

AAPT Introductory Physics Examination—Version 1991 R

This exam was prepared by members of a test-development committee consisting of physics instructors representing the American Association of Physics Teachers (AAPT) and the National Science Teachers Association (NSTA).

High School Physics Examination Development Committee Members

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Directions:

- 1) **Do Not Open** this examination until you are asked to do so by your teacher.
- 2) **Do Not Write** anything in this examination booklet. You will be supplied with scratch paper and an answer sheet.
- 3) Each question or incomplete statement has a single best answer. When you have made your choice for the best answer to a question, completely blacken the corresponding space on the answer sheet. Use a number 2 pencil and make a heavy black mark that completely fills the space to record your answer. Mark only one answer for each question. If you wish to change your answer, completely erase the previous mark.
- 4) This examination is divided into five sections as shown below. During a given time period, you should work only on the questions in the appropriate section.

Part I

SECTION A. Mechanics	24 questions	30 minutes	page 2
SECTION B. Waves, Optics, and Sound	16 questions	20 minutes	page 7

Part II

SECTION C. Heat & Kinetic Theory	8 questions	10 minutes	page 11
SECTION D. Electricity & Magnetism	20 questions	25 minutes	page 13
SECTION E. Modern Physics	12 questions	15 minutes	page 17

- 5) The score on this examination is equal to the number of correct answers. There is no penalty for wrong answers; therefore, you should answer every question in the section(s) assigned by your teacher.
- 6) When you are instructed to stop working, put down your pencil, close the examination booklet, and wait for further instructions.

Values of Some Physical Constants

mass of electron	$m_e = 9.1 \times 10^{-31} \text{ kg}$
mass of proton	$m_p = 1.7 \times 10^{-27} \text{ kg}$
magnitude of electronic charge	$e = 1.6 \times 10^{-19} \text{ C}$
speed of light	$c = 3.0 \times 10^8 \text{ m/s}$
Planck's constant	$h = 6.6 \times 10^{-34} \text{ J} \cdot \text{s}$
Coulomb's law constant ($1/4\pi\epsilon_0$)	$k = 9.0 \times 10^9 \text{ N} \cdot \text{m}^2/\text{C}^2$
permeability constant	$\mu_0 = 4\pi \times 10^{-7} \text{ T} \cdot \text{m/A}$
	$\mu_0/2\pi = k' = 2 \times 10^{-7} \text{ T} \cdot \text{m/A}$
gravitational constant	$G = 6.7 \times 10^{-11} \text{ N} \cdot \text{m}^2/\text{kg}^2$
acceleration due to gravity	$g = 10 \text{ m/s}^2$
electron volt	$1 \text{ eV} = 1.6 \times 10^{-19} \text{ J}$

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Part I • Section A • Mechanics

24 Questions—30 Minutes

1. Units of work equivalent to the joule (J) include which of the following?

I newton · meter
 II newton · second
 III kilogram · meter²/second

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

Questions 2 and 3. An object moving on the x -axis has a velocity v_x as shown on the graph below.

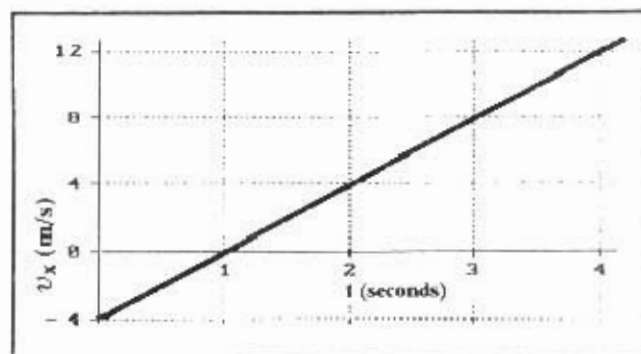


Figure for questions 2 and 3.

