My P30 Diploma is on:_______________

Dear Students:

Please find enclosed 100 practice diploma problems. They have been snatched from old diploma released items from 2008-2009 and 2009-2010. We will work with more current material releasedfrom the government in class. Answer keys have been provided for your convenience.

Some suggestions for working through the questions:

- The **REAL** Diploma is 50 questions in length (36 MC and 14 NR) and you get 2.5 hours to complete it. I suggest blocking off 2.5 hours of your life, locking yourself in a quiet room and completing 50 consecutive questions without interruptions, looking for answers in your notes, looking at the solutions, etc. Make it as much like the real test as possible. Then, take abreak and mark your work. The grade you get doing this will more than likely be the grade you get on the real diploma. A day or two later, do the same thing with the next 50 questions, or even go through the same questions again, this time looking for where you made mistakes and making small notes of those mistakes, so you don't make them again.
- Work through the questions in small groups. This is way more fun than on your own, but remember you won't have someone to work with during the real exam, so don't do all of your studying this way.
- Work through the questions at school with Mr. Putnam around. This way, when you get to a question you don't understand, you can get an answer right away.
- Pick through the questions and focus on areas of the course you had trouble with. If you know Unit A inside and out but had troubles with Unit B, look for Unit B questions and justwork on those. If you need help with optics, look for the optics problems. If you suck at NR, just do the NR. This is a good method if you're short on time.
- Try 5 questions a day. If you get all the questions right, great. If you don't, then ask someoneto clarify the ideas in your head. 5 questions should take you no more than 15 minutes (if you are slower than that, you won't be able to finish the diploma for real), and most people can dedicate 15 minutes a day to studying. That way, over a period of 2 weeks, you can be well prepared for the diploma (doing a little bit of work every day is very effective comparedto cramming the one or two days before).

Good Luck!

Mr. Putnam

1. *The risk of a motorist becoming fatally injured in a vehicle collision is reduced when an airbag or a seatbelt is used because the airbag or seatbelt* __***i***__ *change in momentum by* __***ii***__ *the stopping force the motorist experiences.*

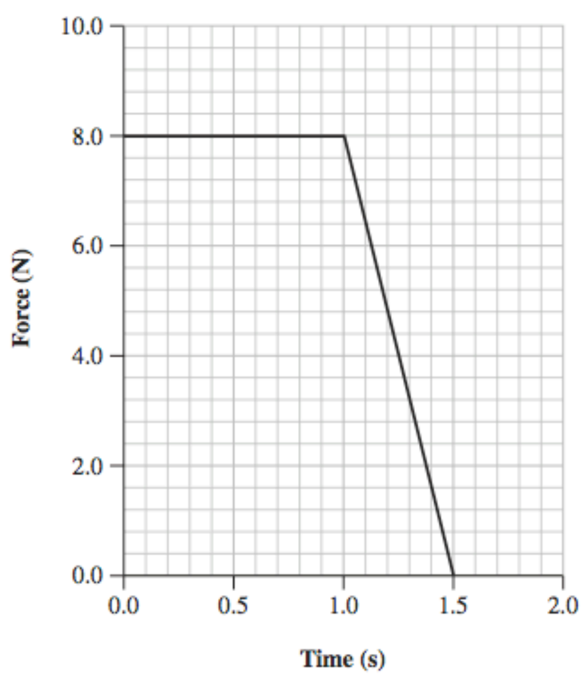
The statement above is completed by the information in row

Row	*i*	*ii*
A.	achieves the same	decreasing
B.	achieves the same	increasing
C.	decreases the	decreasing
D.	increases the	increasing

Use the following information to answer the next two questions.

The initial speed of a remote-controlled toy car on a horizontal surface is 3.0 m/s. The car then experiences a force in the direction of its motion. A graph of this force as a function of time is given below. The mass of the car is 5.0 kg.

Force on Toy Car as a Function of Time



Two students analyze the motion of the car. One student looks at the first 1.0 s time interval. The other student looks at the complete 1.5 s time interval.

2. The speed of the toy car at the end of the 1.0 s time interval is

A. 1.4 m/s

B. 1.6 m/s

C. 4.6 m/s

D. 8.0 m/s

3. The magnitude of the impulse of the toy car during the 1.5 s time interval is

A. 10 kg·m/s

B. 12 kg·m/s

C. 24 kg·m/s

D. 40 kg·m/s

Use the following information to answer the next seven questions.

There are many different types of propulsion engines for satellites. One type of ion propulsion thrust chamber and the satellite to which it is attached are described below.

The cylindrical thrust chamber of the engine has a central spike. Electromagnets are used to produce a non-uniform magnetic field directed radially toward the spike. A virtual cathode consisting of trapped electrons is located at the rear of the thrust chamber. An electric field exists between the anode and the virtual cathode.

Positive xenon ions enter the thrust chamber at the anode and accelerate toward the virtual cathode, which results in thrust on the satellite. As the xenon ions pass through the virtual cathode, they pick up electrons and neutral xenon atoms fly out of the chamber.

Diagram I: Thrust Chamber in Engine

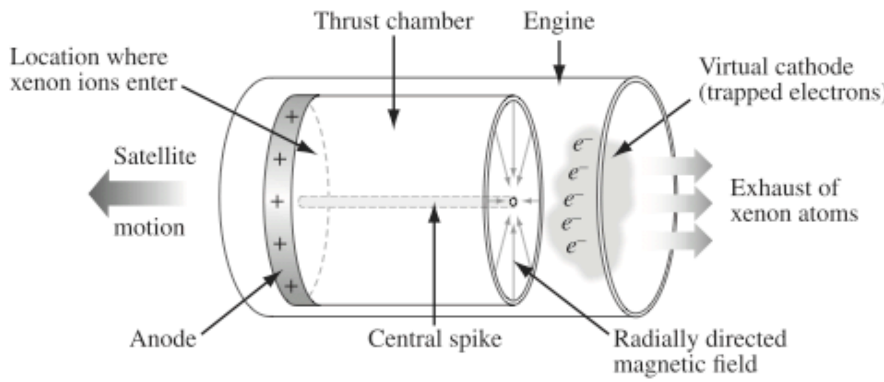
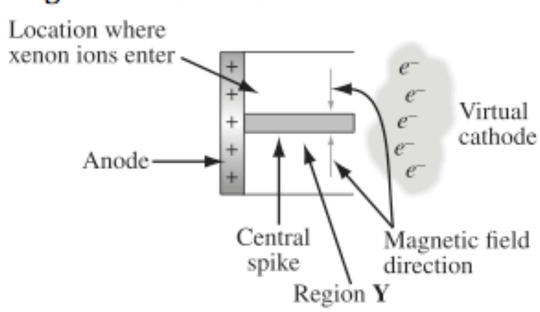


