

AAPT/NSTA High School Physics Examination

Version 1983R

This examination was prepared by members of the high school physics examination development committee appointed jointly by the American Association of Physics Teachers and National Science Teachers Association.

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Directions:

- 1) **DO NOT OPEN** this examination booklet until you are asked to do so by your teacher.
- 2) Please do not write anything in the examination booklet. Your teacher will provide you with scrap paper and an answer sheet.
- 3) Copy the **VERSION NUMBER** onto your answer sheet. (See numbers at the top of this page.)
- 4) Each question or incomplete statement has a single best answer. When you decide which answer is correct for a question, completely blacken the corresponding space on the answer sheet with a soft pencil. Make a heavy black mark to record your answer. Mark only one answer for each question. If you wish to change your answer, completely erase the first answer.
- 5) This examination is divided into five sections as follows:

PART I			
SECTION A. Mechanics.....	24 questions	27 minutes	page 2
SECTION B. Waves, Optics, & Sound	16 questions	18 minutes	page 5
	40 questions	45 minutes	
PART II			
SECTION C. Heat & Kinetic Theory	8 questions	9 minutes	page 8
SECTION D. Electricity & Magnetism	20 questions	23 minutes	page 9
SECTION E. Modern Physics	12 questions	13 minutes	page 13
	40 questions	45 minutes	

You should answer only the questions in the sections(s) that your teacher instructs you to answer.

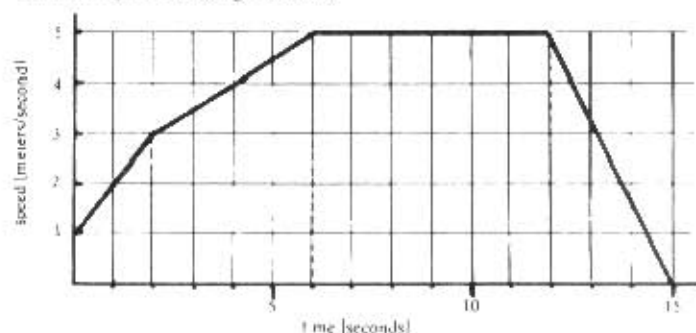
- 6) The score on the examination is equal to the number of correct answers you give. Thus it is to your advantage to answer every question in the sections assigned by your teacher.
- 7) When you are requested to stop working, put down your pencil, close this examination booklet and await instructions.

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Part I - SECTION A Mechanics

DIAGRAM FOR QUESTIONS 1, 2, AND 3

The Graph Below Represents the Motion of an Object Traveling in a Straight Line.



- What is the acceleration of the object between times $t = 2$ seconds and $t = 6$ seconds?
 - 0.5 meters/second².
 - 0.7 meters/second².
 - 0.9 meters/second².
 - 1.0 meters/second².
 - 4.5 meters/second².
- How far did the object travel between times $t = 6$ seconds and $t = 12$ seconds?
 - zero.
 - 10 meters.
 - 30 meters.
 - 45 meters.
 - 57.5 meters.
- What is the average speed of the object for the first 6 seconds?
 - 0.5 meters/second.
 - 2.5 meters/second.
 - 3.0 meters/second.
 - 3.3 meters/second.
 - 5.0 meters/second.

DIAGRAM FOR QUESTION 4

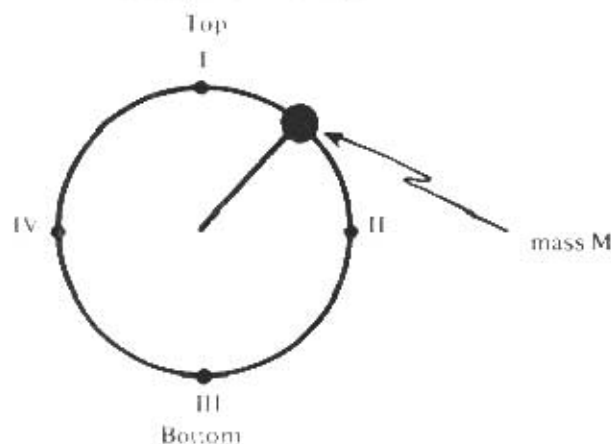
Distance Versus Time Graphs



- Which of the graphs above corresponds to motion in a straight line with positive acceleration?
 - A.
 - B.
 - C.
 - D.
 - E.

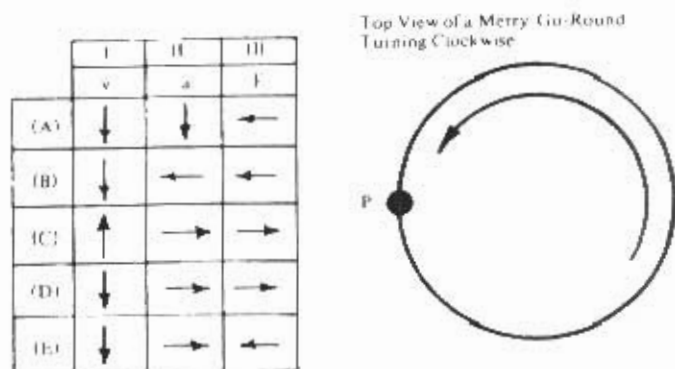
- A stone is moving at constant speed in a horizontal circular path on a frictionless table. If the speed of the stone is doubled without changing the radius of the path, the centripetal force will be
 - one-fourth as great.
 - one-half as great.
 - unchanged.
 - twice as great.
 - four times as great.
- An object is projected horizontally from a vertical cliff on a horizontal plane. At the same instant, a second object is dropped from the same height. Assuming air resistance can be ignored, which statement is most nearly correct?
 - The object that is projected horizontally hits the ground first.
 - The object that is dropped hits the ground first.
 - Both objects hit the ground at the same instant.
 - The heavier of the two objects hits the ground first.
 - The denser of the two objects hits the ground first.

DIAGRAM FOR QUESTION 7



- An object with a mass M on the end of a rod is moving in a vertical circle with a constant speed. The force exerted by the rod is:
 - the same at points I, II, III, and IV.
 - largest at point I (top of circle).
 - largest at point II.
 - largest at point III (bottom of circle).
 - largest at point IV.
- A car is to make a turn without skidding on an unbanked curve with a radius of 90 meters. If the coefficient of friction is 0.64, what is the maximum speed the car can have?
 - Less than 5 meters/second.
 - Between 5 and 10 meters/second.
 - Between 10 and 15 meters/second.
 - Between 15 and 20 meters/second.
 - More than 20 meters/second.