2. The distance traveled by the object from $t = 1.0$ s to $t = 4.0$ s is most nearly
- (A) 4 m
 (B) 6 m
 (C) 9 m
 (D) 12 m
 (E) 18 m
3. The average acceleration a_x for the time interval between $t = 0.0$ and $t = 2.0$ s is most nearly
- (A) -4.0 m/s^2
 (B) -2.0 m/s^2
 (C) 0
 (D) $+2.0 \text{ m/s}^2$
 (E) $+4.0 \text{ m/s}^2$

4. This question involves some estimation. The density of seawater is about 10^3 kilograms/meter³. A whale is about 10 meters long. The mass of the whale is between

- (A) 10^{-3} kg and 10^{-1} kg
 (B) 10^{-1} kg and 10^1 kg
 (C) 10^1 kg and 10^3 kg
 (D) 10^3 kg and 10^6 kg
 (E) 10^6 kg and 10^9 kg

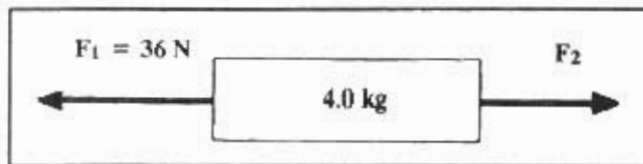
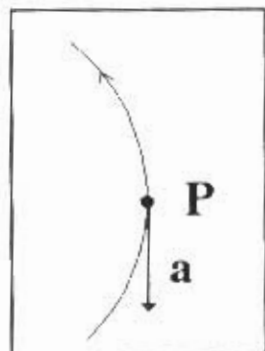


Figure for question 5.

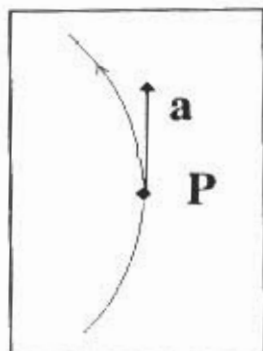
5. Two forces F_1 and F_2 act on a 4.0-kilogram block as shown above, and the block accelerates to the left at $3.0 \text{ meters/second}^2$. The magnitude of the force F_2 is
- (A) 3 N
 (B) 12 N
 (C) 24 N
 (D) 36 N
 (E) 60 N
6. Two rocks are thrown vertically from a bridge with the same initial speed v_0 . The rocks are released from the same level, but one is thrown straight up, and the other is thrown straight down. Air resistance effects are negligible. The rock that is thrown down reaches the water below with a speed v_f . The speed of the other rock when it reaches the water is
- (A) v_f
 (B) $v_f - v_0$
 (C) $v_f + v_0$
 (D) $v_f + 2v_0$
 (E) impossible to determine from the given data

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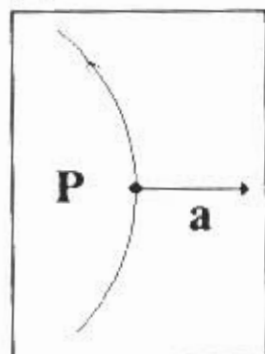
7. A satellite moves with constant speed along a circular path. Which of the following best represents the acceleration \mathbf{a} of the satellite when it is at point P on the path?



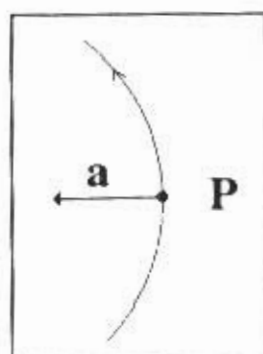
(A)



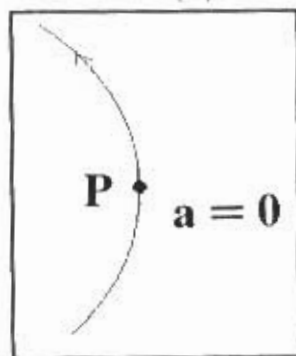
(B)



(C)



(D)



(E)

8. An object is thrown vertically upward. Which of the following must be true when the object is at the top of its path?

- I the object has zero speed
- II the object has zero velocity
- III the object has zero acceleration

- (A) I only
- (B) II only
- (C) I and II only
- (D) I and III only
- (E) I, II, and III

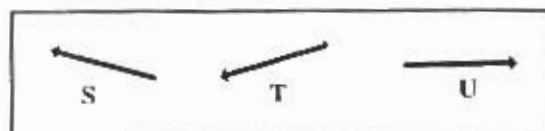
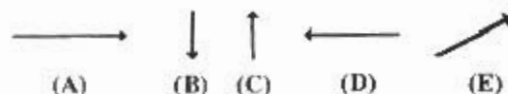


Figure for question 9.

9. Three vectors of equal magnitude are shown above. Which of the following best represents their sum, $\mathbf{S} + \mathbf{T} + \mathbf{U}$?



