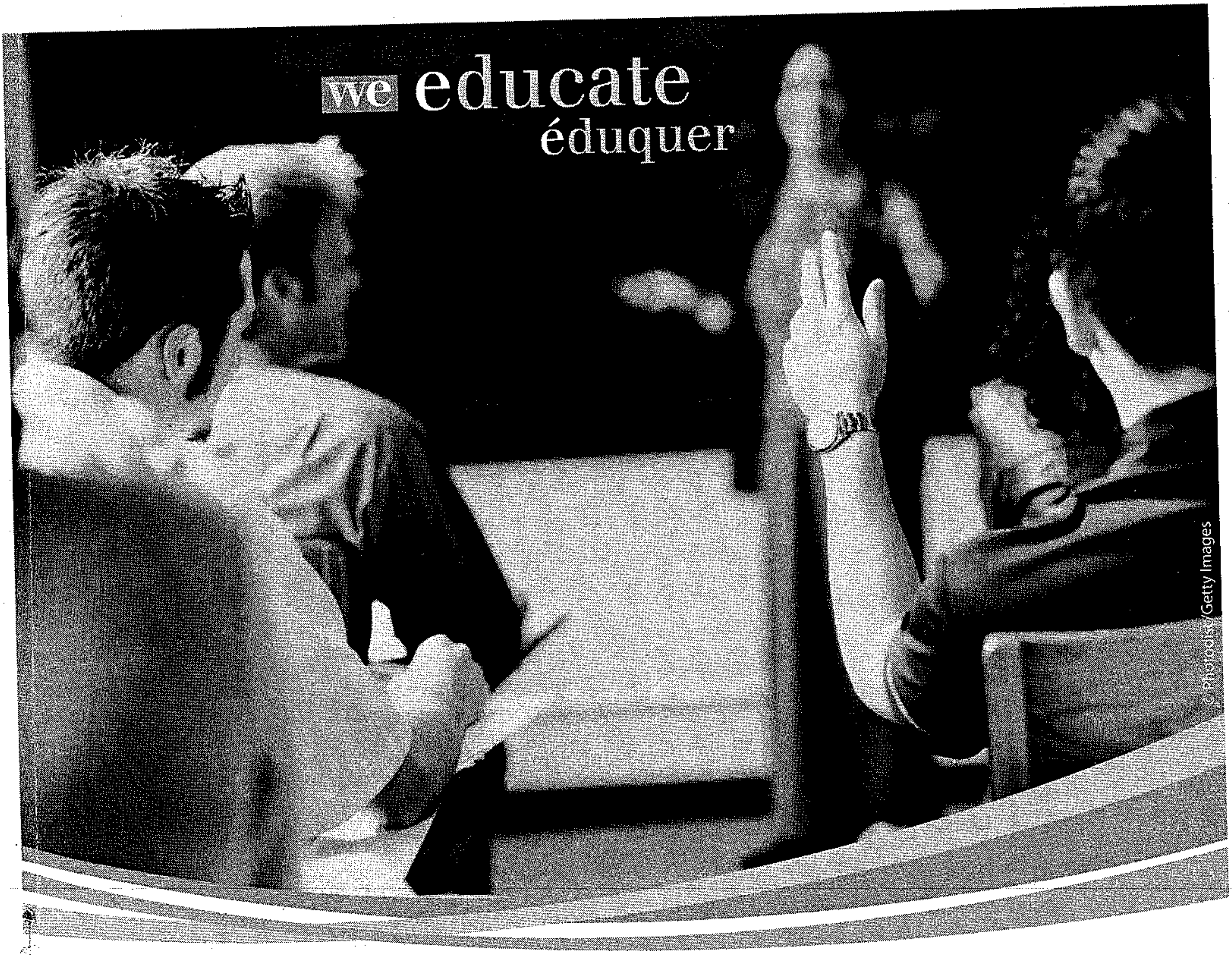
Key

Physics 30 | Released Items

2009 Released Diploma Examination Items



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Our Internet address is education.alberta.ca.

Introduction

These items are the complete Physics 30 January 2009 Part B: Machine Scored Diploma Examination.

For details about these items including provincial difficulties, Program of Studies classifications, and item descriptions, please refer to the Physics 30 Diploma Examination Jurisdiction or School Report January 2009 available to school administrators on the Alberta Education Extranet.

Released items are available in print form only and not available electronically because of copyright limitations.

Additional Documents

Learner Assessment supports the instruction of Physics 30 in classrooms with the following documents available online at www.education.alberta.ca.

Physics 20–30 Classroom-Based Performance Standards
This document provides a detailed but not prescriptive nor exhaustive list of student behaviours observable in the classroom and links those behaviours to the acceptable standard or the standard of excellence.

Physics 30 Information Bulletin
This document provides a description of the diploma examination design and blueprint, written-response sample questions, generic scoring guides, and descriptions of trends in student performance on the physics diploma examinations. In addition, this year's bulletin contains the January 2009 Part A, sample solutions, and illustrative responses with scoring rationale.

Physics 30 Information Bulletin – Archive
This document is the 2008 Physics 30 Information Bulletin that in addition to the usual bulletin content contains a complete illustrative Part B and multiple written-response questions with sample solutions, as well as illustrative responses with scoring rationale.

Physics 30 January 2009 Diploma Examination (3797 0904)
Multiple-Choice and Numerical-Response Keys

Multiple Choice

1.	A	21.	C
2.	C	22.	D
3.	B	23.	A
4.	D	24.	B
5.	B	25.	C
6.	D	26.	B
7.	C	27.	A
8.	A	28.	A
9.	D	29.	D
10.	D	30.	A
11.	B	31.	B
12.	D	32.	A
13.	B	33.	C
14.	D	34.	C
15.	C	35.	A
16.	B	36.	A
17.	D	37.	B
18.	A	38.	C
19.	D	39.	A
20.	A	40.	C

Numerical Response

1.	6747	6.	1.62
2.	1473	7.	1.37
3.	6.24	8.	4.11
4.	7.81	9.	1457 (any order)
5.	1466	10.	5521

Physics 30 Released Questions, 2009–2010

Use the following information to answer the first two questions.

> As a child catches a ball, he exerts a force, F, on the moving ball for a time interval, Δt. The mass of the ball is 250 g and its velocity changes from +5.00 m/s to +1.00 m/s as a result of the force.

no direction needed

1. The magnitude of the impulse that the child applies to the ball is

[✓ **A.**] 1.00 N·s
B. 1.25 N·s
C. 2.50×10^2 N·s
D. 1.00×10^3 N·s

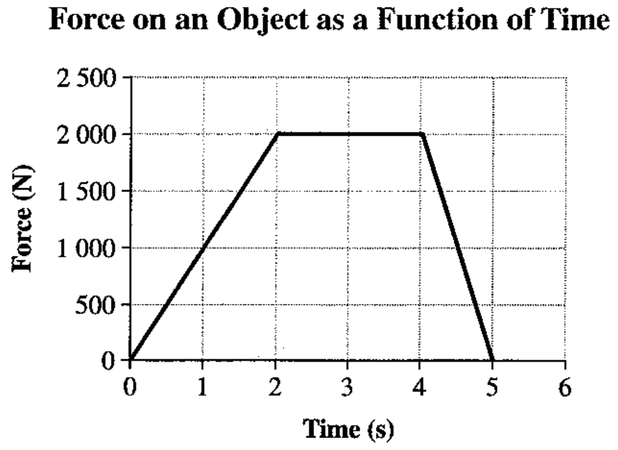
$$\begin{aligned} \text{impulse} &= \Delta p \\ &= m\Delta v \\ &= m(v_f - v_i) \\ &= 0.250\,\text{kg}\left(1.00\,\tfrac{m}{s} - 5.00\,\tfrac{m}{s}\right) \\ &= 1.00\ \text{kg·m/s} \text{ or } 1.00\ \text{N·s} \end{aligned}$$

2. If, when catching the ball, the child had applied triple the force, then the length of time that it would have taken to slow the ball would have been

A. $9\Delta t$
B. $3\Delta t$
[✓ **C.**] $\frac{1}{3}\Delta t$
D. $\frac{1}{9}\Delta t$

$$\text{impulse} = \Delta p$$
$$F\Delta t = \Delta p$$
$$3F \cdot \tfrac{1}{3}\Delta t = \Delta p$$

Use the following information to answer the next question.