DIAGRAM FOR QUESTION 9

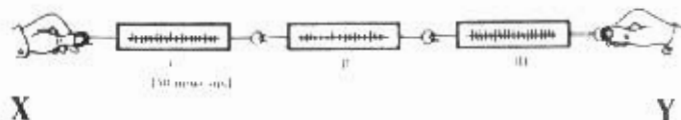


9. A student is riding a constant speed merry-go-round, as shown above. When the student is at point P, which set of vectors shows the direction of the student's

I. velocity \mathbf{v} ,
 II. acceleration \mathbf{a} , and
 III. centripetal force \mathbf{F} ?

- (A) A.
 (B) B.
 (C) C.
 (D) D.
 (E) E.
10. Force can be thought of as the
- (A) quantity that changes the velocity of an object.
 (B) energy used to move an object.
 (C) quantity that keeps an object moving.
 (D) momentum of an object.
 (E) mass of an object.
11. If the speed of an object moving in a straight line is increasing at a constant rate, the net force acting on the object is
- (A) decreasing at a constant rate.
 (B) zero.
 (C) constant, but not zero.
 (D) increasing at a constant rate.
 (E) none of the above.

DIAGRAM FOR QUESTION 12



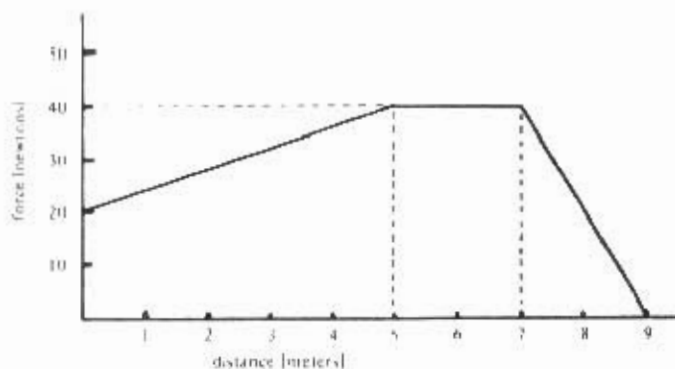
12. Three spring scales are hooked together as shown above. The scales are at rest on a horizontal and frictionless surface. Someone pulls at points X and Y,

but the whole system does not move. Scale I reads 50 newtons. The reading on scale II is

- (A) Zero.
 (B) 50 newtons.
 (C) 100 newtons.
 (D) 150 newtons.
 (E) None of the above.

DIAGRAM FOR QUESTIONS 13 AND 14

The graph below shows the net force exerted on an object (regarded as a particle) with a mass of 5.0 kilograms for a distance of 9.0 meters. Assume the force is in the direction of the motion and that the motion is frictionless.



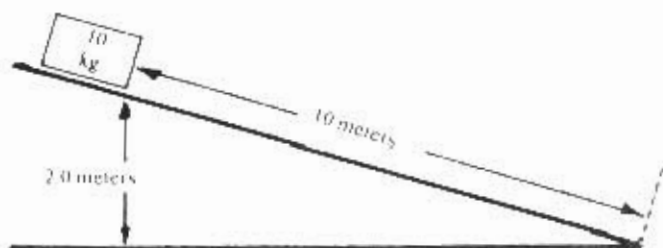
13. What is the work done on the object when it is moved from 5.0 meters to 7.0 meters?
- (A) 40 joules.
 (B) 80 joules.
 (C) 200 joules.
 (D) 280 joules.
 (E) 360 joules.
14. If the object started from rest, what is its speed after the first 5.0 meters?
- (A) less than 2.0 meters/second.
 (B) between 2.0 and 4.0 meters/second.
 (C) between 4.0 and 6.0 meters/second.
 (D) between 6.0 and 8.0 meters/second.
 (E) more than 8.0 meters/second.

15. Energy is to joule as power is to

- (A) watt.
 (B) kilowatt-hour.
 (C) newton.
 (D) newton-meter.
 (E) joule-second.

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DIAGRAM FOR QUESTION 16



16. An object with a mass of 10 kilograms is at rest on the top of a frictionless inclined plane 2.0 meters high and 10 meters long. If the object slides down this incline, what is the speed of the object as it reaches the bottom?
- (A) $\sqrt{10}$ meters/second
 (B) $2\sqrt{10}$ meters/second
 (C) 10 meters/second
 (D) 20 meters/second
 (E) 40 meters/second
17. What constant net force is needed to produce a change in momentum of 200 kilogram-meters/second in 4.0 seconds?
- (A) 5.0 newtons.
 (B) 50 newtons.
 (C) 80 newtons.
 (D) 100 newtons.
 (E) 800 newtons
18. Which of the following is a possible unit for momentum?
- (A) newton.
 (B) joule/second
 (C) newton-second.
 (D) kilogram-meter.
 (E) kilogram/second.
19. A 5.0 kilogram block traveling at 4.0 meters/second collides with a stationary block of equal mass on a horizontal frictionless surface. If the blocks stick together after the collision, what is their speed after the collision?
- (A) zero.
 (B) 2.0 meters/second.
 (C) 2.5 meters/second.
 (D) 4.0 meters/second.
 (E) 20 meters/second.
20. A uranium atom at rest spontaneously decays into two fragments. Which of the following statements is always true?
- (A) Kinetic energy is constant.
 (B) The two fragments have equal kinetic energy.
 (C) The speed of one fragment is equal to the speed of the other.
 (D) The sum of the momenta of the two fragments is zero.
 (E) The sum of the kinetic energies of the two fragments is zero.
21. If the distance between the center of the earth and a satellite were halved, the force of gravitation between the earth and the satellite would be about
- (A) one-fourth as great.
 (B) one-half as great.
 (C) the same.
 (D) twice as great.
 (E) four times as great.
22. Two stationary bodies attract each other with a gravitational force of 5.0×10^{12} newtons. What will be the force if the mass of each body is tripled?
- (A) 1.5×10^{12} newtons.
 (B) 3.0×10^{12} newtons.
 (C) 4.5×10^{12} newtons.
 (D) 2.1×10^{10} newtons.
 (E) 4.1×10^{10} newtons.
23. Which of the following is **not** a vector quantity?
- (A) centripetal acceleration.
 (B) gravitational force.
 (C) momentum.
 (D) weight.
 (E) work.
24. If the amplitude of a pendulum undergoing small oscillations is halved, the period of oscillation will be approximately
- (A) one-fourth as great.
 (B) one-half as great.
 (C) unchanged.
 (D) twice as great.
 (E) four times as great.