Diagram II: Cross Section of Thrust Chamber



Thrust Chamber Specifications

Magnetic field intensity at the location where the xenon ions enter	0.0200 T
Electric field intensity at the location where the xenon ions enter	1.00×10^4 V/m
Mass of one xenon ion, Xe^+	2.19×10^{-25} kg
Exit speed of neutral xenon atom with respect to the thrust chamber	1.5×10^4 m/s

4. In diagram II on the previous page, the direction of the **electric field** in region Y is

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

5. As the xenon ions, Xe^{+}, move through region Y, as labelled in diagram II on the previous page, they experience both electric and magnetic forces. The direction of the **magnetic force** that they experience is

A. into the page
B. out of the page
C. toward the top of the page
D. toward the bottom of the page

6. The xenon ions, Xe^{+}, enter the thrust chamber at a negligible speed. The minimum distance between the anode and the virtual cathode that is required to produce the exit speed is

A. 1.2×10^{-16} m
B. 1.0×10^{-6} m
C. 1.5×10^{-2} m
D. 1.4×10^{12} m

Numerical Response

1. While in the thrust chamber, a xenon ion experiences an impulse, expressed in scientific notation, of $\boldsymbol{a.b} \times 10^{-\boldsymbol{cd}}$ kg·m/s. The values of $\boldsymbol{a}$, $\boldsymbol{b}$, $\boldsymbol{c}$, and $\boldsymbol{d}$ are _____, _____, _____, and _____.

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

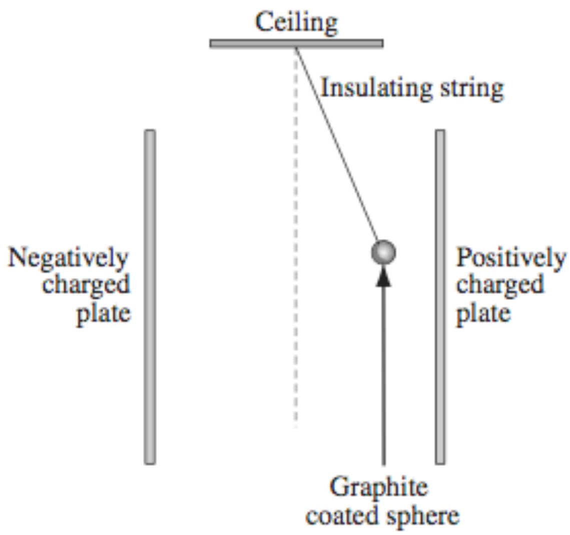
Use the following additional information to answer the next question.

Xenon ions, m_{ion}, reach the virtual cathode with a speed of v_1. When a xenon ion collides with a stationary electron, m_e, in the virtual cathode, the xenon

Use the following information to answer the next four questions.

A negatively charged, graphite-coated sphere is suspended from the ceiling on an insulating string in the region between oppositely charged parallel plates, as illustrated below.

The plates are 20.0 cm apart and are maintained at an electrical potential difference of 3.1×10^2 V. The charged sphere experiences an electrical force of 8.4×10^{-7} N.



10. *One way to give the graphite-coated sphere a negative charge is to touch it with a __**i**__ charged rod. This process is called charging by __**ii**__.*

The statements above are completed by the information in row

Row	***i***	***ii***
A.	positively	induction
B.	positively	conduction
C.	negatively	induction
D.	negatively	conduction

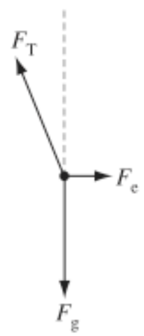
Numerical Response

2. The charge on the graphite-coated sphere, expressed in scientific notation, is $\boldsymbol{a.b} \times 10^{-\boldsymbol{cd}}$ C. The values of $\boldsymbol{a}$, $\boldsymbol{b}$, $\boldsymbol{c}$, and $\boldsymbol{d}$ are _____, _____, _____, and _____.

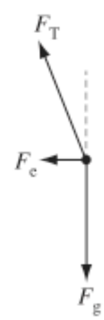
(Record all **four digits** of your answer in the numerical-response section on the answer sheet.)

11. Which of the following scale diagrams is the free-body diagram for the negatively charged sphere?

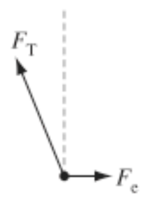
A.



B.



C.



D.

Use the following additional information to answer the next question.

> The charged plates are now removed. The positively charged plate is replaced by the north pole of a strong magnet and the negatively charged plate is replaced by the south pole of a strong magnet. The system is allowed to reach equilibrium.

12. As a result of the magnetic field, the negatively charged, graphite-coated sphere will

A. swing back and forth between the magnetic poles
B. be deflected toward the magnetic north pole
C. be deflected toward the magnetic south pole
D. hang midway between the magnetic poles

Use the following information to answer the next question.

> Two small metal spheres are fixed to insulated stands and given static charges of -4.00×10^{-6} C and $+2.00 \times 10^{-6}$ C, respectively. The spheres are then placed 0.500 m apart. Point *P* is halfway between the charged spheres.

13. At point *P*, the magnitude of the electric field caused by the two charged spheres is

A. 8.63×10^{5} N/C
B. 2.88×10^{5} N/C
C. 2.16×10^{5} N/C
D. 7.19×10^{4} N/C

Use the following information to answer the next question.

> In all electronic camera flashes, there is a capacitor, which is a device that allows large quantities of charge to be stored. The charge accumulates and is then released very quickly.
>
> The electrical energy stored in a capacitor is given by $E = \frac{1}{2}CV^2$,
>
> where V = potential difference across the capacitor
> and C = the capacitance of the capacitor in farads

14. Which of the following combinations of coulombs, joules, and/or volts is equivalent to a farad?

A. $\frac{C^2}{J}$

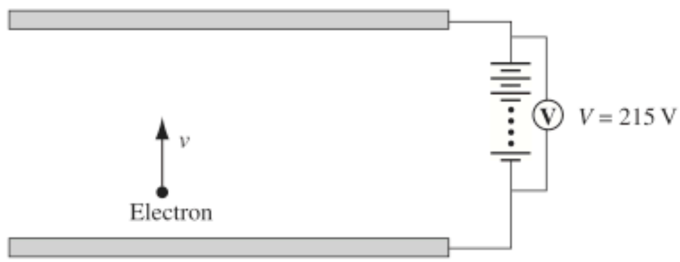
B. $\frac{V}{C}$

C. $\frac{J}{C^2}$

D. $\frac{C^2}{V}$

Use the following information to answer the next question.