Force on an Object as a Function of Time

3. The area under the curve represents the

A. work done on the object
[✓ **B.**] impulse experienced by the object
C. displacement of the object while the force is being applied
D. acceleration of the object as a result of the net force being applied

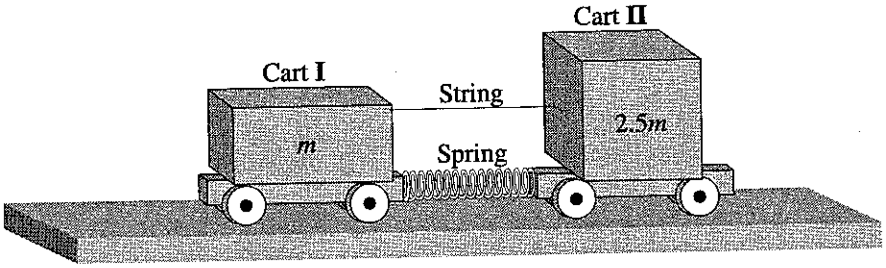
analysis units of area

since area units are N.s
it represents impulse

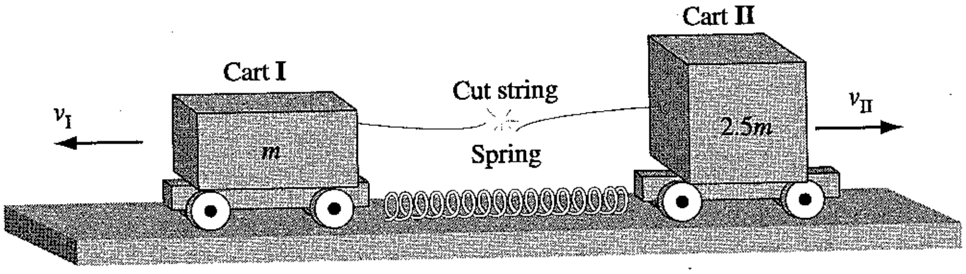
impulse = $F\Delta t$
impulse = N.s

Use the following information to answer the next question.

Two laboratory carts are placed on a frictionless surface. A spring is attached to both carts and compressed. A string holds the two carts together so that they are motionless. Cart I has a mass of m and cart II has a mass of $2.5m$.



The string is cut and the carts move in opposite directions; cart I has a velocity of 0.80 m/s, left.



4. The speed of cart II after the string is cut is

1 Dimensional

A. 3.1 m/s
B. 2.0 m/s
C. 0.80 m/s
[✓ **D.**] 0.32 m/s

$$\vec{P}_{before} = \vec{p}_{after}$$

$$0 = m_A v_A' + m_B v_B'$$

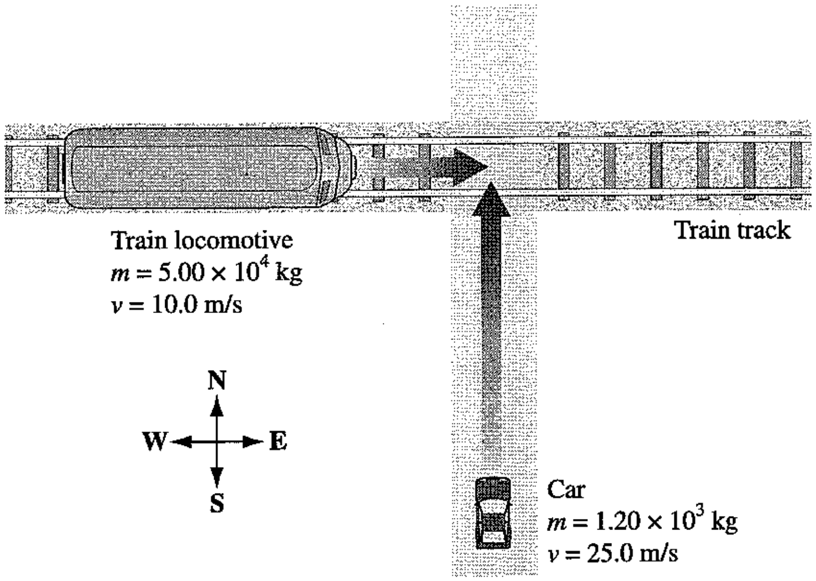
$$0 = (1 \cdot -0.80) + 2.5\, v_B'$$

$$\frac{0.80\,kg \cdot \frac{m}{s}}{2.5\,kg} = v_B'$$

$$0.32\,\frac{m}{s} = v_B'$$

Use the following information to answer the next question.

In a movie stunt, a car and a train locomotive intentionally crash. The collision is illustrated in the diagram below.

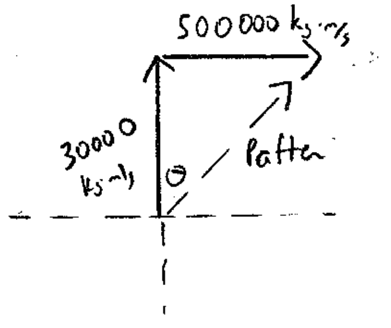


5. Immediately before the collision, the momentum of the locomotive–car system is

A. 5.01×10^5 kg·m/s, 68.2° north of east
[✓ **B.**] 5.01×10^5 kg·m/s, 3.43° north of east
C. 5.30×10^5 kg·m/s, 68.2° north of east
D. 5.30×10^5 kg·m/s, 3.43° north of east

2 Dimensional (⊥ vectors)

Pbefore = Pafter



$P_{after} = \sqrt{(500000)^2 + (30000)^2}$

$P_{after} = \boxed{5.01 \times 10^5 \text{ kg}\cdot\text{m/s}}$

$\tan\theta = \frac{500000}{30000} = 86.6°$ E of N or $\boxed{3.43° \text{ N of E}}$

note Pafter = Pbefore because momentum is conserved.

Use the following information to answer the next question.

A positively charged object is brought near to, but does not touch, one end of a neutral metal rod on an insulated stand. The opposite end of the metal rod is grounded. The ground is removed, and then the positively charged object is removed.

6. As a result of the procedure described above, the metal rod will

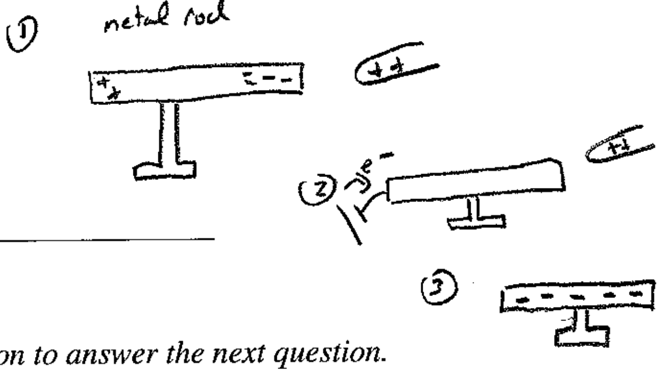
charging by induction with ground.

A. be neutral

B. have a net charge of zero

C. have a positive net charge

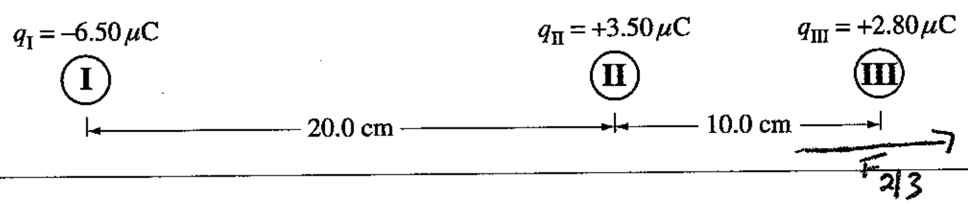
[✓ **D.**] have a negative net charge



Use the following information to answer the next question.

