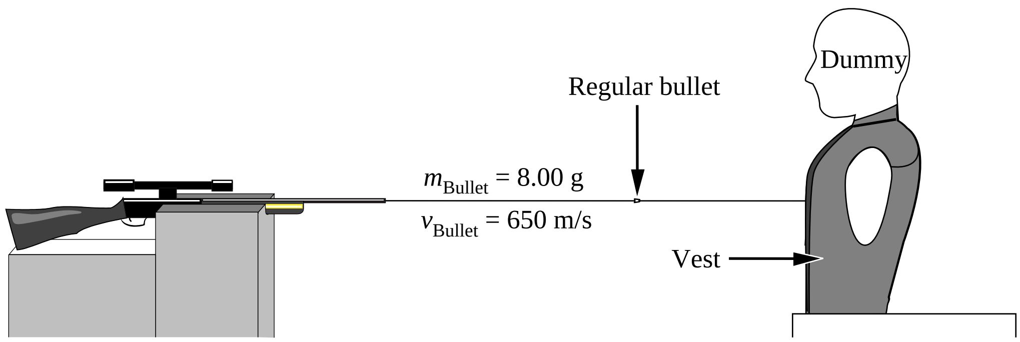
In both modes of operation, the fan must be on and blowing air over the coils. When the coils are switched "on", heat will be generated in the coils. It is this heat that is used to dry hair. If the fan was not on, the coil would heat up and eventually melt and/or you would probably have a hard time drying hair.

Scoring Guide for Anaholistic Questions

Major Concepts: Energy; Impulse; Vectors; Momentum.	
Score	**Criteria**
NR	No response is given.
0	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
1	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
2	In the response, the student • uses an appropriate method that reflects a basic understanding of three of the four major concepts **or** a good understanding of two of the major concepts • 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
3	In the response, the student • uses an appropriate method that reflects a basic understanding of all four of the major concepts **or** a good understanding of three of the major concepts • uses an appropriate method that reflects an excellent understanding of two of the major concepts **and** a basic understanding of one of the two remaining concepts • uses formulas and/or diagrams that may be implicit, but are applied correctly; errors in calculations and/or substitutions are present that hinder the understanding of the physics content • provides explanations that are correct but lack detail • has a major omission or inconsistency
4	In the response, the student • uses an appropriate method that reflects a good understanding of all major concepts **or** an excellent understanding of three of the major concepts • provides explanations that are correct and detailed • states most formulas explicitly and applies them correctly • has minor errors, omissions, or inconsistencies in calculations and/or substitutions but these do not hinder the understanding of the physics content • draws most diagrams appropriately, correctly, and completely • may have errors in units, significant digits, rounding, or graphing
5	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, but this does not hinder the understanding of the physics content • draws diagrams that are appropriate, correct, and complete • may have an error in significant digits or rounding

Use the following information to answer the next question.

Several Canadian companies are redesigning and testing bulletproof vests. One company does a test that involves firing a target rifle at a crash test dummy wearing a vest.



The company is testing the vests with both regular bullets and armour-piercing bullets. The armour-piercing bullet travels 1.20 times faster and has 1.20 times the mass of the regular bullet shown above.

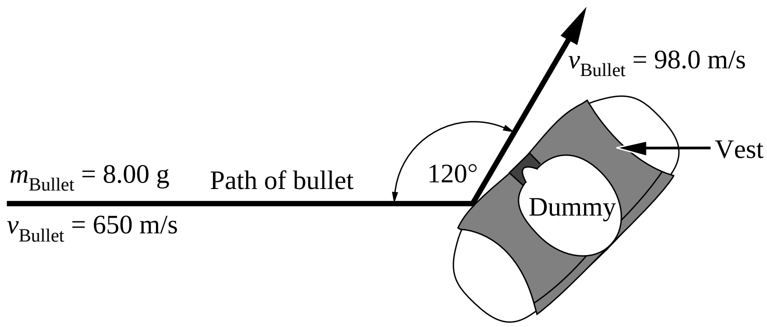
Written Response — 15%

2.

- Quantitatively compare the kinetic energy of the armour-piercing bullet with the kinetic energy of the regular bullet.
- How much energy is released by the explosion of the gunpowder if the transfer of energy from the explosion to the regular bullet is 90.0% efficient?
- The regular bullet is in the rifle barrel for 1.42×10^{-3} s. What is the average force exerted on the regular bullet by the expanding gases?

Use this additional information to answer the next part of the question.

A second test performed by the company has the regular bullet strike the vest at a glancing angle. The mass of the vest and the dummy is 56.0 kg. The bullet–vest collision is inelastic.



- Determine the resultant **speed** of the vest and the dummy following the glancing collision shown above.

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

Sample Solution

- Energy of the armour-piercing bullet compared to energy of the regular bullet.