An electron is initially at rest at the negatively charged plate. At the instant illustrated below, the electron has 50.0 eV of kinetic energy.



Numerical Response

3. At any point along the path followed by the electron, the sum of the kinetic energy of the electron and its electrical potential energy, in units of electronvolts, is __________ eV.

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

Use the following information to answer the next question.

An electron is fired into an electric field between oppositely charged plates, as shown below.

15. The path taken by the electron while inside the electric field resembles the path taken by

A. a rock thrown horizontally from a high cliff

B. an alpha particle entering a magnetic field perpendicularly

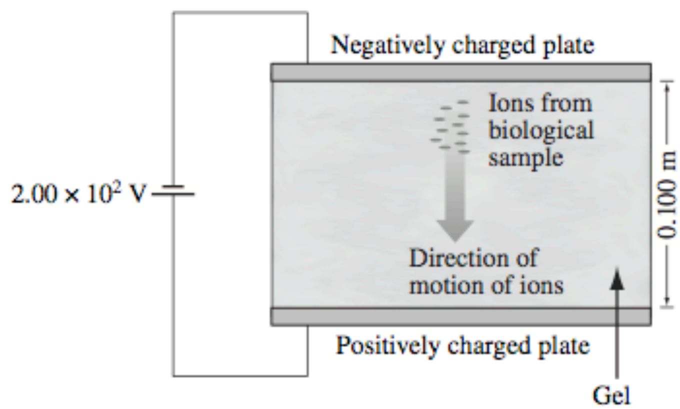
C. a hammer tied to a string and whirled above a person's head

D. a charged oil drop released in the region between oppositely charged plates

Use the following information to answer the next four questions.

One of the methods used to link a person to a crime scene is DNA fingerprinting. DNA fingerprints are as unique as the patterns on fingertips. The laboratory procedure used to produce a DNA fingerprint is called gel electrophoresis.

The apparatus used in gel electrophoresis consists of two parallel plates that have an electrical potential difference between them. A layer of thick gel is placed in the region between the parallel plates such that the electric field direction is parallel to and inside the layer. In one step in creating a DNA fingerprint, molecules from a sample are given an electrical charge turning them into ions. These ions are placed at one end of the gel layer next to the negatively charged plate. As a result of the electrostatic repulsion, the electrical force does work moving the ions through the thick gel. Ions with a smaller size or a larger charge move farther through the gel layer.



16. When the molecules in the biological sample are turned into ions,

A. protons are added
B. electrons are added
C. protons are removed
D. electrons are removed

Use the following information to answer the next question.

Electrons can produce gravitational, electric, and magnetic fields as a result of the following properties.

1 Charge
2 Mass
3 Speed

Numerical Response

5. Match electron properties as listed above with the field that they produce as given below. You may use a number more than once. There is more than one correct answer.

Property:	__________	__________	__________ and __________
Field:	**Gravitational Field**	**Constant Electric Field**	**Magnetic Field**

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

19. An electromagnetic wave is created by

A. a constant electromagnet
B. a changing field of any kind
C. a magnet in an electric field
D. an accelerating electric charge

Use the following information to answer the next question.

Several Methods Used to Estimate the Speed of Light

1 Observe the time delay for an eclipse of a moon of Jupiter.
2 Observe the time delay between uncovering a light on one mountain and having an observer on another mountain react to the sign and uncover a second light.
3 Observe the interference pattern produced by a single source that emits light that travels slightly different but precisely measured distances.

Numerical Response

6. When the methods given above are ordered from the one that produced the least accurate estimate to the one that produced the most accurate estimate, the order is

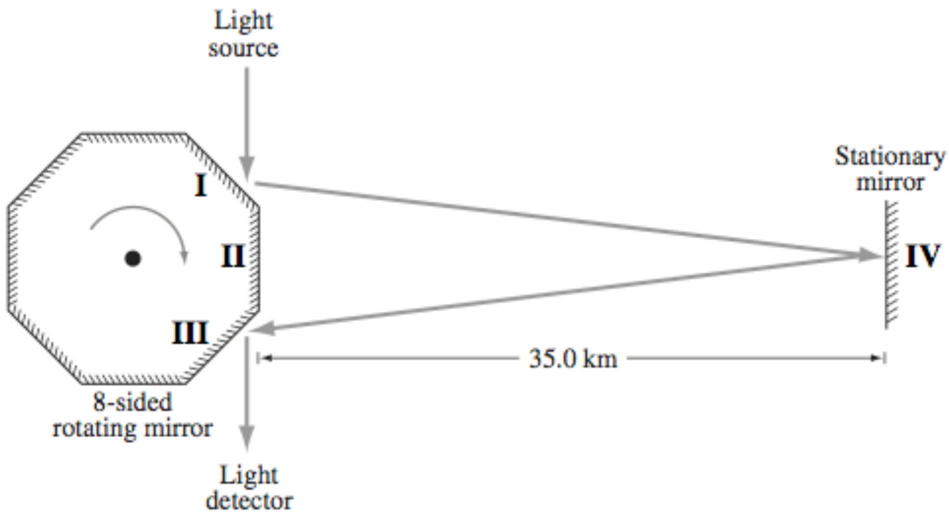
__________, __________, __________.

least accurate … **most accurate**

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

Use the following information to answer the next question.

One accurate method to measure the speed of light is illustrated below. When the 8-sided mirror is stationary, light from the source reflects from surface I, travels to the stationary mirror, reflects from surface IV, travels back to the 8-sided mirror, reflects from surface III, and is incident on the detector.



As the 8-sided mirror begins to rotate, the light does not follow the path illustrated. Eventually, as the frequency of rotation of the mirror increases, a series of light pulses follow the path illustrated.

20. The minimum frequency at which the 8-sided mirror must rotate so that a pulse of light follows the path illustrated is

A. 5.36×10^2 Hz

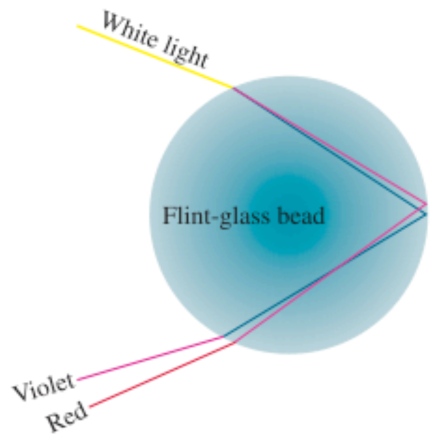
B. 1.07×10^3 Hz

C. 4.29×10^3 Hz

D. 3.43×10^4 Hz

Use the following information to answer the next question.