Charged spheres I, II, and III are located as shown below.

1 Dimension



7. The net electrostatic force on sphere III that is caused by the charges on spheres I and II is

A. 6.99×10^{-4} N, right

B. 1.06×10^{-3} N, right

[✓ **C.**] 6.99 N, right

D. 10.6 N, right

$$F_{213} = \frac{kq_2q_3}{R^2} = \frac{(8.99\times10^9)(2.8\times10^{-6})(3.5\times10^{-6})}{(0.10m)^2} = 8.81..N\,[E]$$

$$F_{113} = \frac{kq_1q_3}{R^2} = \frac{(8.99\times10^9)(6.5\times10^{-6})(2.8\times10^{-6})}{(0.30m)^2}$$

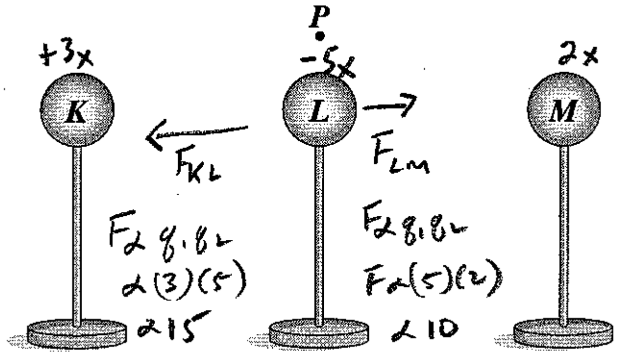
$$= 1.817..\,N\,[W]$$

$$F_{net} = 8.81..N - 1.817N$$

$$= 6.99\,N\,[E]$$

Use the following information to answer the next three questions.

A student has three identical spheres, *K*, *L*, and *M*, on insulated stands equally spaced in a line as shown below. The charges on the spheres are $q_K = +3x$, $q_L = -5x$, and $q_M = +2x$.



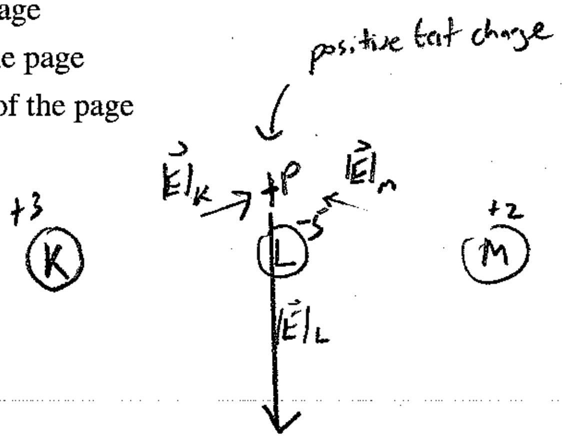
8. The direction of the net electric force on sphere *L* due to spheres *K* and *M* is

[✓ **A.**] to the left of the page
B. to the right of the page
C. toward the top of the page
D. toward the bottom of the page

$F_{net} = F_{KL} - F_{LM}$
$= 15 - 10$
$= 5$ (left)

9. At point *P*, above sphere *L*, the direction of the net electric field is **mostly**

A. to the left of the page
B. to the right of the page
C. toward the top of the page
[✓ **D.**] toward the bottom of the page



$|\vec{E}| = \frac{kq}{R^2}$

$|\vec{E}| \propto \frac{q}{R^2}$

Since charge L is larger than K or M and it is much closer to P, it will exert the greatest $|\vec{E}|$ on P.

Use the following additional information to answer the next question.

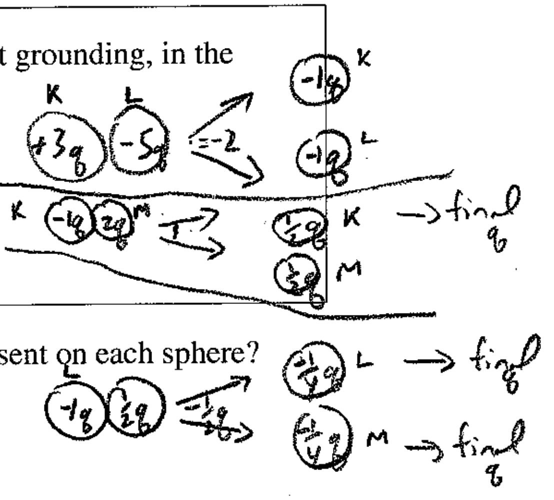
The spheres are touched together and separated, without grounding, in the following order.

Step I Spheres *K* and *L*

Step II Spheres *K* and *M*

Step III Spheres *L* and *M*

10. Which of the following rows indicates the final charge present on each sphere?



Row	Sphere *K*	Sphere *L*	Sphere *M*
A.	0	0	0
B.	$-x$	$-x$	$+2x$
C.	$\frac{+x}{2}$	$-x$	$\frac{+x}{2}$
[✓ **D.**]	$\frac{+x}{2}$	$\frac{-x}{4}$	$\frac{-x}{4}$

Numerical Response

1. The electric field strength at a distance of 4.00 cm from a 1.20×10^{-5} C point charge, expressed in scientific notation, is $a.bc \times 10^{d}$ N/C. The values of $a, b, c,$ and d are _____, _____, _____, and _____.

producing charge

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

$$|\vec{E}| = \frac{kq}{R^2} = \frac{(8.99\times10^9)(1.20\times10^{-5})}{(0.04\text{ m})^2}$$

$$= 6.74\times10^7 \text{ ⓓ}$$

ⓐⓑⓒ

6 7 4 7

uniform field - same strength anywhere between plates

Numerical Response

$|\vec{E}| = \frac{V}{d} = \frac{44{,}0\text{V}}{0{,}030\text{m}} = 1466.6 \frac{\text{V}}{\text{m}} \text{ n } \frac{\text{N}}{\text{C}}$

2. Two parallel plates are 3.00 cm apart and there is an electric potential difference of 44.0 V between them. The electric field strength between the plates 1.00 cm from the positively charged plate, expressed in scientific notation, is ***a.bc*** $\times 10^{d}$ N/C. The values of ***a***, ***b***, ***c***, and ***d*** are _1_, _4_, _7_, and _3_.

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

$1{,}47 \times 10^{3}$ N/C

11. An oil drop of mass 6.6×10^{-14} kg is suspended in an electric field of 2.0×10^{6} N/C between horizontal plates that are 4.0×10^{-2} m apart. The number of excess electrons on the oil drop is

Draw FBD

↑ Fep

↓ Fg

A. 1

[✓ **B.**] 2

C. 5

D. 20

If suspended or moving at constant speed

$F_{el} = F_g$

$q|\vec{E}| = mg$

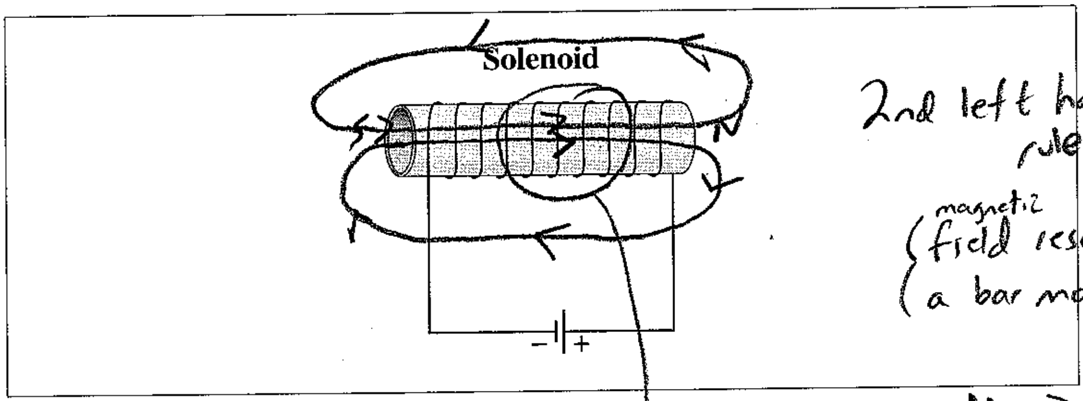
$q(2{,}0 \times 10^{6}) = (6{,}6 \times 10^{-14})(9.81)$

$q = \frac{6{,}4746.. \times 10^{-13} \text{ N}}{2.0 \times 10^{6} \text{ N/C}}$

$q = \frac{3{,}2373 \times 10^{-19}\text{C}}{1{,}6 \times 10^{-19} \frac{\text{C}}{e^-}}$

$= 2 e^-$

Use the following information to answer the next question.