10. A warehouse worker exerts a horizontal force of magnitude 300 newtons on a 150-kilogram crate, so that the crate moves across a horizontal floor in a straight line at a constant speed of 2 meters/second. The coefficient of sliding friction between the crate and the floor is most nearly

- (A) 0
- (B) 0.2
- (C) 0.5
- (D) 1
- (E) 2

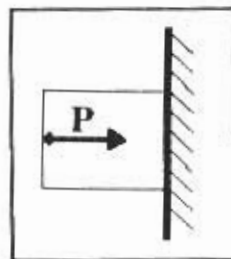


Figure for question 11.

11. A heavy block is held in place on a vertical wall by applying a horizontal force \mathbf{P} as shown above. The direction of the frictional force exerted on the block by the wall is

- (A) up
- (B) down
- (C) to the left
- (D) to the right
- (E) not defined because there is no frictional force acting

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12. A satellite is in a circular orbit about the Earth. The gravitational force exerted on the satellite by the Earth is
- zero
 - less than the centripetal force exerted on the satellite
 - independent of the mass of the satellite
 - equal but opposite to the gravitational force exerted on the Earth by the satellite
 - less than but opposite to the gravitational force exerted on the Earth by the satellite
13. An object of mass M and speed v has momentum of magnitude p . An object of mass $2M$ and speed $3v$ has momentum of magnitude
- $1.5p$
 - $6p$
 - $12p$
 - $18p$
 - $36p$
14. Planet Earth has mass M and radius R ; planet X has mass $2M$ and radius $3R$. If Janie weighs 450 newtons (N) on the Earth, then her weight on planet X is most nearly
- 100 N
 - 200 N
 - 300 N
 - 450 N
 - 680 N

Questions 15 and 16. A 0.50-kilogram ball moving to the right with speed 3.0 meters/second is struck by a club. The club is in contact with the ball for 0.025 seconds and afterward the ball moves to the left with speed 7.0 meters/second.

15. The magnitude of the change in momentum of the ball is
- $0.025 \text{ kg} \cdot \text{m/s}$
 - $1.5 \text{ kg} \cdot \text{m/s}$
 - $3.5 \text{ kg} \cdot \text{m/s}$
 - $5.0 \text{ kg} \cdot \text{m/s}$
 - $80 \text{ kg} \cdot \text{m/s}$
16. The change in kinetic energy of the ball in joules (J) is
- 1
 - 2.5 J
 - 10 J
 - 20 J
 - 25 J

17. A simple pendulum of mass M and length L swings with small amplitude and has a period T . The period of a similar pendulum of mass $2M$ and length $2L$ is
- $T/\sqrt{2}$
 - $\sqrt{2}T$
 - T
 - $T/2$
 - $2T$
18. If a given spring is stretched by 0.25 meters, the potential energy of the spring is 12 joules (J). If the spring is stretched by 0.50 meters, the potential energy of the spring is
- 6 J
 - 12 J
 - 24 J
 - 36 J
 - 48 J

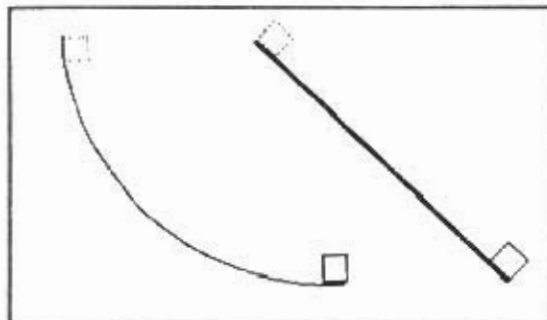


Figure for question 19.

19. Two identical blocks are released from rest from the same height and slide down different tracks as shown above. Both tracks end at the same level, and friction is negligible. Which of the following quantities is the same for both blocks at the bottom of the tracks?
- speed
 - kinetic energy
 - potential energy
- I only
 - II only
 - III only
 - I and II only
 - I, II, and III

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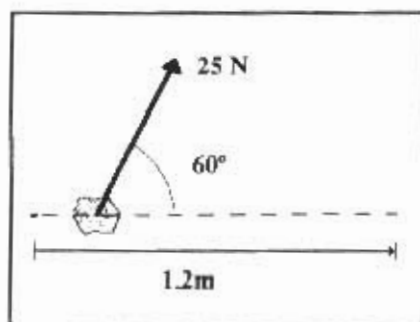


Figure for question 20.