When white light from the sun strikes a flint-glass bead, the white light is separated into its component colours, two of which are illustrated in the diagram below.



21. Which of the following statements contains a valid prediction of the relative indices of refraction for red and violet light and a justification of that predication?

A. The index of refraction of red light in flint glass is greater than that of violet light because red light refracts more inside the flint-glass bead.

B. The index of refraction of red light in flint glass is less than that of violet light because red light refracts less inside the flint-glass bead.

C. The index of refraction of violet light in flint glass is greater than that of red light because violet light reflects more inside the flint-glass bead.

D. The index of refraction of violet light in flint glass is less than that of red light because red light reflects less inside the flint-glass bead.

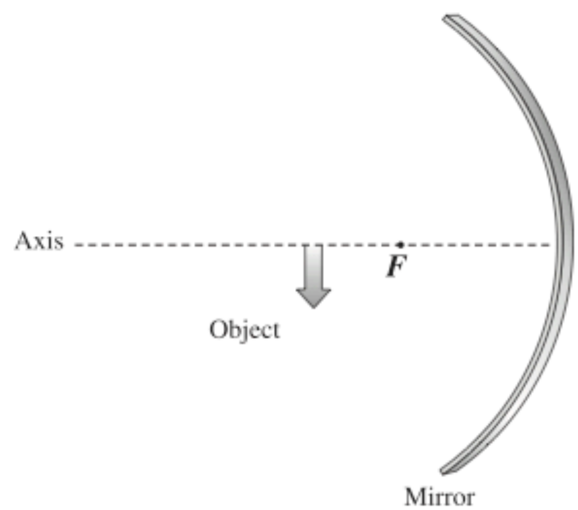
Numerical Response

7. On a particular day, the index of refraction of a 5 MHz radio signal in Earth's atmosphere is 1.81. The critical angle for this radio signal is __________°.

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

Use the following information to answer the next question.

A concave mirror, its central axis, and an object are shown in the diagram below.



The distance from the object to the focal point is 2.40 cm and the focal length of the mirror is 4.30 cm.

22. The distance from the image to the mirror is

A. 0.0833 cm

B. 0.184 cm

C. 5.43 cm

D. 12.0 cm

24. *In procedure I, the wavelength of the laser light in the crystal is* ___***i***___.
The speed of the laser light in the crystal is ___***ii***___ *than its speed in air.*

The statements above are completed by the information in row

Row	***i***	***ii***
A.	4.14×10^{-7} m	less
B.	4.14×10^{-7} m	greater
C.	9.70×10^{-7} m	less
D.	9.70×10^{-7} m	greater

Numerical Response

8. In procedure II, the angle between the central maximum and the first bright spot of the interference pattern is __________°.

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

25. *In order to produce an electrical current in procedure III, the student must use electromagnetic radiation that has a* ___*i*___ *wavelength or a photovoltaic plate that has a* ___*ii*___ *work function than those she actually used in procedure III.*

The statement above is completed by the information in row

Row	*i*	*ii*
A.	shorter	larger
B.	longer	larger
C.	shorter	smaller
D.	longer	smaller

26. Which of the following lists has selected regions of the electromagnetic spectrum arranged in order of increasing photon energy?

A. Radio, microwaves, X-rays, visible
B. Infrared, ultraviolet, X-rays, gamma
C. Gamma, visible, infrared, microwaves
D. Microwaves, ultraviolet, visible, infrared

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C. Gamma, visible, infrared, microwaves
D. Microwaves, ultraviolet, visible, infrared

27. A photocathode that has a threshold frequency of 5.6×10^{14} Hz is illuminated with light that has a frequency of 8.2×10^{14} Hz. The maximum kinetic energy of the ejected photoelectrons is

A. 1.7×10^{-19} J
B. 3.7×10^{-19} J
C. 5.4×10^{-19} J
D. 9.1×10^{-19} J

28. The explanation of the Compton effect requires the

A. wave nature of light
B. particle nature of light
C. probabilistic nature of quantum physics
D. ejection of electrons from a metal surface

29. One immediate result of the discovery of cathode ray particles was that the theory of the atom was revised to a theory that hypothesized that

A. an atom is an indivisible sphere
B. electrons exist in probability clouds
C. an atom is mostly made up of empty space
D. an atom contains negatively charged particles

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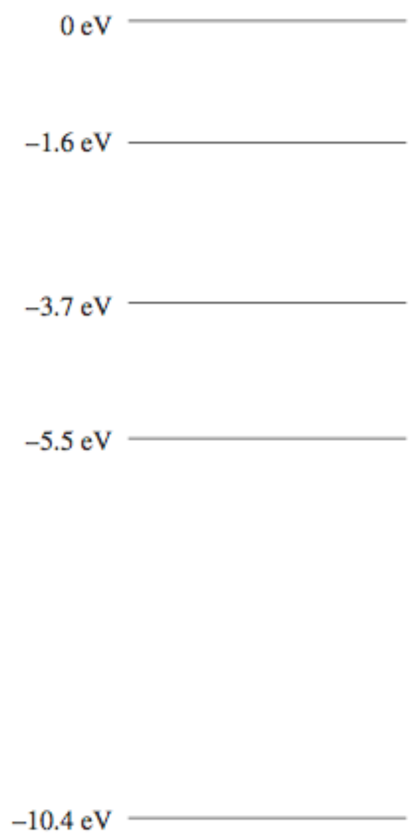
30. *The analysis of the observations from the Rutherford alpha particle scattering experiment lead to a model of the atom in which the* ___***i***___ *is on the order of* 10^{-10} *m in diameter, the* ___***ii***___ *is on the order of* 10^{-15} *m in diameter, and the majority of the* ___***iii***___ *of the atom is in the nucleus.*

The statement above is completed by the information in row

Row	*i*	*ii*	*iii*
A.	atom	nucleus	charge
B.	nucleus	atom	charge
C.	atom	nucleus	mass
D.	nucleus	atom	mass

Use the following information to answer the next question.

Energy Levels for Mercury Atoms (eV)



31. If an electron is in the –1.6 eV energy level, the minimum frequency of a photon that would ionize the atom is

A. 3.9×10^{14} Hz

B. 2.1×10^{15} Hz

C. 2.4×10^{33} Hz

D. 1.3×10^{34} Hz

32. For which of the following explanations did the diffraction of high-speed electrons provide experimental support?

A. Bohr's explanation of line spectra

B. Compton's explanation of the Compton effect

C. Einstein's explanation of the photoelectric effect

D. De Broglie's explanation of wave nature of matter

Use the following information to answer the next two questions.