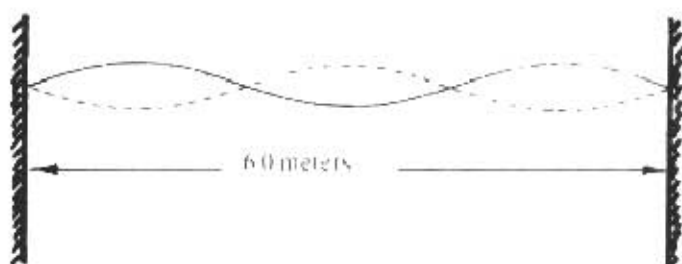
END OF SECTION A

Part I - SECTION B

Waves, Optics, and Sound

25. Which term describes a fraction of a periodic wave's wavelength divided by its entire wavelength?
- (A) Phase.
(B) Speed.
(C) Wavelength.
(D) Period.
(E) Amplitude.

DIAGRAM FOR QUESTION 26

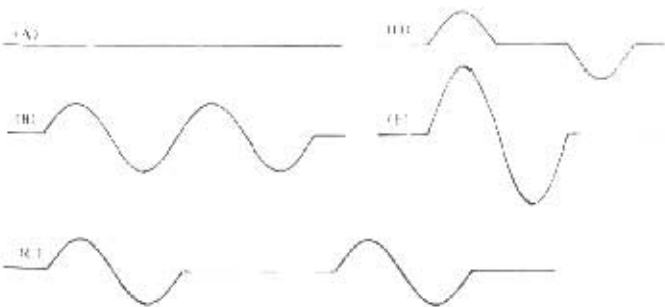


26. A string fixed at both ends as shown in the diagram above is set into a standing wave vibration. If the length of the string is 6.0 meters and the frequency of vibration is 340 hertz (cycles/second), what is the speed of the waves in this string?
- (A) 340 meters/second.
(B) 680 meters/second.
(C) 1020 meters/second.
(D) 1360 meters/second.
(E) 2040 meters/second.

DIAGRAM FOR QUESTION 27

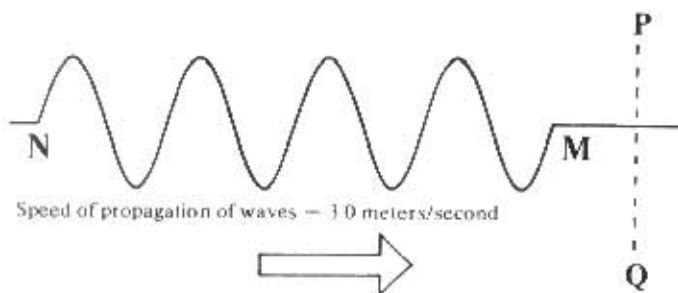


27. Two double pulses on a string are sent toward each other as shown above. Which of the diagrams below shows a situation that **cannot** be produced as the pulses pass through each other?



28. When periodic waves move from one medium into another, which of the following properties certainly does **not** change?
- (A) frequency.
(B) speed of propagation.
(C) wavelength.
(D) amplitude.
(E) none of the above.

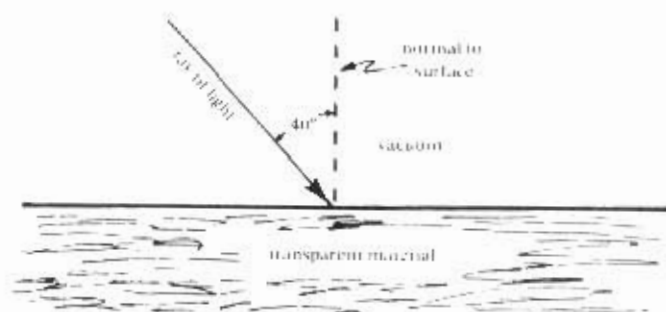
DIAGRAM FOR QUESTION 29



29. Waves are traveling with a speed of 3.0 meters/second toward line PQ as shown in the diagram above. If the entire set of waves MN passes the line PQ in one second, what is the wavelength of these waves?
- (A) 0.75 meters.
(B) 1.5 meters.
(C) 3.0 meters.
(D) 6.0 meters.
(E) 12 meters.
30. A string is fixed at each end. For all standing waves formed on the string, the length of the string must be equal to
- (A) the wavelength.
(B) one-half the wavelength.
(C) a whole-number multiple of the wavelength.
(D) a whole-number multiple of one-half the wavelength.
(E) none of the above.

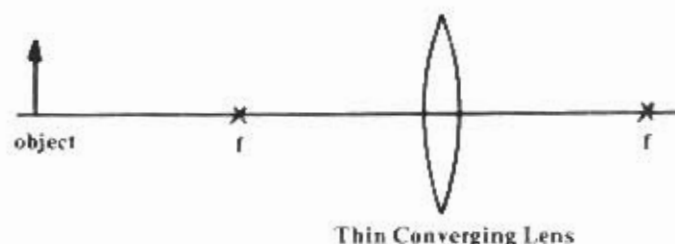
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DIAGRAM FOR QUESTION 31



31. A ray of light, initially traveling in a vacuum, is incident on the surface of a flat transparent material as shown in the diagram above. Part of the light is reflected at the surface and part is refracted. The angle between the **reflected** ray and the **refracted** ray is
- (A) less than 40° .
 (B) between 40° and 50° .
 (C) between 50° and 100° .
 (D) between 100° and 140° .
 (E) more than 140° .