2nd left hand rule

(magnetic field resembles a bar magnet)

N → S

(closed loops)

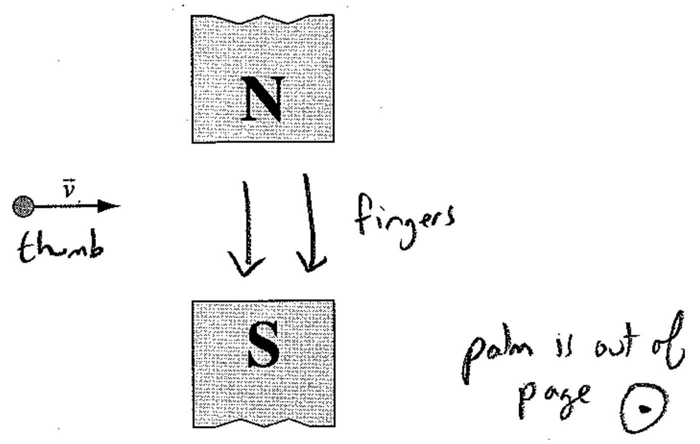
12. The magnetic field created inside the solenoid is directed

A. into the page
B. out of the page
C. toward the left of the page
[✓ **D.**] toward the right of the page

inside solenoid $\vec{B}$ is toward right

Use the following information to answer the next question.

A negatively charged particle is projected into a magnetic field, as shown in the diagram below.



13. As the negatively charged particle enters the magnetic field, the direction of the magnetic force that it experiences is

3rd left hand rule

A. into the page
[✓ **B.**] out of the page
C. toward the top of the page
D. toward the bottom of the page

14. Which of the following unit combinations is appropriate for magnetic field strength?

Use data book - solve equation for $\vec{B}$

A. $\frac{\text{N}\cdot\text{m}}{\text{A}}$

B. $\frac{\text{N}\cdot\text{A}}{\text{m}}$

C. $\frac{\text{N}\cdot\text{m}}{\text{C}\cdot\text{s}}$

[✓ D.] $\frac{\text{N}\cdot\text{s}}{\text{C}\cdot\text{m}}$

$$F_m = qvB_\perp$$

$$B_\perp = \frac{F_m}{qv} = \frac{N}{C\cdot\frac{m}{s}} = \frac{N\cdot s}{C\cdot m}$$

Use the following information to answer the next question.

A current-carrying wire is placed in an external magnetic field. The magnetic field strength is 5.00×10^{-2} T. When the current in the wire is 1.25 A, the wire experiences a magnetic force of 3.90×10^{-3} N.

Numerical Response

3. The length of the wire that is inside of and perpendicular to the magnetic field, expressed in scientific notation, is __________ $\times 10^{-w}$ m.

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

$$F_m = B_\perp I l$$

$$3.90\times10^{-3}N = 5,00\times10^{-2}\,T\cdot 1,25\,A\cdot l$$

$$0,0624\,m = l$$

$$\boxed{6.24}\times10^{-2}\,m$$

Use the following information to answer the next ten questions.

A scanning electron microscope (SEM) is a microscope that uses a beam of electrons rather than visible light to produce images of specimens.

Description of the Operation of an SEM

Electrons are accelerated from the electron gun to the anode. The electric potential difference between the electron gun and the anode accelerates the electrons to a speed of 2.65×10^7 m/s. After this acceleration, the electrons pass through an opening in the anode and enter the magnetic lens.

The magnetic lens focuses the beam of electrons. A particular electron experiences a magnetic force of 3.31×10^{-12} N while in the magnetic lens. As a result of this magnetic force, the path of the electrons spirals and the beam of electrons becomes focused.

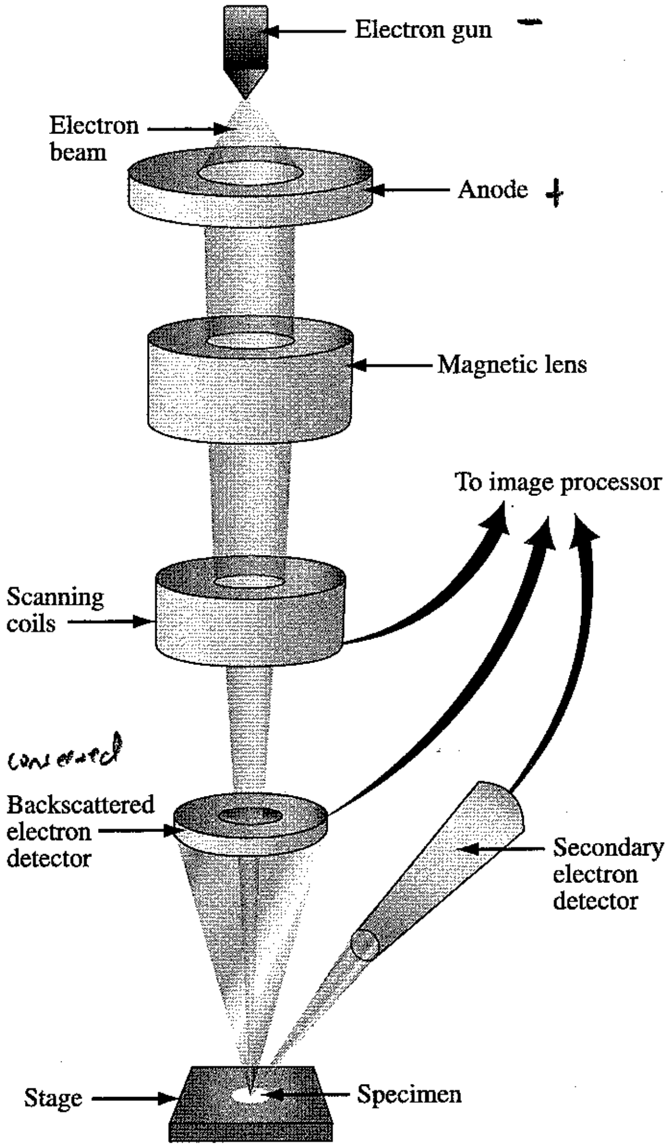
Scanning coils deflect the beam of electrons back and forth across the specimen.

Some electrons from the beam reflect off the specimen at the same speed at which they hit. The backscattered electron detector picks up these electrons. These backscattered electrons provide information about the composition and surface characteristics of the specimen.

E_k conserved

The electron beam causes the specimen to emit electrons from its surface. The secondary electron detector picks up these electrons.