20. A force of magnitude 25 newtons acts on a stone in a direction that is 60° from the straight line path of the stone. The length of the path is 1.2 meters. The work in joules (J) done by the force on the stone is most nearly
- (A) 1.5 J
(B) 15 J
(C) 30 J
(D) 150 J
(E) 300 J
21. A 5-kilogram body is raised vertically 10 meters in 20 seconds. The change in the potential energy in joules (J) of the body is most nearly
- (A) 5 J
(B) 25 J
(C) 50 J
(D) 500 J
(E) 1,000 J

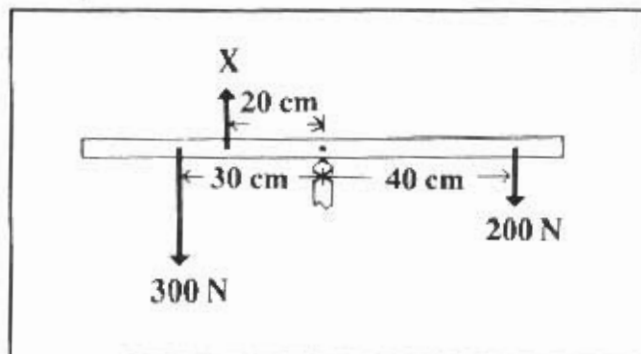


Figure for question 22.

22. A uniform meter-stick is balanced at its midpoint with several forces applied as shown above. If the stick is in equilibrium, the magnitude of the force X in newtons (N) is
- (A) 50 N
(B) 100 N
(C) 200 N
(D) 300 N
(E) impossible to determine unless the weight of the stick is given

23. A 2-kilogram ball with an initial velocity of 10 meters/second to the right has a head-on, elastic collision with a 3-kilogram ball that is initially at rest. After the collision, the velocity of the 3-kilogram ball is 8 meters/second to the right and the velocity of the 2-kilogram ball is

(A) 0
(B) 2 m/s, to the left
(C) 3 m/s, to the right
(D) 4 m/s, to the right
(E) 10 m/s, to the left

24. A particle on the end of a spring undergoes simple harmonic motion. Which of the following statements about the motion is correct?

I the speed is a maximum at the midpoint of the motion
II the acceleration is zero at the midpoint of the motion
III the magnitude of the acceleration is a maximum when the speed is zero

(A) I only
(B) II only
(C) I and II only
(D) I and III only
(E) I, II, and III

End of Section A

No test material on this page.

Part I • Section B • Waves, Optics, Sound

16 Questions—20 Minutes

25. Sound waves in air can exhibit all of the following EXCEPT

(A) polarization
(B) beats
(C) interference
(D) Doppler shift
(E) diffraction

26. A sound wave travels in air with a speed of 340 meters/second. A standing wave in an air column has frequency 100 hertz. The distance between adjacent nodes is

(A) 0.85 m
(B) 1.7 m
(C) 3.4 m
(D) 6.8 m
(E) 13.6 m

27. When a sound wave crosses a boundary between two different media, quantities that change include which of the following?

I speed
II frequency
III wavelength

(A) I only
(B) II only
(C) III only
(D) I and II only
(E) I and III only

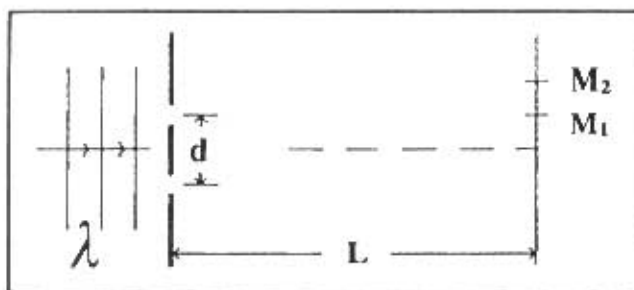


Figure for question 28.

28. Coherent light of wavelength λ is incident on two slits separated by distance d as shown above. An interference pattern is observed on a screen a distance L from the slits. Changes that would increase the separation of maxima M_1 and M_2 on the screen include which of the following?