DIAGRAM FOR QUESTIONS 32 AND 33

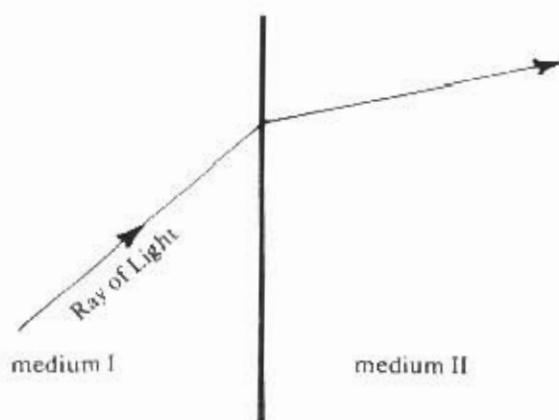


32. An object placed two focal lengths from a thin converging lens forms an image. As the object is moved toward the lens, the image **initially** moves
- (A) away from the lens and decreases in size.
 (B) away from the lens and increases in size.
 (C) toward the lens and decreases in size.
 (D) toward the lens and increases in size.
 (E) toward the lens and remains the same size.
33. An object is placed two focal lengths from a thin converging lens. The magnification of the resulting image is
- (A) one-fourth.
 (B) one-half.
 (C) one.
 (D) two.
 (E) four.

34. An object is placed 30 centimeters from a thin converging lens with a focal length of 10 centimeters. The image will be described as

- (A) real and 7.5 centimeters from the lens.
 (B) virtual and 7.5 centimeters from the lens.
 (C) virtual and 15 centimeters from the lens.
 (D) real and 15 centimeters from the lens.
 (E) real and 30 centimeters from the lens.

DIAGRAM FOR QUESTION 35

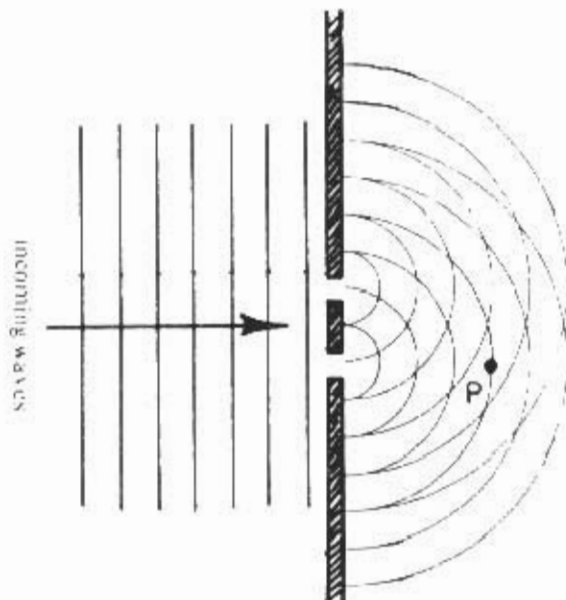


35. Monochromatic light follows the path shown in the diagram above. Compared with the light in medium I, the light in medium II has a
- (A) lower frequency.
 (B) higher frequency.
 (C) lower speed.
 (D) higher speed.
 (E) greater intensity.
36. If the earth-sun distance were doubled, the intensity of solar radiation at the earth's surface would be
- (A) one-fourth as great.
 (B) one-half as great.
 (C) unchanged.
 (D) twice as great.
 (E) four times as great.
37. "Light is believed to act like a wave." Which experimental observation provides the best support for the quoted statement?
- (A) Light can be reflected by a mirror.
 (B) Light is scattered when passing through smoke.
 (C) Light forms light and dark bands after passing through a narrow slit.
 (D) White light can be broken into its component colors by a prism.
 (E) Light is bent by a gravitational field.

38. Which of the following cannot be polarized?
- (A) Radio waves.
 - (B) Standing waves on a string.
 - (C) Microwaves.
 - (D) Sound waves.
 - (E) Light.

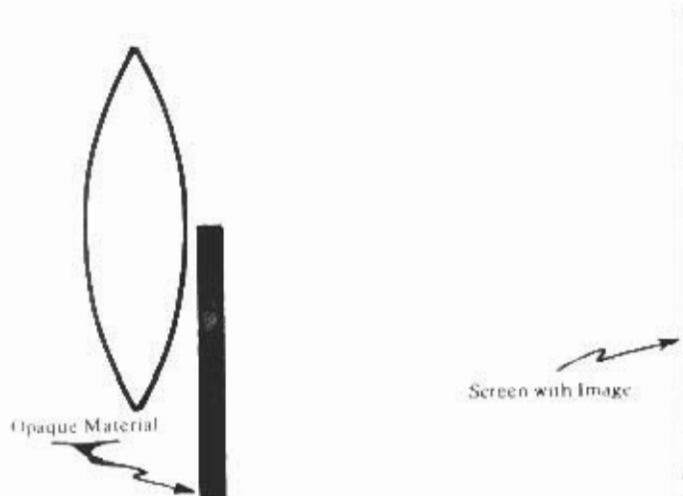
DIAGRAM FOR QUESTION 39

The Lines Shown are Amplitude Maxima One Wavelength Apart.



39. Plane waves incident from the left pass through two slits as shown in the diagram above. When do waves arriving at point P have a phase difference of 180° (that is one-half wavelength)?
- (A) never.
 - (B) once every half cycle.
 - (C) once every cycle.
 - (D) twice every cycle.
 - (E) at all times.

DIAGRAM FOR QUESTION 40



40. A projector forms a real image on a screen. The lower half of a projector lens is accidentally covered (see diagram). One will find that
- (A) the focal length is increased.
 - (B) the focal length is decreased.
 - (C) only the bottom half of the image will be seen on the screen.
 - (D) only the top half of the image will be seen on the screen.
 - (E) none of the above is true.