Information collected from the scanning coils and the two detectors is sent to the image processor. This processor produces a three-dimensional image of the specimen.



$$F_m = q\vec{v}B_\perp$$

$$3.31\times10^{-12} = (1.6\times10^{-19})(2.65\times10^{7})\,B_\perp$$

$$0.7806\ \text{T} = B_\perp$$

Numerical Response

4. The magnitude of the magnetic field in the magnetic lens, expressed in scientific notation, is __________ × 10^{-w} T.

$$\boxed{7.81}\times10^{-1}\ \text{T} = B_\perp$$

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

15. The instantaneous radius of the resulting spiral of the electron's path in the magnetic lens is

$$F_m = F_c$$

$$qvB_\perp = \frac{mv^{\cancel{2}}}{R}$$

$$R = \frac{mv}{qB_\perp} = \frac{(9.11\times10^{-31})(2.65\times10^{7})}{(1.6\times10^{-19})(.78066..)}$$

$$R = 1.93\times10^{-4}\ \text{m}$$

A. 5.17×10^{3} m

B. 3.54×10^{-1} m

[✓ **C.**] 1.93×10^{-4} m

D. 7.29×10^{-12} m

16. *The collision that produces a backscattered electron is classified as ___i___ because there is ___ii___ in the kinetic energy of the system.*

The statement above is completed by the information in row

Row	*i*	*ii*
A.	elastic	a decrease
[✓ **B.**]	elastic	no change
C.	inelastic	a decrease
D.	inelastic	no change

if $E_{kb} = E_{ka}$ collision is elastic

if $E_{kb} > E_{ka}$ " " inelastic

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

The wavelength of an electron is modelled by the following formula, hypothesized by de Broglie.

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

In this formula, λ is the wavelength of the electron, h is Planck's constant, and p is the momentum of the electron.

The higher the resolution of a microscope, the smaller the details it can distinguish. A microscope, whether it uses light or a beam of electrons, has a resolution that is approximately 2 times the wavelength of the wave used to examine the specimen.

17. The reason that electron microscopes have a higher resolution than visible-light microscopes is that electrons have

A. mass

B. charge

C. longer wavelengths than visible light

[✓ **D.**] shorter wavelengths than visible light

A shorter wave can reflect off a smaller object and this reflection can be magnified.

A longer wave will diffract around a smaller object leaving no image to magnify.

Numerical Response

e^- waves are shorter than visible light
(10^{-10} m) (10^{-7} m)

5. In order to achieve an SEM resolution of 1.000 nm, the speed of the electrons, expressed in scientific notation, should be $a.bc \times 10^{d}$ m/s. The values of $a, b, c,$ and d are __1__, __4__, __6__, and __6__.

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

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

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

$0.5 \times 10^{-9} = \frac{6.63 \times 10^{-34}}{9.11 \times 10^{-31} \cdot \vec{v}}$

Since resolution is 2x the λ, use 0.5 nm

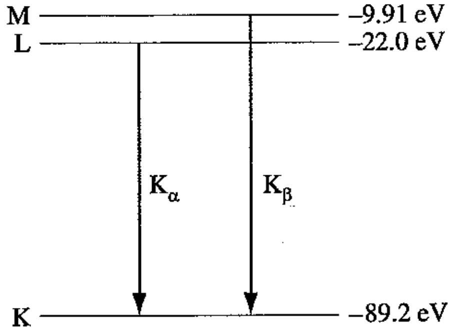
$\vec{v} = 1.46 \times 10^{6}$ m/s

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

In the SEM, some of the electrons in the original beam knock electrons loose from lower energy levels of the atoms in the specimen. An electron in a higher energy level of these atoms then makes a transition to fill the vacated lower energy level.

The following energy level diagram shows two possible electron transitions in lead.

Energy Level Diagram



Numerical Response

– energy is means light emitted

$\Delta E = E_f - E_i$

$= -89.2 eV - (-22.0) eV$

$= \boxed{-} 67.2 eV$

6. The frequency of the photons emitted in the K_α transition for lead, expressed in scientific notation, is __________ × 10^w Hz.

$E = hf$

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

$\frac{67.2 eV}{4.14 \times 10^{-15} eV \cdot s} = f$

$\boxed{1.62} \times 10^{16} Hz$ f

18. The region of the electromagnetic spectrum in which the photons corresponding to the K_α and K_β lines for lead are classified is **most likely**

- [✓ **A.** X-ray]
- **B.** visible
- **C.** infrared
- **D.** microwave

visible light is 10^{14} Hz

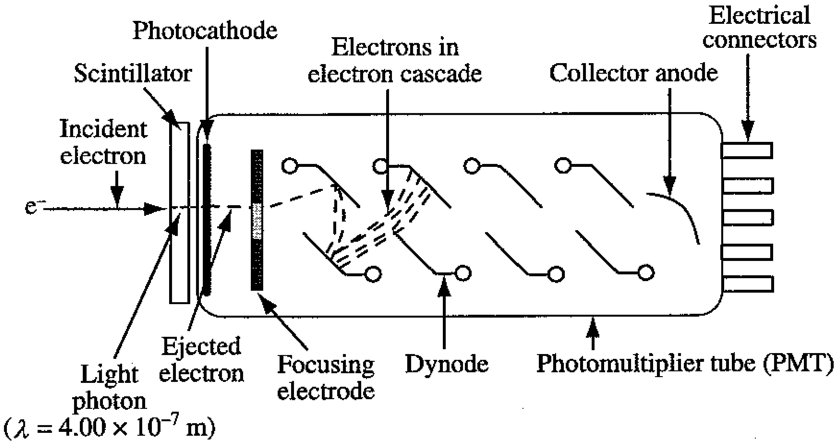
so... 10^{16} Hz is higher freq than visible.

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

The original electron beam can knock loose valence electrons from the specimen. To detect these secondary electrons, a scintillator and a photomultiplier tube are used.

Description of a Scintillator and a Photomultiplier Tube (PMT)

For each secondary electron that hits the scintillator, a photon that has a wavelength of 4.00×10^{-7} m is produced. This photon hits the photocathode, which has a work function of 1.80 eV, and initiates an electron cascade, as illustrated below.



Inside the photomultiplier tube are several dynodes (intermediate anodes) and a final collector anode. Each dynode is kept at a greater positive potential than the one previous to it. The electric potential difference between one dynode and the next is 150 V.

An electron released from the photocathode is accelerated toward and collides with the first dynode, releasing a number of tertiary electrons, which are in turn accelerated toward the next dynode. The process repeats with as much as a million-fold increase in the number of electrons released by the time they reach the collector anode. This provides a strong electrical signal in response to the detection of a single photon.

19. The process by which an electron is ejected from the photocathode in the PMT is

- **A.** X-ray production
- **B.** radioactive decay
- **C.** the Compton effect
- [✓ **D.**] the photoelectric effect

photons (light) hit the photocathode and eject electrons.

20. The maximum kinetic energy of an electron ejected from the photocathode in this PMT is

- [✓ **A.**] 1.31 eV
- **B.** 1.80 eV
- **C.** 3.11 eV
- **D.** 4.91 eV

$E_{photon} = E_{e^-} + W$

$\frac{hc}{\lambda} = E_e + 1.80eV$

$\frac{4.14\times10^{-15} \cdot 3\times10^{8}}{4.00\times10^{-7}} = E_{e^-} + 1.80eV$

$3.105eV = E_{e^-} + 1.80eV$

$E_e = 3.105 - 1.80$

$E_{e^-} = 1.31eV$

21. A particular electron, as it leaves one dynode, has a kinetic energy of 1.00×10^{-17} J. The speed of this electron when it reaches the next dynode will be

- **A.** 5.93×10^6 m/s
- **B.** 7.26×10^6 m/s
- [✓ **C.**] 8.64×10^6 m/s
- **D.** 1.32×10^7 m/s

① find v_i

$E_k = .5mv^2$

$1.00\times10^{-17} = .5\times9.11\times10^{-31} v^2$

$v_i = 4.685..\times10^{6} m/s$

② accelerated through 150V

$\downarrow E_p = \uparrow E_k$

$qV = \frac{1}{2}mv_f^2 - v_i^2$

$(1.60\times10^{-19})(150) = \frac{1}{2}(9.11\times10^{-31})(v_f^2 - (4.685\times10^{6})^2)$

$2.4\times10^{-17} = 4.555\times10^{-31}(v_f^2 - 2.194..\times10^{13})$

$5.268..\times10^{13} = v_f^2 - 2.194\times10^{13}$

$7.4629..\times10^{13} = v_f^2$

$8.64\times10^{6} m/s = v_f$

alternate solution

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

$V = \frac{E_f - E_i}{q}$

$150 = \frac{E_f - 1.00\times10^{-17}}{1.60\times10^{-19}}$

$E_f = 3.14\times10^{-17} J$

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

$3.14\times10^{-17} = \frac{1}{2} 9.11\times10^{-31} v^2$

$8.64\times10^{6} m/s = v$

22. Which of the following sentences describes the electric and magnetic field components of an electromagnetic wave?

see workbook page 185!