I increase d
II increase L
III increase λ

(A) I only
(B) II only
(C) III only
(D) II and III only
(E) I, II, and III

29. A real, inverted image can be formed by which of the following?

I plane mirror
II convex mirror
III concave mirror

(A) I only
(B) II only
(C) III only
(D) I and II only
(E) I, II, and III

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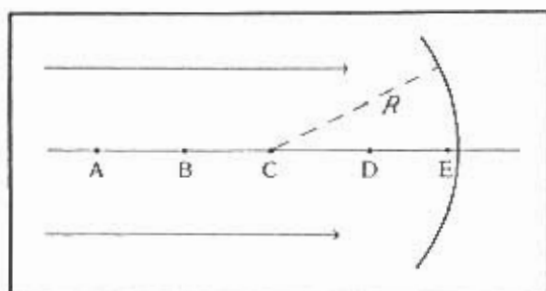


Figure for question 30.

30. Light from a very distant object is incident from the left on a spherical concave mirror of radius R as shown above. The image is located closest to point

(A) A
(B) B
(C) C
(D) D
(E) E

31. A small object is placed 150 millimeters from a concave mirror of focal length 250 millimeters. The image is

(A) virtual, erect, and smaller than the object
(B) virtual, erect, and larger than the object
(C) virtual, inverted, and larger than the object
(D) real, inverted, and 100 millimeters from the mirror
(E) real, erect, and 100 millimeters from the mirror

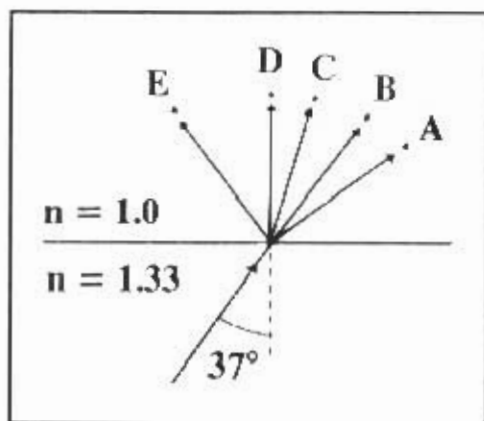


Figure for question 32.

32. A light ray is incident from water ($n = 1.33$) toward air ($n = 1.0$) as shown above. The refracted ray in air will pass through point

(A) A
(B) B
(C) C
(D) D
(E) E

33. When placed in air a transparent plastic has a critical angle for total internal reflection of 45° . The index of refraction of this material is

(A) $\sin 45^\circ$
(B) $\tan 45^\circ$
(C) $1/\tan 45^\circ$
(D) $1/\sin 45^\circ$
(E) 2.0

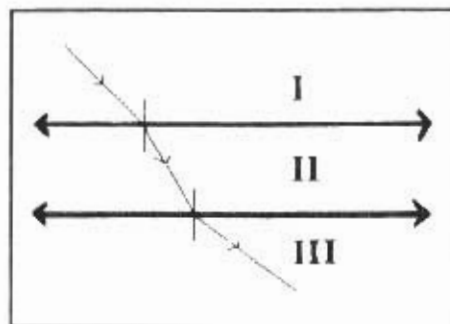


Figure for question 34.

34. A ray of light passes through layers of three materials labeled I, II, and III as shown above. The materials, not necessarily in order, are air ($n = 1.0$), plastic ($n = 1.3$) and glass ($n = 1.6$). The materials, in the order of I, II, and III, are

	I	II	III
(A)	air	plastic	glass
(B)	air	glass	plastic
(C)	plastic	glass	air
(D)	glass	air	plastic
(E)	glass	plastic	air

35. An object is placed 4.0 cm from a lens and its image is found at 6.0 cm from the lens on the side opposite the object. The focal length of this lens is most nearly

(A) 2.4 cm
(B) 5.0 cm
(C) -5.0 cm
(D) 12 cm
(E) -12 cm

36. A 444 hertz (Hz) note is sounded with a 448 hertz note. Which of the following can be heard?

I A note of frequency 892 Hz
II A note of frequency 223 Hz
III Beats of frequency 4 Hz

(A) I only
(B) II only
(C) III only
(D) I and II only
(E) I and III only

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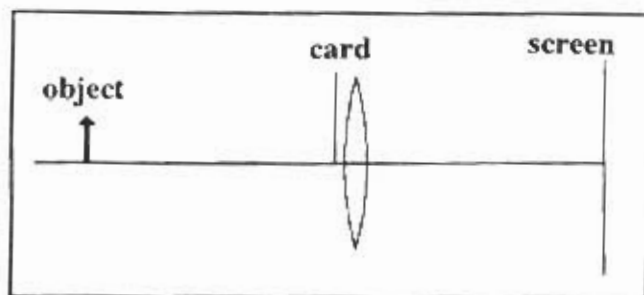


Figure for question 37.