END OF SECTION B

END OF PART I

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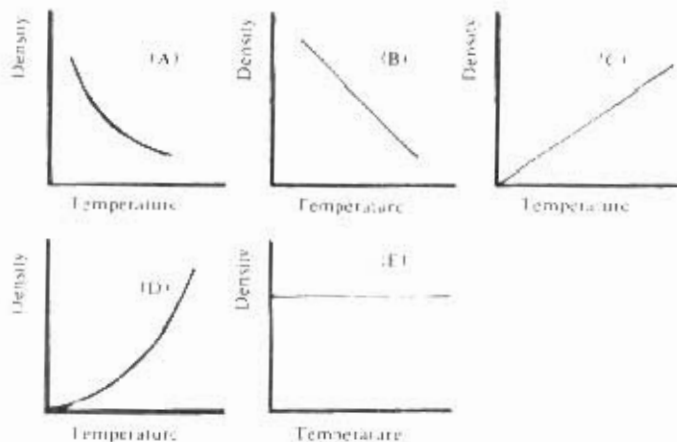
Part II - SECTION C

Heat and Kinetic Theory

41. The kilocalorie is the amount of energy needed to raise the temperature of one
- pound of water by 1 Fahrenheit degree.
 - pound of water by 1 Celsius degree.
 - kilogram of water by 1 Fahrenheit degree.
 - kilogram of water by 1 Celsius degree.
 - gram of water by 1 Fahrenheit degree.
42. A kilogram of pure steam at 100° Celsius is condensed to water at 100° Celsius and then is cooled to 80° Celsius. The heat of vaporization for water at 100° is 540 kilocalories/kilogram. How much heat energy is given off in this process?
- 80 kilocalories.
 - 100 kilocalories.
 - 520 kilocalories.
 - 540 kilocalories.
 - 560 kilocalories.
43. One kilogram of lead at 90° Celsius is placed into one kilogram of water at 10° Celsius. Assume the mixture is well insulated. When the mixture reaches thermal equilibrium, the
- temperature change of the lead will be equal to the temperature change of the water.
 - temperature change of the lead will be greater than the temperature change of the water.
 - heat lost by the lead will be greater than the heat gained by the water.
 - heat lost by the lead will be less than the heat gained by the water.
 - none of the above are true.
44. One hundred grams of ice at 0° Celsius is added to 400 grams of water at 16° Celsius in a beaker. Assume no heat energy is lost to or gained from the beaker or other surroundings. If the heat of fusion of water is 80 calories per gram, what is the final equilibrium temperature of the mixture?
- -4.0° Celsius
 - -1.6° Celsius
 - 0° Celsius
 - 1.6° Celsius
 - 4.0° Celsius

45. Two liters of a gas are expanded from one atmosphere at 300 kelvin to four liters at 400 kelvin. The new pressure of the gas is
- $3/32$ atmospheres.
 - $1/6$ atmospheres.
 - $2/3$ atmospheres.
 - $3/2$ atmospheres.
 - 6 atmospheres.
46. The temperature of gas X is greater than the temperature of gas Y. Compared to gas Y molecules, the molecules of gas X certainly must have greater
- speed.
 - momentum.
 - mass.
 - kinetic energy.
 - potential energy.

DIAGRAM FOR QUESTION 47



47. Which of the above graphs best describes the density of an ideal gas as a function of its absolute temperature, at constant pressure?
- A
 - B
 - C
 - D
 - E
48. The ideal gas law, $pV = nRT$, describes the condition of gases best when the
- density of the gas is low.
 - pressure is high.
 - gas is colorless.
 - gas is diatomic.
 - temperature is close to absolute zero.

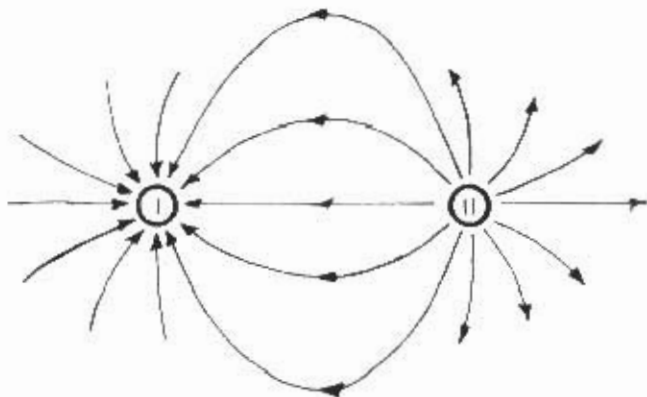
END OF SECTION C

Part II - SECTION D

Electricity and Magnetism

49. In general, a positively charged electroscope
- (A) has more electrons than protons.
 - (B) has fewer electrons than protons.
 - (C) repels a negatively charged object.
 - (D) has the same number of protons as electrons.
 - (E) has no protons.

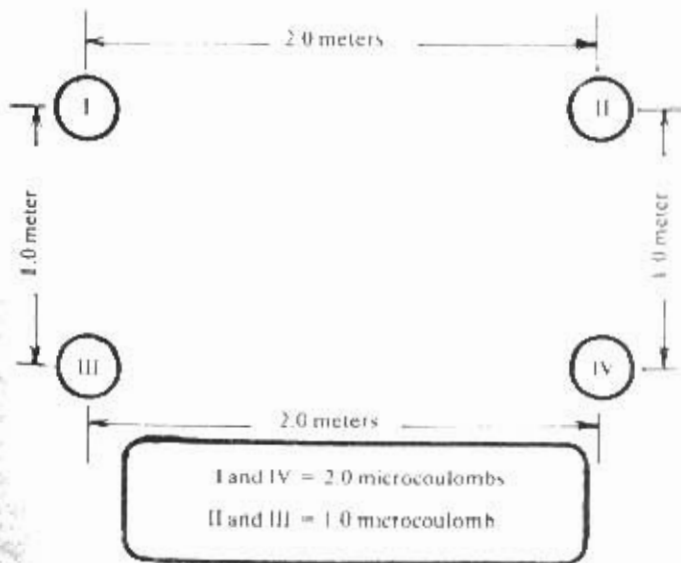
DIAGRAM FOR QUESTION 50



50. The electric field lines shown in the diagram above could be caused by which of the following conditions?

	CHARGE ON I	CHARGE ON II
(A)	+	-
(B)	-	+
(C)	+	+
(D)	-	-
(E)	+	0

DIAGRAM FOR QUESTION 51



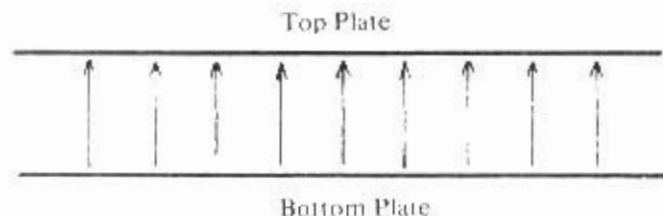
51. Four spherical objects carrying positive electric charges I, II, III, and IV are arranged as shown above in the diagram for question 51. The electric force is **least** between charges

- (A) I and II.
- (B) I and III.
- (C) I and IV.
- (D) II and III.
- (E) II and IV.