Method 1:

$$\frac{E_{K_{AP}}}{E_{K_B}} = \frac{\frac{1}{2} m_{AP} v_{AP}^2}{\frac{1}{2} m_B v_B^2}$$

$$\frac{\frac{1}{2}(8.00 \times 10^{-3}\ \text{kg} \bullet 1.2)(1.2 \bullet 650\ \text{m/s})^2}{\frac{1}{2}(8.00 \times 10^{-3}\ \text{kg})(650\ \text{m/s})^2} = \frac{1.2(1.2)^2}{1}$$

$$\frac{E_{K_{AP}}}{E_{K_B}} = 1.73$$

The armour-piercing bullet has 1.73 times as much kinetic energy as the regular bullet.

Method 2:

$$E_{K_B} = \tfrac{1}{2} m_B {v_B}^2$$
$$= \tfrac{1}{2}(8.00 \times 10^{-3}\ \text{kg})(650\ \text{m/s})^2$$
$$= 1.69 \times 10^3\ \text{J}$$

$$E_{K_{AP}} = \tfrac{1}{2}[(1.2)(8.00 \times 10^{-3}\ \text{kg})][(650\ \text{m/s})(1.2)]^2$$
$$= 2.92 \times 10^3\ \text{J}$$

The $E_{K_{AP}}$ is greater by 1.23×10^3 J

or

The $E_{K_{AP}}$ is 1.73 times greater

- The energy released by the explosion of the gunpowder at 90% efficiency.

$$E_k = \tfrac{1}{2} mv^2$$
$$= \tfrac{1}{2}(8.00 \times 10^{-3}\ \text{kg})(650\ \text{m/s})^2$$
$$E_k = 1.69 \times 10^3\ \text{J}$$

$$90\%\ \text{of}\ E_p = E_k$$
$$\frac{E_k}{0.9} = \text{energy of gunpowder}$$
$$\frac{1.69 \times 10^3\ \text{J}}{0.9} = 1.88 \times 10^3\ \text{J}$$

The energy released by the gunpowder is 1.88×10^3 J.

- The average force exerted on the regular bullet by the expanding gases.

$$F\Delta t = m\Delta v$$
$$F = \frac{m\Delta v}{\Delta t}$$
$$F = \frac{(8.00 \times 10^{-3}\ \text{kg})(650\ \text{m/s} - 0)}{(1.42 \times 10^{-3}\ \text{s})}$$
$$F = 3.66 \times 10^3\ \text{N}$$

The force of the expanding gas on the bullet is 3.66×10^3 N.

- The resultant velocity of the vest and dummy.

  Conservation of momentum in 2D implies two separate sets of calculations. Momentum is conserved in X direction and momentum is conserved in Y direction.

$$\begin{aligned} p'_{B} &= mv \\ &= (8.00 \times 10^{-3}\ \text{kg})(98.0\ \text{m/s}) \\ p'_{B} &= 0.784\ \text{N}\cdot\text{s} \end{aligned}$$

$$\begin{aligned} p'_{B_y} &= p'_{B} \sin 60^\circ \\ &= 0.784 \sin 60^\circ \\ p'_{B_y} &= 0.67896\ \text{kg}\cdot\text{m/s} \end{aligned}$$

$$\begin{aligned} p'_{B_x} &= p'_{B} \cos 60^\circ \\ &= 0.784 \cos 60^\circ \\ p'_{B_x} &= 0.392\ \text{kg}\cdot\text{m/s} \end{aligned}$$

$$\begin{aligned} p_{B_x} + p_{D_x} &= p'_{B_x} + p'_{D_x} \\ (8.00 \times 10^{-3}\ \text{kg})(650\ \text{m/s}) + 0 &= (0.392\ \text{kg}\cdot\text{m/s}) + p'_{D_x} \\ (5.20\ \text{kg}\cdot\text{m/s}) - (0.392\ \text{kg}\cdot\text{m/s}) &= p'_{D_x} \\ 4.808\ \text{kg}\cdot\text{m/s} &= p'_{D_x} \end{aligned}$$

$$\begin{aligned} p_{B_y} + p_{D_y} &= p'_{B_y} + p'_{D_y} \\ 0 + 0 &= p'_{B_y} + p'_{D_y} \\ \text{Therefore:}\quad p'_{D_y} &= -p'_{B_y} \\ p'_{D_y} &= -0.67896\ \text{kg}\cdot\text{m/s} \end{aligned}$$

To find the resultant vector from *x* and *y* components, use Pythagoras:

$$p_D' = \sqrt{(p'_{D_x})^2 + (p'_{D_y})^2}$$
$$= \sqrt{(4.808)^2 + (0.67896)^2}$$
$$p_D' = 4.85 \text{ kg·m/s}$$

$$p_D' = mv'$$
$$v' = \frac{4.85 \text{ kg·m/s}}{56.0 \text{ kg}}$$
$$v' = 0.0867 \text{ m/s}$$

The vest and dummy will have a speed of 8.67×10^{-2} m/s.