37. An object is placed in front of a lens and an image can be seen on a screen. An opaque card is then placed to block the top half of the lens as shown above. How is the image changed?

(A) the image is formed closer to the lens
 (B) the image is formed farther from the lens
 (C) only half of the original image can be seen
 (D) none of the original image can be seen
 (E) all of the original image can be seen, but the intensity is reduced

38. Constructive and destructive interference can be observed for which of the following?

I water waves
 II sound waves
 III violet light

(A) I only
 (B) II only
 (C) III only
 (D) I and II only
 (E) I, II, and III

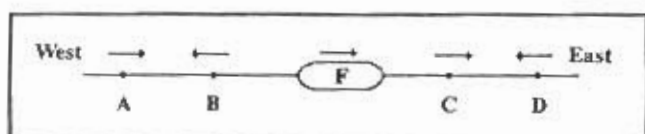


Figure for question 39.

39. A fire truck F traveling east sounds a siren. Four motorists, all with the same speed, are represented by A, B, C, and D in the diagram above. Which motorist hears the highest frequency?

(A) motorist A: traveling east behind the fire truck and following it
 (B) motorist B: traveling west behind the fire truck and away from it
 (C) motorist C: traveling east in front of the fire truck and away from it
 (D) motorist D: traveling west in front of the fire truck and toward it
 (E) all motorists hear the same frequency

40. An object can be placed at various points on the axis of a converging lens. Images that can be formed include which of the following?

I real, erect, and larger than the object
 II virtual, erect, and larger than the object
 III virtual, erect, and smaller than the object

(A) I only
 (B) II only
 (C) III only
 (D) I and II only
 (E) I, II, and III

End of Section B

End of Part I

No test material on this page.

Part II • Section C • Heat & Kinetic Theory

8 Questions — 10 Minutes

41. A copper rod is 2.000 meters long at 0.0°C and 2.001 meters long at 25°C . The length of the copper rod at -50°C is most nearly

(A) -2.001 m
 (B) -2.002 m
 (C) 2.002 m
 (D) 1.999 m
 (E) 1.998 m

42. A 300-gram sample of water at 20°C is mixed with a 200-gram sample of water at 60°C in an insulated container. Neglect any heat exchange with the container. The final temperature of the mixture is closest to

(A) 36°C
 (B) 42°C
 (C) 46°C
 (D) 56°C
 (E) 80°C

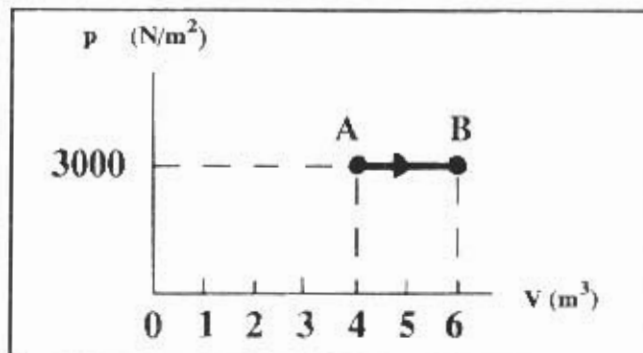


Figure for question 43.

43. A substance undergoes a process $A \rightarrow B$ as shown on the pV diagram above. The work in joules (J) done by the substance is most nearly

(A) 0
 (B) 1500 J
 (C) 3000 J
 (D) 6000 J
 (E) 18,000 J

44. A substance does 5000 joules (J) of work when 6000 joules of heat are added. The increase in internal energy of the substance is

(A) 0
 (B) 1000 J
 (C) 5000 J
 (D) 5500 J
 (E) 6000 J

45. An ideal gas is initially in a state with pressure 2.0 atmospheres, temperature 400 kelvin, and volume 3.0 liters (L). If the same amount of gas is later in a state with pressure 5.0 atmospheres and temperature 600 kelvin, then the volume is

(A) 0.8 L
 (B) 1.2 L
 (C) 1.8 L
 (D) 3.0 L
 (E) 5.0 L

46. A solid object S is immersed in a liquid L , and they are in thermal equilibrium. Which of the following statements is necessarily true?