52. A unit that may be used to measure electric field intensity is the

- (A) newton.
- (B) coulomb.
- (C) volt.
- (D) volt-meter.
- (E) newton/coulomb.

DIAGRAM FOR QUESTION 53

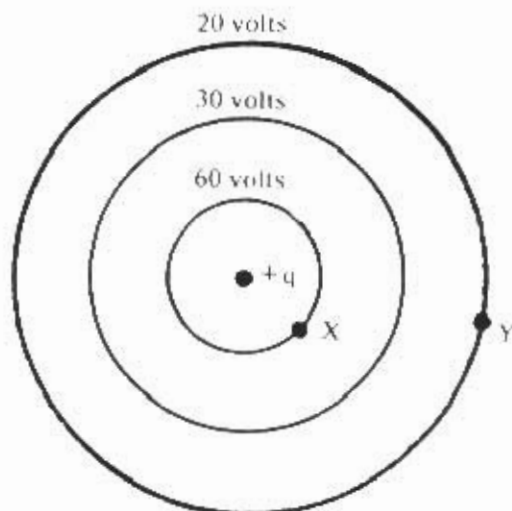


53. Two closely spaced parallel plates are charged by a battery. The electric field is directed from the bottom plate to the top plate. Which of the following statements is **false**?

- (A) The upper plate is negative and the bottom plate is positive.
- (B) The electric force on a proton placed in the electric field between the plates is upward.
- (C) The electric force on a charged particle between the plates is smaller near the plates than it is midway between the plates.
- (D) The electric force on an electron placed between the plates is downward.
- (E) The electric force on a particle between the plates is independent of the mass of the particle.

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DIAGRAM FOR QUESTION 54



54. In the diagram above, circular equipotential lines are drawn at 60 volts, 30 volts, and 20 volts about an electric charge $+q$. The total work done in moving an object with a charge of 10 coulombs from position Y to position X is

(A) zero.
 (B) 40 joules.
 (C) 110 joules.
 (D) 200 joules.
 (E) 400 joules.

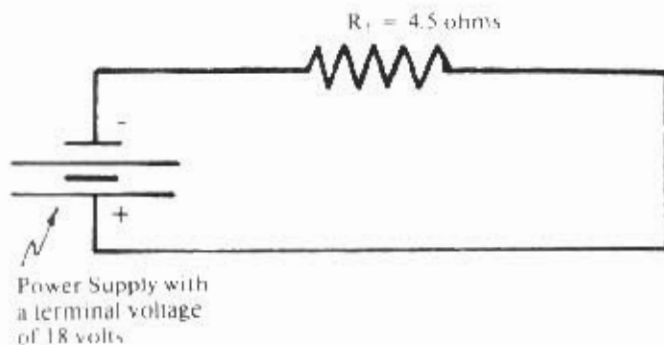
55. Gravitational and electrical forces are similar in the sense that for point objects or spherical distributions both are

(A) always attractive and strong.
 (B) always attractive and weak.
 (C) directly proportional to the square of the distance of separation.
 (D) inversely proportional to the square of the distance of separation.
 (E) inversely proportional to the distance of separation.

56. What is the minimum equipment needed to determine the power dissipated in a resistor of unknown value connected to a direct current power supply?

(A) a voltmeter.
 (B) an ammeter.
 (C) an ammeter and a stopwatch.
 (D) an ammeter and a voltmeter.
 (E) an ammeter, a voltmeter, and a stopwatch.

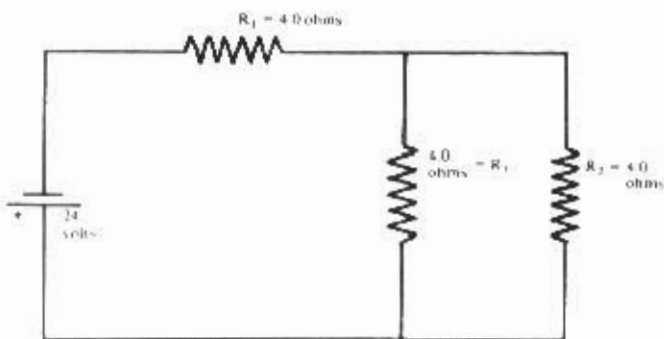
DIAGRAM FOR QUESTION 57



57. The current through resistor R_1 in the diagram above is

(A) 2.0 amperes.
 (B) 4.0 amperes.
 (C) 6.0 amperes.
 (D) 12 amperes.
 (E) 18 amperes.

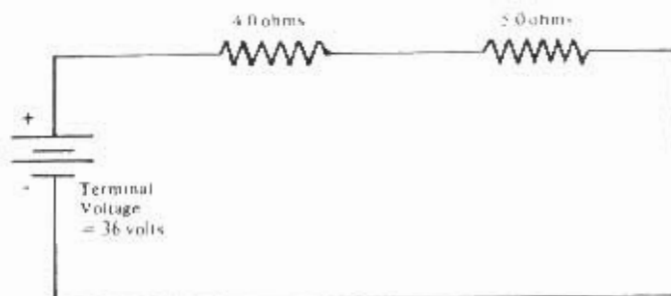
DIAGRAM FOR QUESTION 58



58. The total resistance of the circuit shown above is

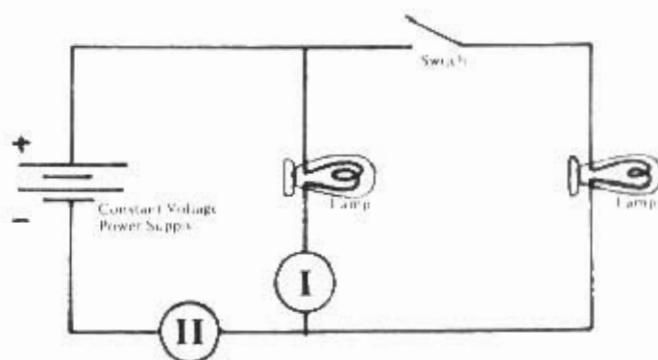
(A) 2.0 ohms.
 (B) 4.0 ohms.
 (C) 6.0 ohms.
 (D) 8.0 ohms.
 (E) 12 ohms.