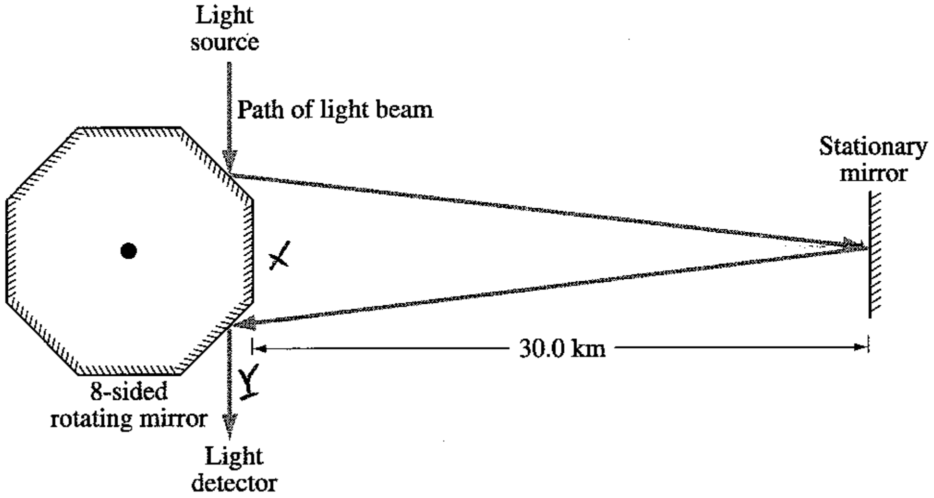
- **A.** The changes in their magnitudes are equal.
- **B.** The changes in their magnitudes are unrelated.
- **C.** They are parallel to the direction of wave propagation.
- [✓ **D.**] They are perpendicular to the direction of wave propagation.

Use the following information to answer the next question.

In a Michelson-type experiment, the path followed by a beam of light when the 8-sided mirror is at rest is as shown below. The detector indicates a maximum signal.

As the 8-sided mirror begins to rotate, the beam of light no longer follows this path, and the detector indicates a decreased signal.

speed of light



Note: This diagram is **not** drawn to scale.

23. Once the 8-sided mirror is rotating, the frequency of rotation for which the detector will first indicate a maximum signal is

- [✓ **A.**] 6.25×10^2 revolutions per second
- **B.** 1.25×10^3 revolutions per second
- **C.** 5.00×10^3 revolutions per second
- **D.** 1.00×10^4 revolutions per second

① $t = \frac{d}{v} = \frac{60000\text{ m}}{3\times10^{8}\text{ m/s}}$

$t = 2.0\times10^{-4}\text{ s}$

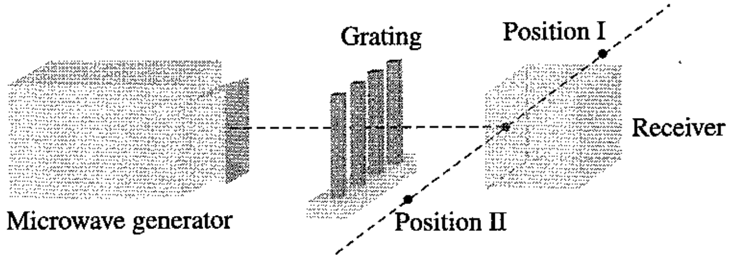
- in this time light has travelled 60000m and the mirror has made $\frac{1}{8}$ of a rotation

② $\frac{\frac{1}{8}R}{2.0\times10^{-4}\text{ s}} = \frac{?R}{1\text{ s}}$

Use the following information to answer the next question.

In a laboratory experiment, a microwave generator is used to produce a beam of monochromatic microwaves. These waves are incident on a series of metal tubes that forms a diffraction grating. The metal tubes are spaced 1.80 cm apart.

When the microwave signal passes through the grating, a receiver placed 52.0 cm from the grating detects a maximum signal. A first-order maximum signal is also detected at each of positions I and II, as labelled in the diagram below.



diffraction

Note: This diagram is **not** drawn to scale.

The angle from the central maximum to either position I or II is 49.8°.

Numerical Response

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

7. The experimental wavelength of the microwaves, in centimetres, is 1.37 cm.

$$\lambda = \frac{1.8\,\text{cm} \cdot \sin 49.8^\circ}{1}$$

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

$\lambda = 1.37$ cm

Numerical Response

8. Visible light that has a wavelength of 6.00×10^{-7} m in air is directed into fused quartz. The index of refraction of fused quartz is 1.46. The wavelength of this light inside the fused quartz, expressed in scientific notation, is $\boxed{4.11}$ $\times 10^{-w}$ m.

10^{-7}

refraction

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

1 - air
2 - quartz

$$\frac{n_2}{n_1} = \frac{\lambda_1}{\lambda_2}$$

$$\frac{1.46}{1.00} = \frac{6.00 \times 10^{-7}\,\text{m}}{\lambda_2}$$

from data book

$\lambda_2 = \boxed{4.11} \times 10^{-7}$

24. At what distance above this page would a convex magnifying lens that has a focal length of 10.0 cm have to be held for the image of the letters to appear upright and 3 times as tall?

A. 3.33 cm
[✓ **B.**] 6.67 cm
C. 13.3 cm
D. 15.0 cm

$$M = 3 = \frac{-d_i}{d_o}$$

$$3d_o = -d_i$$

$$\boxed{-3d_o} = d_i$$

$$\frac{1}{f} = \frac{1}{d_o} + \frac{1}{d_i}$$

$$\frac{1}{10} = \frac{1}{d_o} + \frac{1}{\boxed{-3d_o}} \text{ sub}$$

$$\frac{1}{10} = \frac{-3}{-3d_o} + \frac{1}{-3d_o} \text{ common denominator}$$

$$\frac{1}{10} = \frac{-2}{-3d_o}$$

$$\frac{1}{10} = \frac{2}{3d_o}$$

$$3d_o = 20$$

$$d_o = 6.67\text{cm}$$

Use the following information to answer the next question.

Students use various apparatus to investigate optical phenomena. During their investigations, they make the following eight observations.

Observations

✓ **1** The apparatus produces a continuous spectrum with white light.
2 The apparatus produces a bright-line spectrum with white light.
3 The apparatus produces an interference pattern with monochromatic light.
✓ **4** The apparatus produces a single bright line with monochromatic light.
✓ **5** The apparatus bends red light through a smaller angle than it bends blue light.
6 The apparatus bends red light through a larger angle than it bends blue light.
✓ **7** The apparatus produces a single spectrum when white light is incident perpendicular to the apparatus.
8 The apparatus produces multiple spectra when white light is incident perpendicular to the apparatus.

Numerical Response

9. Four observations that could be produced using only a triangular glass prism are numbered 1, 4, 5, and 7.

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

Use the following information to answer the next question.

A satellite in orbit around Earth is exposed to radiation from the Sun. This radiation may cause the satellite to become positively charged.

Some Wavelengths Incident on a Satellite

convert to Energies using $E = \frac{hc}{\lambda}$

have enough energy to overcome W

I	2.25×10^{-7} m	$= 8.84 \times 10^{-19}$ J
II	2.33×10^{-7} m	8.54×10^{-19} J
III	3.24×10^{-7} m	6.13×10^{-19} J
IV	4.28×10^{-7} m	4.65×10^{-19} J

Platinum is commonly used to coat satellites and has a work function of 8.5×10^{-19} J.