Cobalt-60 is a common radiation source used in cancer treatment. The half-life of cobalt-60 is 5.2 years. A cobalt-60 nucleus decays by emitting a beta negative particle and a gamma photon.

33. Which of the following equations describes the decay of cobalt-60?

A. ${}^{60}_{27}\text{Co} \rightarrow {}^{60}_{28}\text{Ni} + {}^{0}_{-1}\beta + \gamma + \nu$

B. ${}^{60}_{27}\text{Co} \rightarrow {}^{60}_{28}\text{Ni} + {}^{0}_{-1}\beta + \gamma + \overline{\nu}$

C. ${}^{60}_{27}\text{Co} \rightarrow {}^{60}_{26}\text{Fe} + {}^{0}_{+1}\beta + \gamma + \nu$

D. ${}^{60}_{27}\text{Co} \rightarrow {}^{60}_{26}\text{Fe} + {}^{0}_{+1}\beta + \gamma + \overline{\nu}$

Numerical Response

9. The percentage of cobalt-60 remaining after 15.6 years is ____________ %.

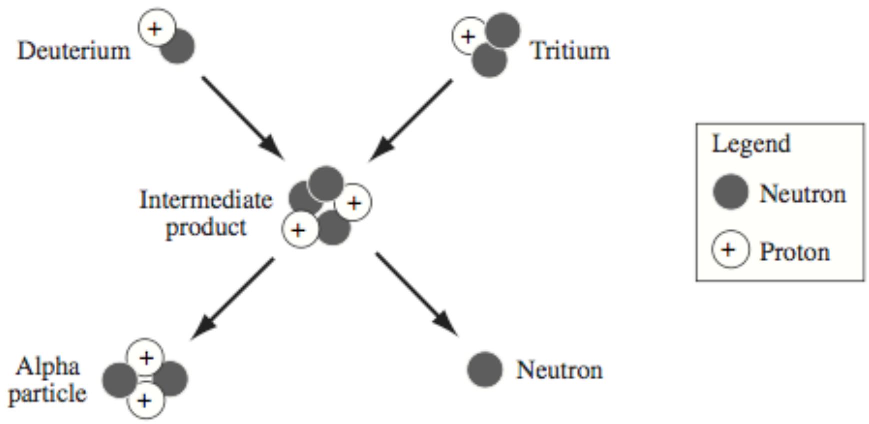
(Record your **three-digit answer** in the numerical-response section on the answer sheet.)

Use the following information to answer the next six questions.

One Solar Nuclear Fusion Reaction Equation

$${}^{2}_{1}\text{H} + {}^{3}_{1}\text{H} \rightarrow {}^{4}_{2}\text{He} + {}^{1}_{0}\text{n} + \text{Energy}$$

Representation of Nuclei Involved in This Fusion Reaction



One way to harness this energy on Earth is to use a nuclear fusion reactor. One of the problems in terrestrial fusion reactors is the very high energy required to overcome the electrostatic repulsive force between the deuterium ions and the tritium ions.

A particular reactor design uses magnetic fields in a process called magnetic confinement to keep the ions inside the reactor. However, neutrons escape magnetic confinement. These neutrons are captured by a shield called a lithium blanket.

34. Energy is released in this nuclear fusion reaction because the

A. free neutron has a high energy

B. number of protons remains the same

C. number of nucleons remains the same

D. mass of the alpha particle and neutron is less than the mass of the intermediate product

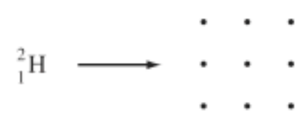
Numerical Response

10. At a particular instant, the electrostatic force that the deuterium ion exerts on the tritium ion is 23.3 N. The distance between the centres of the two ions, expressed in scientific notation, is __________ $\times 10^{-w}$ m.

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

Use the following additional information to answer the next question.

A positively charged deuterium ion enters a magnetic field directed out of the page, as shown below.



• Represents a magnetic field directed out of the page

35. The direction of the magnetic deflecting force that acts on the positively charged deuterium ion as it just enters the magnetic field is

A. into the page

B. out of the page

C. toward the top of the page

D. toward the bottom of the page

36. The neutron produced in the fusion reaction escapes the magnetic confinement because

A. neutral particles are not deflected by magnetic fields

B. the neutron is moving so fast that it escapes the magnetic field

C. the energy produced in the nuclear reaction is enough to cause the neutron to escape

D. conservation of momentum requires that the neutron has to be pushed in the opposite direction to that of the helium produced

37. *As a particular neutron travelling at 5.21×10^6 m/s hits the lithium blanket and stops, it experiences an impulse of* __***i***__*, and the neutron–lithium collision is classified as* __***ii***__.

The statement above is completed by the information in row

Row	*i*	*ii*
A.	-8.70×10^{-21} N·s	elastic
B.	-8.70×10^{-21} N·s	inelastic
C.	-2.27×10^{-14} J	elastic
D.	-2.27×10^{-14} J	inelastic

38. Which of the following equations **most likely** describes a neutron–lithium collision?

A. ${}^{1}_{0}\text{n} + {}^{7}_{3}\text{Li} \rightarrow {}^{8}_{3}\text{Li}$

B. ${}^{1}_{0}\text{n} + {}^{4}_{3}\text{Li} \rightarrow {}^{5}_{3}\text{Li}$

C. ${}^{0}_{1}\text{n} + {}^{7}_{3}\text{Li} \rightarrow {}^{7}_{4}\text{Be}$

D. ${}^{1}_{1}\text{n} + {}^{4}_{3}\text{Li} \rightarrow {}^{5}_{4}\text{Be}$

39. To study sub-nuclear structure, high-energy particle accelerators are required because

A. plasma exists at high energy

B. antimatter exists at high energy

C. of the strength of the electrostatic force

D. of the strength of the strong nuclear force

40. Which of the following decay equations describes beta positive decay?

A. $udd \rightarrow uud + e^{-} + \bar{\nu}$

B. $udd \rightarrow uud + e^{+} + \bar{\nu}$

C. $uud \rightarrow udd + e^{-} + \nu$

D. $uud \rightarrow udd + e^{+} + \nu$

Multiple Choice – Part B Machine-Scored Key

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

Numerical Response

1	3321	**6**	213
2	5410	**7**	33.5
3	215	**8**	18.5
4	2003	**9**	12.5
5	2113 or 2131	**10**	3.14

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.