DIAGRAM FOR QUESTION 59



59. In the circuit above, what is the power dissipated by the 4.0 ohm resistor?
- (A) 36 watts.
 (B) 64 watts.
 (C) 96 watts.
 (D) 128 watts.
 (E) 144 watts.

DIAGRAM FOR QUESTION 60



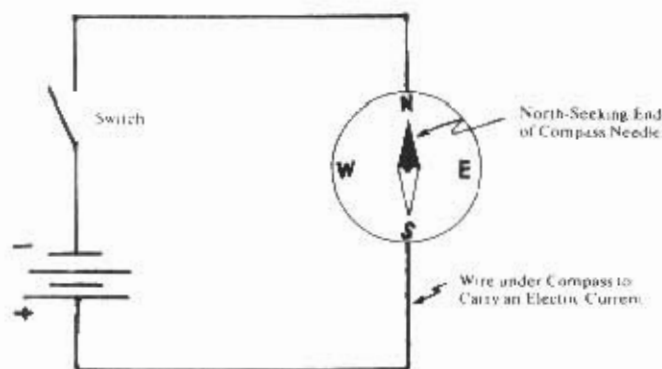
60. A constant voltage power supply is connected to a lamp as shown above and the current is measured with ammeters at I and II. If a second similar lamp is connected into the circuit by closing the switch, the current at
- (A) I will remain about the same.
 (B) II will remain about the same.
 (C) I will become about half as large.
 (D) II will become about half as large.
 (E) I will become about twice as large.
61. A charged particle moving in a vacuum at a constant speed enters a uniform magnetic field. If the initial motion of the particle is perpendicular to the magnetic field lines, the particle will
- (A) follow a circular path.
 (B) follow a parabolic path.
 (C) experience a retarding magnetic force.
 (D) experience no magnetic force.
 (E) experience a magnetic force in the direction of the particle's motion.

DIAGRAM FOR QUESTION 62



62. An electron (e) moving in the plane of the page between a pair of magnetic poles as shown above, will be deflected
- (A) out of the page, (that is, toward you).
 (B) into the page (that is, away from you).
 (C) toward the N-pole.
 (D) toward the S-pole.
 (E) in none of the above ways.

DIAGRAM FOR QUESTION 63



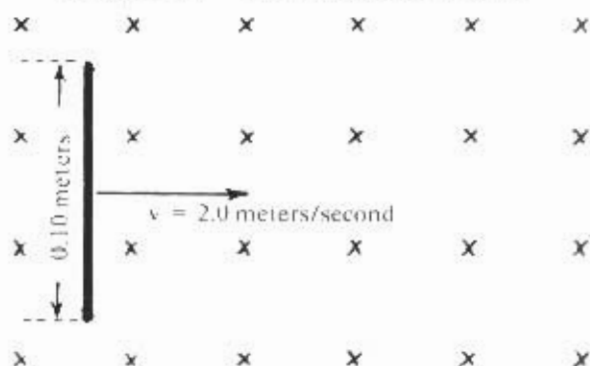
63. A wire is located directly under and parallel to a compass needle that is pointing North. An electric current is started in the wire by closing the switch. The North-seeking end of the compass needle will
- (A) remain undisturbed.
 (B) deflect toward the East.
 (C) deflect toward the West.
 (D) be disturbed, but finally point South.
 (E) be disturbed, but finally point North.
64. The magnetic force experienced by a moving charged particle depends upon which of the following?
1. The particle's charge.
 2. The particle's velocity.
 3. The magnetic field strength.
- (A) 3 only.
 (B) 1 and 2 only.
 (C) 1 and 3 only.
 (D) 2 and 3 only.
 (E) 1, 2, and 3.

Go on to next page

DIAGRAM FOR QUESTION 65

magnetic field into page \times

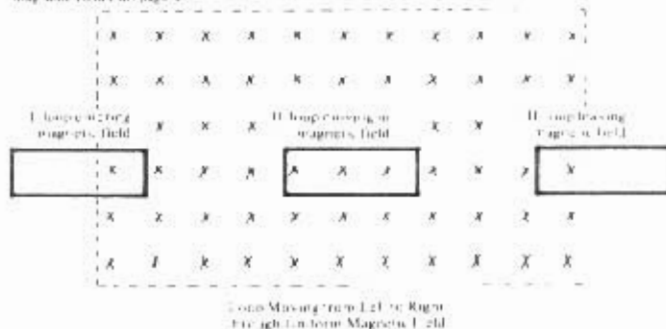
magnet field = 10 newtons/ampere meter



Assume that wire is perpendicular to direction of motion and to direction of magnetic field

65. A 0.10-meter conductor is moving at a speed of 2.0 meters/second as shown in the diagram above. While the conductor is in the magnetic field of intensity of 10 newtons/ampere-meter the potential difference induced across its length is
- (A) zero.
 (B) 2.0 volts.
 (C) 5.0 volts.
 (D) 50 volts.
 (E) 200 volts.

DIAGRAM FOR QUESTION 66

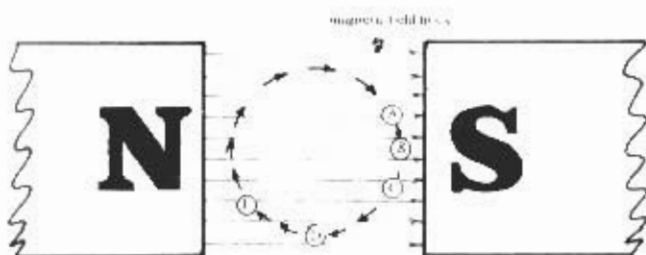
magnetic field into page \times 

66. A closed conductive loop enters, moves through, and leaves a uniform magnetic field as shown above. Which of the following indicates the direction of the induced conventional current in the loop at the three locations?