I The temperature of S is equal to the temperature of L .
 II The specific heat of S is greater than the specific heat of L .
 III The specific heat of S is less than the specific heat of L .

(A) I only
 (B) II only
 (C) III only
 (D) I and II only
 (E) I and III only

47. The efficiency of a Carnot heat engine operating between two reservoirs at temperatures of 400 kelvin and 600 kelvin is most nearly

(A) 20%
 (B) 33%
 (C) 40%
 (D) 60%
 (E) 67%

48. In a container of helium gas at temperature T , pressure p , and volume V , the average speed of a molecule is v . If the pressure and volume are changed to $2p$ and $V/2$, but the temperature is held fixed, then the average speed of a molecule is

(A) $v/4$
 (B) $v/2$
 (C) v
 (D) $2v$
 (E) $4v$

End of Section C

No test material on this page.

Part II • Section D • Electricity & Magnetism

20 Questions—25 Minutes

49. When connected to a constant voltage source, a conductor of resistance R dissipates power P . A conductor of resistance $2R$ connected to the same constant voltage source dissipates power

(A) $P/4$
 (B) $P/2$
 (C) P
 (D) $2P$
 (E) $4P$

50. As a positively charged rod is brought close to the knob of a positively charged electroscope, the leaves of the electroscope will

(A) not move because of electrostatic shielding
 (B) come closer together because the leaves become more negatively charged
 (C) come closer together because the leaves become more positively charged
 (D) spread farther apart because the leaves become more negatively charged
 (E) spread farther apart because the leaves become more positively charged

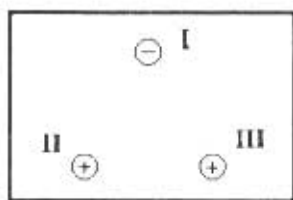
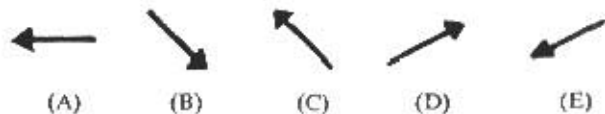


Figure for question 51.

51. Three charges of equal magnitude are arranged as shown above. Which of the following best represents the direction of the electrostatic force on charge II?



52. Two resistors in series in an operating circuit will necessarily have the same

(A) current
 (B) potential difference
 (C) power dissipated
 (D) resistance
 (E) length

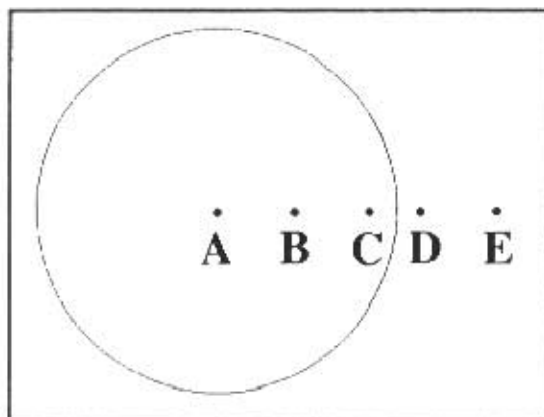


Figure for question 53.

53. A hollow conducting sphere bears a positive charge Q . The magnitude of the electric field is greatest at point

(A) A
 (B) B
 (C) C
 (D) D
 (E) E

54. Two resistors in parallel in an operating circuit will necessarily have the same

(A) diameter
 (B) current
 (C) resistance
 (D) power dissipated
 (E) potential difference

55. The magnetic field due to a current I in a long, straight wire has magnitude B at a perpendicular distance R from the wire. The magnitude of the magnetic field due to a current $2I$ at a distance of $3R$ from the wire is

(A) $2B/9$
 (B) $4B/9$
 (C) $2B/3$
 (D) $4B/3$
 (E) B

56. What is the smallest equivalent capacitance that can be formed by connecting a 3.0 microfarad (μF) capacitor and a 6.0 microfarad capacitor?