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

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. $9\Delta t$

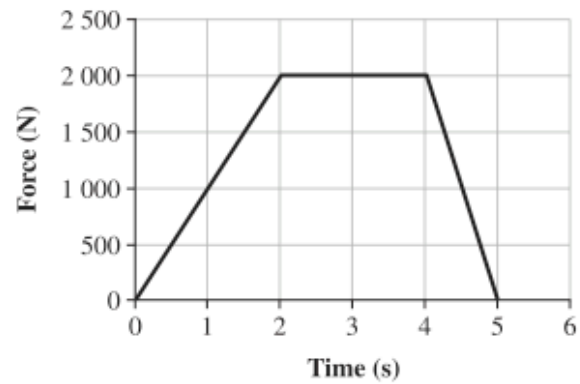
B. $3\Delta t$

C. $\frac{1}{3}\Delta t$

D. $\frac{1}{9}\Delta t$

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

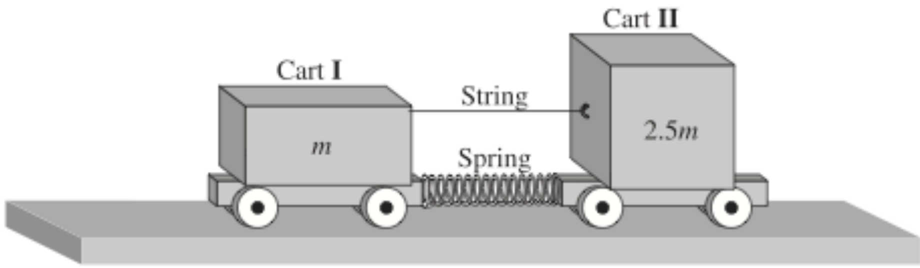
B. impulse experienced by the object

C. displacement of the object while the force is being applied

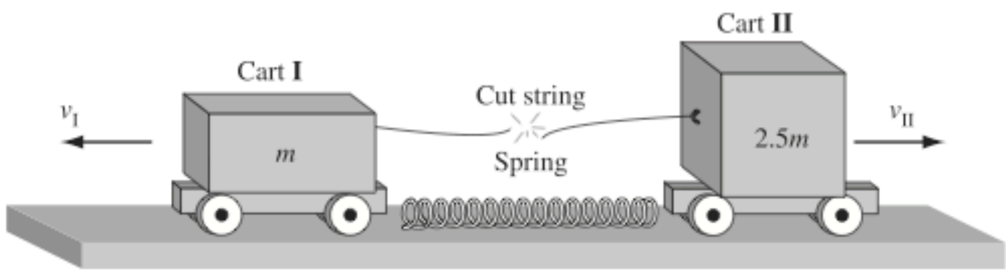
D. acceleration of the object as a result of the net force being applied

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

A. 3.1 m/s

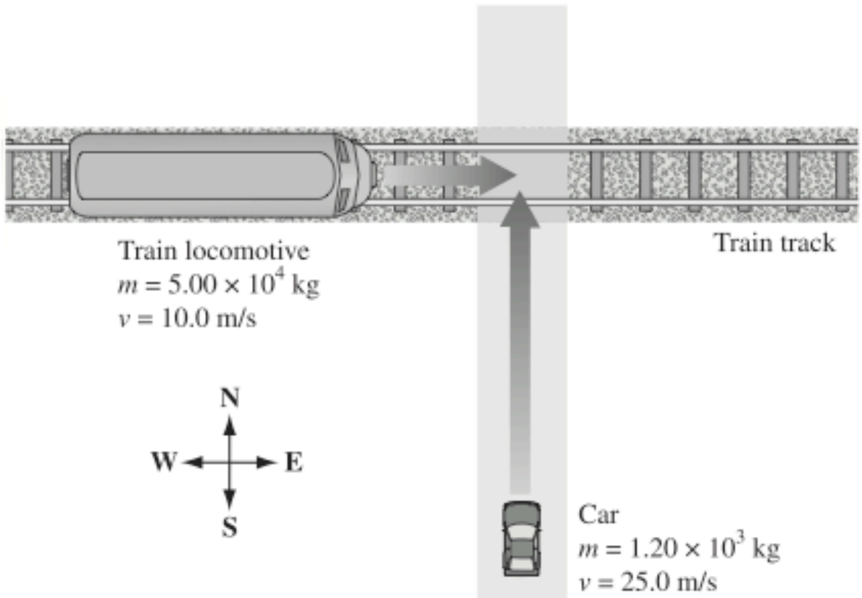
B. 2.0 m/s

C. 0.80 m/s

D. 0.32 m/s

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

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

A. be neutral

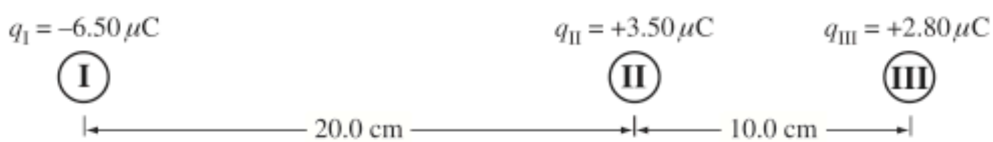
B. have a net charge of zero

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.



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

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.	$\frac{+x}{2}$	$\frac{-x}{4}$	$\frac{-x}{4}$

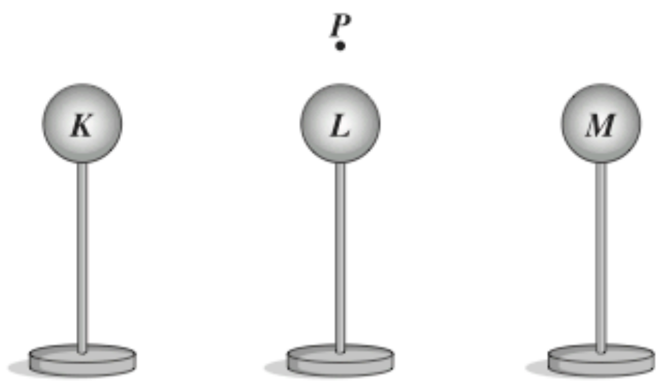
Numerical Response

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 $\boldsymbol{a.bc} \times 10^{\boldsymbol{d}}$ N/C. The values of ***a***, ***b***, ***c***, and ***d*** are _____, _____, _____, and _____.