	LOCATION I	LOCATION II	LOCATION III
(A)	clockwise	counterclockwise	zero
(B)	counterclockwise	zero	clockwise
(C)	zero	clockwise	zero
(D)	clockwise	zero	counterclockwise
(E)	counterclockwise	counterclockwise	counterclockwise

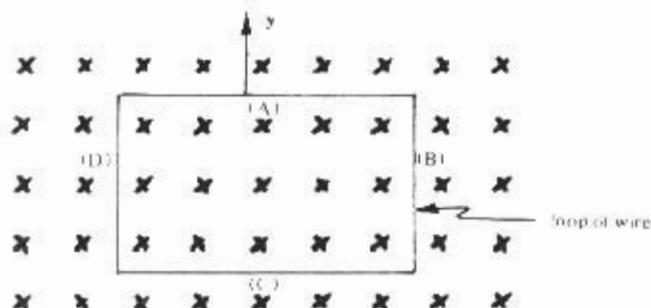
DIAGRAM FOR QUESTION 67

The diagram below shows a wire which is perpendicular to the page, moving in a circular path. The magnetic field between the N and S poles is uniform and the speed of the wire is constant. The letters A, B, C, D, and E show positions of the wire.



67. The induced emf (that is, voltage) in the wire is a minimum when the wire is at position
- (A) A.
 (B) B.
 (C) C.
 (D) D.
 (E) E.

DIAGRAM FOR QUESTION 68

magnetic field into page \times 

68. As shown above, a rectangular loop of wire is moving in the direction y through a uniform magnetic field directed into the page. The plane of the loop is always perpendicular to the direction of the field. Which of the following is true?
- (A) A clockwise conventional current is induced in the loop.
 (B) Positive charges will be in excess on side B of the loop.
 (C) Positive charges will be in excess on side C of the loop.
 (D) Positive charges will be in excess on side D of the loop.
 (E) A counterclockwise conventional current is induced in the loop.

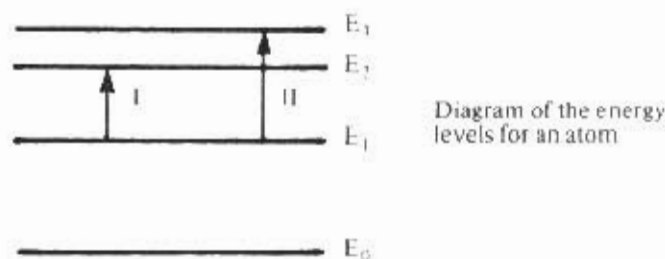
END OF SECTION D

Part II - SECTION E

Modern Physics

69. Which type of radiation has the greatest energy per photon?
- (A) Gamma.
(B) Infrared.
(C) Microwave.
(D) Ultraviolet.
(E) Visible.

DIAGRAM FOR QUESTION 70



70. Transition I in the drawing above represents absorption of a photon of blue light. Transition II could represent absorption of
- (A) radio waves.
(B) infrared radiation.
(C) green light.
(D) ultraviolet radiation.
(E) none of the above.
71. The bright-line spectrum produced by isolated and excited atoms of an element contains wavelengths that are
- (A) characteristic of the particular element.
(B) the same for all elements.
(C) evenly distributed throughout the visible spectrum.
(D) dependent upon the intensity of the source.
(E) described by none of the above.

72. In an experiment on the photoelectric effect with a metal whose work function was 3.8 electron volts, an opposing voltage of 8.0 volts was found to just reduce the current to zero. This indicated that the
- (A) released electrons had an average of 8 electron volts of energy.
(B) released electrons had 11.8 electron volts of energy.
(C) photons striking the metal had 4.2 electron volts of energy.
(D) photons striking the metal had 3.8 electron volts of energy.
(E) photons striking the metal had at most 11.8 electron volts of energy.

73. An atomic particle of mass m moving at speed v is found to have wavelength λ . What is the speed of a second particle with mass $2m$ and the same wavelength?
- (A) $0.5v$.
(B) v .
(C) \sqrt{v} .
(D) $2v$.
(E) v^2 .

74. Consider the following statements:
- I. An atom has two energy levels whose energy difference matches the energy of a photon.
 - II. The lower of these two levels is occupied by an electron.
 - III. The higher of these two levels is occupied by an electron.
- Which of the following must be true for the atom to absorb the photon in a one-photon process?
- (A) Both I and II.
(B) Both II and III.
(C) Only I.
(D) Only II.
(E) Only III.

75. Radium ($^{226}_{88}\text{Ra}$) undergoes negative beta decay. What is the daughter nucleus?
- (A) $^{225}_{88}\text{Ra}$.
(B) $^{224}_{89}\text{Ac}$.
(C) $^{225}_{89}\text{Ac}$.
(D) $^{225}_{87}\text{Fr}$.
(E) $^{226}_{88}\text{Ra}$.

Go on to next page

76. A radioactive sample has a half-life of nine months. What fraction of the original activity will remain after three years?
- (A) $1/2$.
(B) $1/4$.
(C) $1/8$.
(D) $1/16$.
(E) $1/32$.
77. The atomic mass number of an element is
- (A) always equal to or less than its atomic number.
(B) always greater than or equal to its atomic number.
(C) sometimes greater and sometimes less than its atomic number.
(D) equal to its atomic number except in the case of isotopes.
(E) always equal to the number of protons in the nucleus.
78. Thorium ($^{232}_{90}\text{Th}$) undergoes alpha decay. What is the daughter nucleus of this process?
- (A) $^{228}_{90}\text{Th}$.
(B) $^{228}_{88}\text{Ra}$.
(C) $^{227}_{88}\text{Ra}$.
(D) $^{227}_{88}\text{Rn}$.
(E) $^{228}_{86}\text{Rn}$.
79. Atoms whose nuclei contain the same number of protons, but different numbers of neutrons, are called
- (A) alpha particles.
(B) isotopes.
(C) isobars.
(D) isomers.
(E) positrons.
80. According to the special theory of relativity, which one of the following quantities has the same value for all observers?
- (A) the length of an object.
(B) the speed of an object.
(C) the duration of a time interval.
(D) the speed of light in a vacuum.
(E) the mass of an object.

END OF SECTION E

END OF EXAMINATION