25. Which of the wavelengths listed above would cause a satellite with a platinum coating to become positively charged? (Pt lose e^- to become +)

A. Wavelength I only
B. Wavelength IV only
[✓ **C.**] Wavelengths I and II
D. Wavelengths III and IV

---

26. The equation $hf = q_e V_{stop} + W$ for the photoelectric effect is derived using the physics principle of conservation of

A. charge
[✓ **B.**] energy
C. nucleons
D. momentum

$E_{photon} = E_{k\,electron} + \text{work Function}$

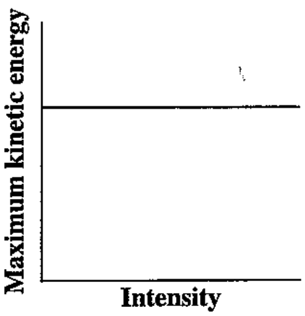
$hf = q V_{stop} + W$

or or

$\frac{hc}{\lambda} = \frac{1}{2} mv^2 + W$

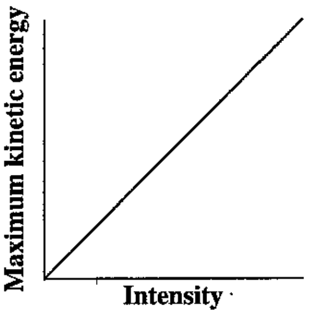
27. Electromagnetic radiation of constant wavelength is incident on a metal cathode, and the photoelectric effect is observed. Which of the following graphs represents the relationship between the maximum kinetic energy of the emitted photoelectrons and the intensity of the incident radiation?

[✓ A.]

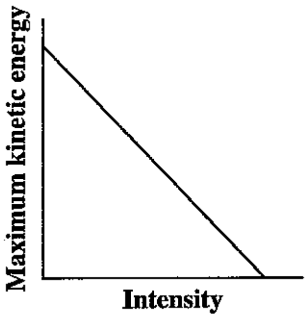


E_k of emitted e^- is affected by frequency.
Intensity only affects the amount of e^- emitted (current) not their energy.

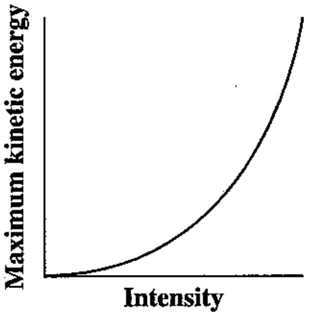
B.



C.



D.



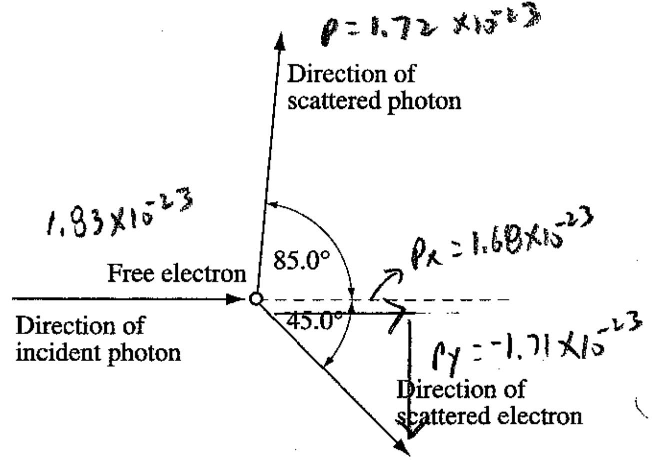
28. Which of the following conclusions **most closely** followed the discovery that cathode rays consist of charged particles?

- [✓ **A**] J. J. Thomson's conclusion that all atoms contain smaller parts called electrons
- **B.** Bohr's conclusion that electrons inhabit discrete energy levels around the nucleus
- **C.** Maxwell's conclusion that accelerating charges produce electromagnetic radiation
- **D.** Rutherford's conclusion that the atom has a dense, positively charged nucleus that electrons orbit

Cathode rays are e^-

Use the following information to answer the next question.

One example of Compton scattering is shown below. The incident photon has a momentum of 1.83×10^{-23} N·s. It collides with a free electron that is initially at rest. The scattered photon has a momentum of 1.72×10^{-23} N·s, 85.0° from the direction of the incident photon.



conservation of p (2D)

$p_R = \sqrt{(1.68\times10^{-23})^2 + (1.71\times10^{-23})^2}$

$p_R = 2.40 \times 10^{-23}$ N·s

29. The magnitude of the momentum of the free electron after it has been hit by the incident photon is

A. 1.10×10^{-24} kg·m/s
B. 1.68×10^{-23} kg·m/s
C. 1.71×10^{-23} kg·m/s
[✓ **D.**] 2.40×10^{-23} kg·m/s

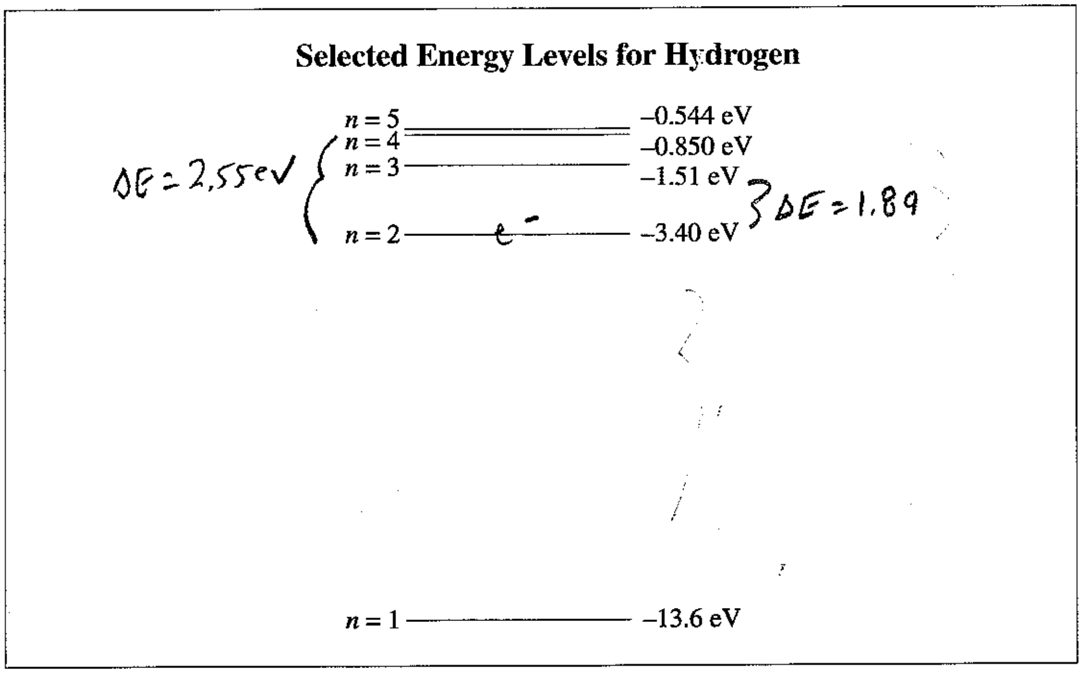
$p_{xb} = p_{xa}$
$1.83 \times 10^{-23} = (\cos 85 \times 1.72 \times 10^{-23}) + p_{xe^-}$
$1.83 \times 10^{-23} = 1.499 \times 10^{-24} + p_{xe^-}$
1.68×10^{-23} N·s $= p_{xe^-}$

$p_{yb} = p_{ya}$
$0 = (\sin 85 \times 1.72 \times 10^{-23}) + p_{ye^-}$
$-1.71 \times 10^{-23} = p_{ye^-}$

30. Which of the following phenomena produces a continuous spectrum?

[✓ **A.**] Light emitted by a hot solid
B. Light emitted by a hot, low-density gas
C. Light emitted by a cool gas and then passed through a hot, low-density gas
D. Light emitted by a hot solid and then passed through a cool, low-density gas

Use the following diagram to answer the next question.