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

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

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

Numerical Response

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 $\boldsymbol{a.bc} \times 10^{\boldsymbol{d}}$ N/C. The values of ***a***, ***b***, ***c***, and ***d*** are _____, _____, _____, and _____.

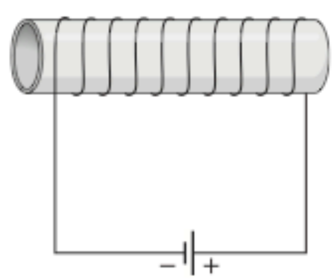
(Record **all four digits** of your answer in the numerical-response section on the answer sheet.)

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

A. 1
B. 2
C. 5
D. 20

Use the following information to answer the next question.

Solenoid

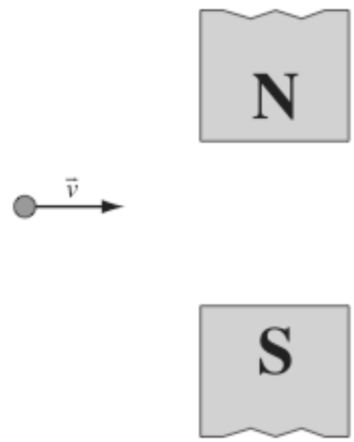


12. The magnetic field created inside the solenoid is directed

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

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

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?

A. $\frac{\text{N·m}}{\text{A}}$

B. $\frac{\text{N·A}}{\text{m}}$

C. $\frac{\text{N·m}}{\text{C·s}}$

D. $\frac{\text{N·s}}{\text{C·m}}$

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.)

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.

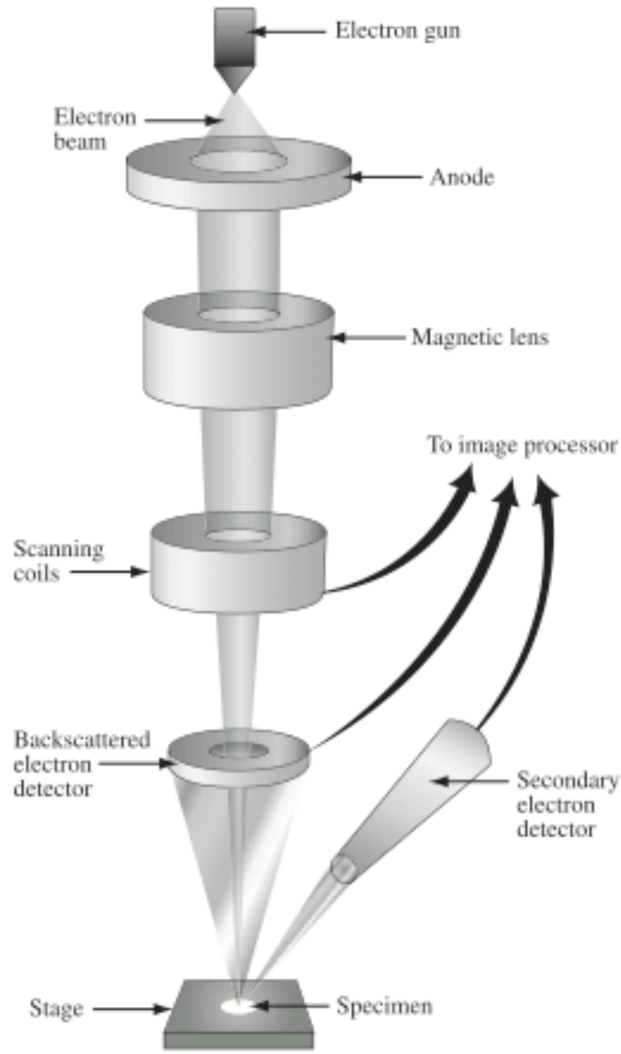
The magnetic lens focuses the beam of electrons. A particular electron experiences a magnetic force of 3.31×10^{-12} N while in the magnetic lens. As a result of this magnetic force, the path of the electrons spirals and the beam of electrons becomes focused.

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.

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.



Numerical Response

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

(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

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

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

Numerical Response

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

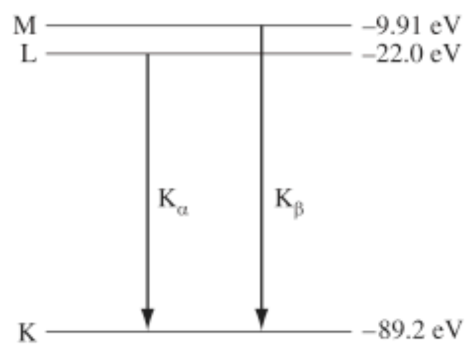
(Record all **four digits** of your answer in the numerical-response section on the answer sheet.)