31. A free electron that has a kinetic energy of 2.0 eV collides with an excited hydrogen atom in which the electron is in the $n = 2$ energy level. As a result of this collision, the electron in the hydrogen atom is in energy level

A. $n = 2$

[✓ **B.**] $n = 3$

C. $n = 4$

D. $n = 5$

$\Delta E_{2-3} = -1.51\ eV - (-3.40) = 1.89\ eV$

the free e⁻ will transfer 1.89 eV of energy to the hydrogen e⁻, retaining .11 eV. The free e⁻ does not have enough energy to cause a transition to level 4 (2.55 eV required)

32. Together, the Compton effect and the de Broglie hypothesis support the concept of

[✓ **A.**] wave-particle duality

B. the wave nature of matter

C. the particle nature of light

D. the particle nature of matter

light behaves as a photon (particle)

matter was demonstred to behave as a wave (electron diffraction)

Use the following information to answer the next five questions.

The element ununquadium ($^{289}_{114}$Uuq) has been created by fusing calcium ions ($^{48}_{20}$Ca) with plutonium nuclei ($^{244}_{94}$Pu).

The calcium ions are doubly charged ($+2e$) and have a mass of 7.96×10^{-26} kg. To accelerate these ions to a high enough energy to fuse with plutonium, they are repeatedly accelerated by an electric potential difference. They are contained in a magnetic field between these accelerations.

In one stage of the acceleration process, calcium ions enter the accelerating chamber at a speed of 1.00×10^{6} m/s and exit it at a speed of 2.75×10^{6} m/s. They immediately enter a magnetic field and follow a path that has a radius of 1.24 m.

33. Which of the following equations could be the nuclear reaction equation for the fusion of calcium and plutonium in the production of ununquadium?

A. $\frac{292}{114}$ $^{48}_{20}\text{Ca} + ^{244}_{94}\text{Pu} \rightarrow ^{289}_{114}\text{Uuq} + ^{4}_{2}\alpha$ $\frac{293}{116}$ ×

B. $\frac{292}{114}$ $^{48}_{20}\text{Ca} + ^{244}_{94}\text{Pu} \rightarrow ^{289}_{114}\text{Uuq} + 3\,^{0}_{-1}\beta + ^{0}_{0}\bar{v}$ $\frac{289}{111}$ ×

[✓ **C.**] $\frac{292}{114}$ $^{48}_{20}\text{Ca} + ^{244}_{94}\text{Pu} \rightarrow ^{289}_{114}\text{Uuq} + 3\,^{1}_{0}\text{n}$ $\frac{292}{114}$ ✓

D. $\frac{292}{114}$ $^{48}_{20}\text{Ca} + ^{244}_{94}\text{Pu} + 3\,^{1}_{0}\text{n} \rightarrow ^{289}_{114}\text{Uuq}$ $\frac{289}{114}$

cons of charge
cons of nucleon

34. The electric potential difference in the accelerating chamber is

A. 1.24×10^{5} V

B. 1.52×10^{5} V $\downarrow E_p = \uparrow E_k$

[✓ **C.**] 8.16×10^{5} V $qV = \frac{1}{2}m{v_f}^2 - {v_i}^2$

D. 9.38×10^{5} V $3.2\times10^{-19}V = \frac{1}{2}7.96\times10^{-26}(2.75\times10^{6})^2 - (1\times10^{6})^2$

$$V = \frac{2.61\times10^{-13}}{3.2\times10^{-19}} = 8.16\times10^{5} ✓$$

$$V = \frac{\Delta E}{q} = \frac{\frac{1}{2}m{v_f}^2 - \frac{1}{2}m{v_i}^2}{3.20\times10^{-19}}$$

$$= \frac{\frac{1}{2}7.96\times10^{-26}(2.75\times10^{6})^2 - \frac{1}{2}7.96\times10^{-26}\cdot(1.0\times10^{6})^2}{3.20\times10^{-19}}$$

$$= \frac{3.0\times10^{-13} - 3.98\times10^{-14}}{3.20\times10^{-19}} = \frac{2.6\times10^{-13}\,J}{3.20\times10^{-19}\,C}$$

$$= 8.1\times10^{5}V ✓$$

Numerical Response

10. The strength of the magnetic field used to contain the calcium ions, expressed in scientific notation, is $\boldsymbol{a.bc} \times 10^{-\boldsymbol{d}}$ T. The values of $\boldsymbol{a}$, $\boldsymbol{b}$, $\boldsymbol{c}$, and $\boldsymbol{d}$ are 5, 5, 2, and 1.

$$\vec{F_m} = \vec{F_c}$$

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

$$qvB = \frac{mv^{\cancel{2}}}{R}$$

$$B = \frac{mv}{qR} = \frac{(7.96\times10^{-26})(2.75\times10^{6})}{(3.2\times10^{-19})(1.24)} = 5.52\times10^{-1}m$$

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

The decay chain of ununquadium-289 is shown below.

$$^{289}_{114}\text{Uuq} \rightarrow {}^{285}_{112}\text{Uub} + \overset{4\alpha}{\underset{2}{X}} \rightarrow {}^{281}_{110}\text{Ds} + Y \;\; 2 \; {}^{4}_{2}\alpha$$

Ununquadium-289 has a half-life of 30.4 s.

35. The decay particles *X* and *Y* are

[✓ **A.**] both alpha particles
B. both beta positive particles
C. a beta positive particle and an alpha particle, respectively
D. an alpha particle and a beta positive particle, respectively

36. If 1.00 μg of ununquadium-289 is initially produced, the mass of ununquadium-289 remaining after 1.00 min will be

[✓ **A.**] 0.255 μg
B. 0.507 μg
C. 0.703 μg
D. 0.977 μg

$$n = \frac{\text{time}}{t_{1/2}} = \frac{60\text{s}}{30.4} = 1.97\ldots$$

$$N = N_0 \cdot .5^{n}$$

$$= 1.00 \cdot .5^{1.97\ldots}$$

$$= 0.255\,\mu\text{g}$$

37. *The product of radioactive decay that penetrates matter the least is the* ___**i**___ *particle, because of its relatively* ___**ii**___ *mass and charge.*

The statement above is completed by the information in row

Row	*i*	*ii*
A.	alpha	small
[✓ **B.**]	alpha	large
C.	beta negative	small
D.	beta negative	large

38. Which of the following statements provides a reason for the use of nuclear fusion rather than nuclear fission as a source of energy?

- **A.** Fusion reactions can be produced in magnetic-field containment devices, whereas fission reactions require nuclear reactors.
- **B.** Fusion energy is in the form of heat, whereas fission energy is in the form of gamma radiation.
- [✓ **C.**] Fusion products are relatively harmless, whereas fission products are extremely hazardous.
- **D.** Fusion reactions are economically feasible, whereas fission reactions are not.

39. When an electron and a positron collide, they annihilate and all of their mass is converted into energy. The energy released by the annihilation of an electron-positron pair is

- [✓ **A.**] 1.64×10^{-13} J
- **B.** 8.20×10^{-14} J
- **C.** 5.47×10^{-22} J
- **D.** 2.73×10^{-22} J

$E = mc^2$

$E = (2 \times 9.11 \times 10^{-31})(3.0 \times 10^{8})^2$

$E = 1.64 \times 10^{-13}$ J

40. Two types of pions are modelled as consisting of either a down quark and an anti-up antiquark or an up quark and an anti-down antiquark. The only possible charges for these types of pions are

- **A.** $-\frac{2}{3}e$ or $-\frac{1}{3}e$
- **B.** $+\frac{1}{3}e$ or $+\frac{2}{3}e$
- [✓ **C.**] $-1e$ or $+1e$
- **D.** $-1e$ or 0

down + antiup

$-\frac{1}{3} + -\frac{2}{3} = -1$

up + antidown

$+\frac{2}{3} + +\frac{1}{3} = +1$

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