Use the following 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

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

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

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

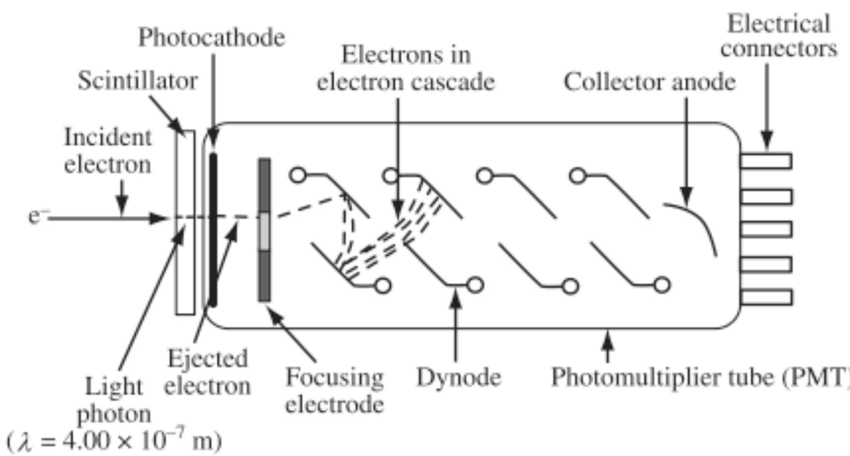
D. microwave

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

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

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

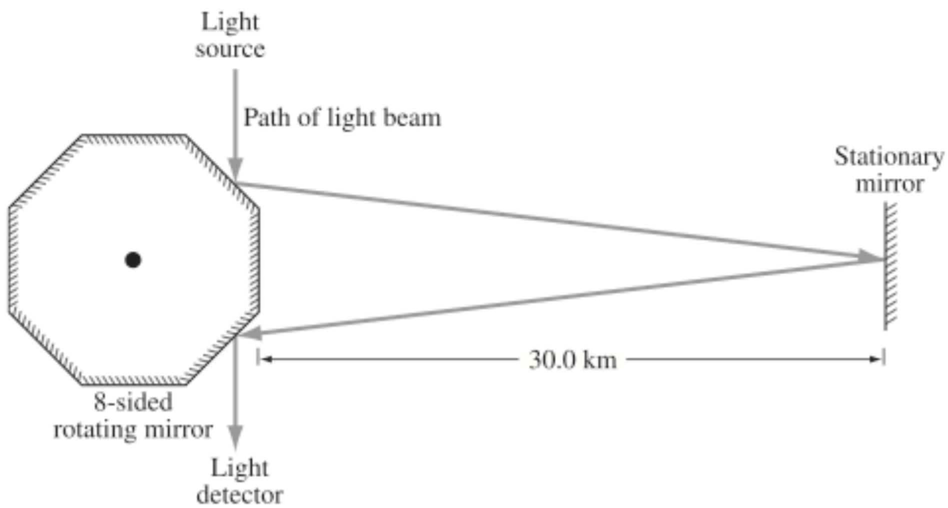
22. Which of the following sentences describes the electric and magnetic field components of an electromagnetic wave?

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.



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

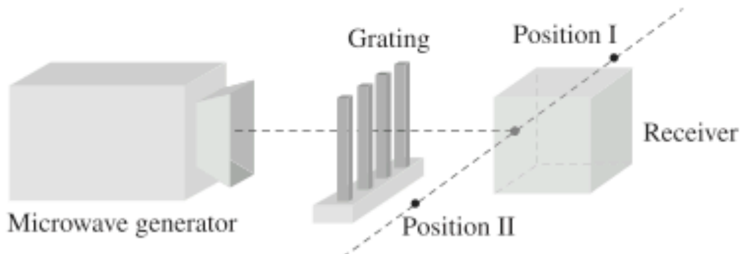
C. 5.00×10^3 revolutions per second

D. 1.00×10^4 revolutions per second

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.



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

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

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

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 __________ $\times 10^{-w}$ m.

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

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

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 _____, _____, _____, and _____.

(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

I	2.25×10^{-7} m
II	2.33×10^{-7} m
III	3.24×10^{-7} m
IV	4.28×10^{-7} m

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?

- **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

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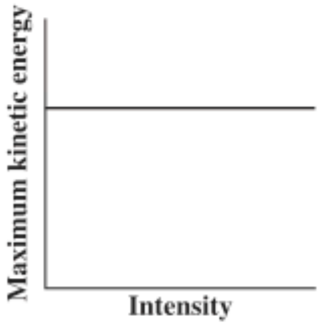
B. Wavelength IV only
C. Wavelengths I and II
D. Wavelengths III and IV

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

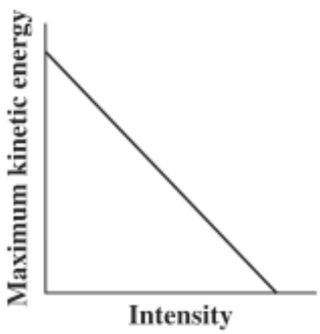
27. Electromagnetic radiation of constant wavelength is incident on a metal cathode, and the photoelectric effect is observed. Which of the following graphs represents the relationship between the maximum kinetic energy of the emitted photoelectrons and the intensity of the incident radiation?

A.

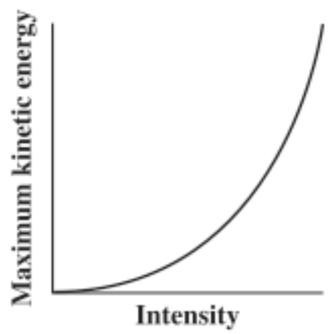


B.

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

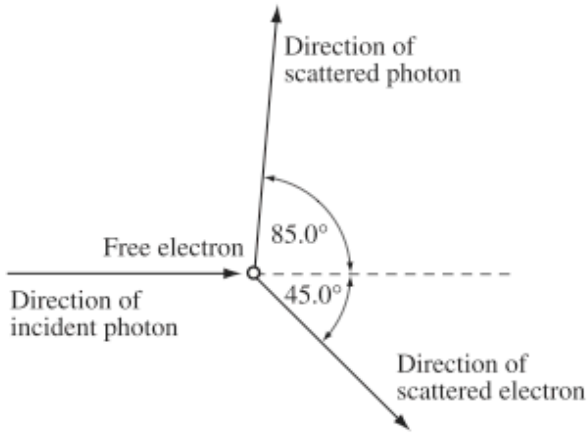
B. Bohr's conclusion that electrons inhabit discrete energy levels around the nucleus

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

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.



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

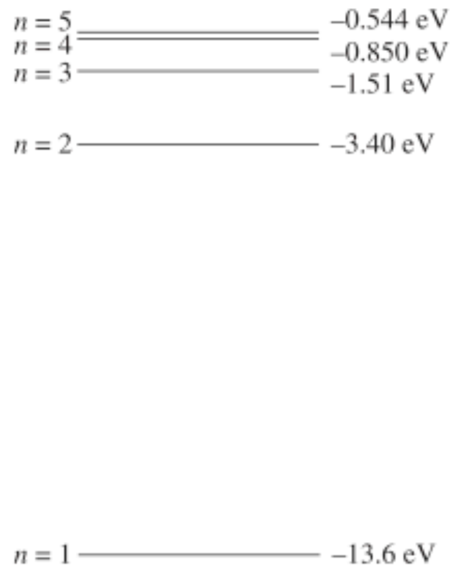
---

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.

Selected Energy Levels for Hydrogen



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. $n = 5$

---

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

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 (+2*e*) 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. $^{48}_{20}\text{Ca} + ^{244}_{94}\text{Pu} \rightarrow ^{289}_{114}\text{Uuq} + ^{4}_{2}\alpha$

B. $^{48}_{20}\text{Ca} + ^{244}_{94}\text{Pu} \rightarrow ^{289}_{114}\text{Uuq} + 3\,^{0}_{-1}\beta + \overline{\nu}$

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

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

34. The electric potential difference in the accelerating chamber is

A. 1.24×10^5 V

B. 1.52×10^5 V

C. 8.16×10^5 V

D. 9.38×10^5 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 _____, _____, _____, and _____.

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

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

The decay chain of ununquadium-289 is shown below.

$$^{289}_{114}\text{Uuq} \rightarrow {}^{285}_{112}\text{Uub} + \boldsymbol{X} \rightarrow {}^{281}_{110}\text{Ds} + \boldsymbol{Y}$$

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

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

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

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