(A) $0.5 \mu\text{F}$
 (B) $2.0 \mu\text{F}$
 (C) $3.0 \mu\text{F}$
 (D) $9.0 \mu\text{F}$
 (E) $18 \mu\text{F}$

Go to next page.

Questions 57 and 58 are based on the following description:
Two equal positive charges Q lie on a line as shown below.

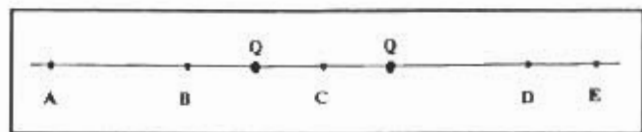


Figure for questions 57 and 58.

57. The magnitude of the resultant electric field due to the two charges is *greatest* at which of the labeled points?

(A) A
(B) B
(C) C
(D) D
(E) E

58. The magnitude of the resultant electric field due to the two charges is *least* at which of the labeled points?

(A) A
(B) B
(C) C
(D) D
(E) E

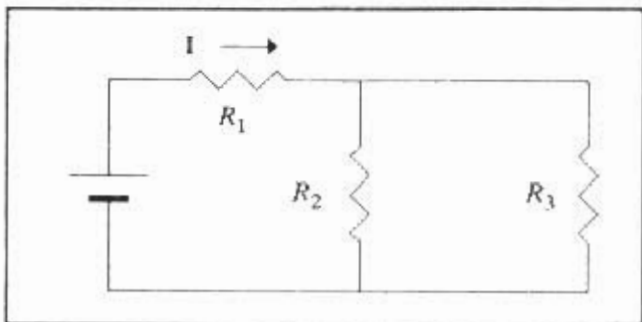


Figure for question 59.

59. Changes that can cause an *increase* in the current I in resistor R_1 include which of the following?

I Decreasing the resistance R_1
II Decreasing the resistance R_2
III Decreasing the resistance R_3

(A) I only
(B) II only
(C) III only
(D) I and III only
(E) I, II, and III

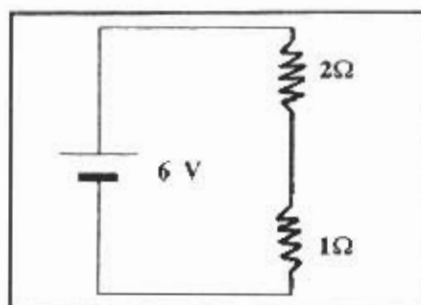


Figure for question 60.

60. What is the potential difference across the 2-ohm (Ω) resistor in the circuit shown above? Assume that the internal resistance of the battery is negligible.

(A) 1 V
(B) 2 V
(C) 3 V
(D) 4 V
(E) 6 V

61. Units equivalent to a volt include which of the following?

I watt/ampere
II ampere/ohm
III watt \cdot ohm

(A) I only
(B) II only
(C) III only
(D) I and II only
(E) II and III only

62. Two stationary charges exert an electrostatic force F on a third stationary charge. If the value of each of the three charges is doubled, then the force on the third charge is

(A) $F/2$
(B) F
(C) $3F$
(D) $4F$
(E) $9F$

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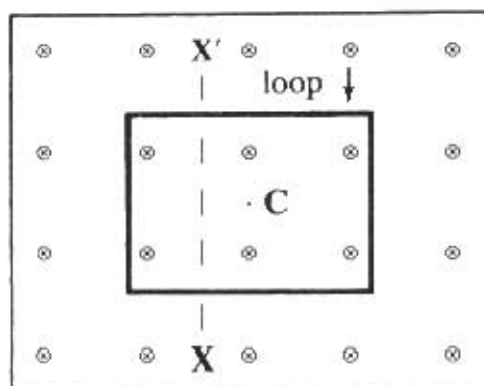


Figure for question 63.

63. A rectangular loop of wire is initially perpendicular to a magnetic field into the plane of the figure as shown above. A current will be induced in the loop by each of the following procedures EXCEPT

(A) The magnitude of the magnetic field is increased
 (B) The magnitude of the magnetic field is decreased
 (C) The rectangular loop is deformed into a circle of larger area
 (D) The loop is rotated about axis $X - X'$
 (E) The loop is rotated about an axis that is perpendicular to the page and passes through point C

64. A unit for electric field is newton/coulomb. An equivalent unit is

(A) volt/coulomb
 (B) volt \cdot coulomb
 (C) volt/meter
 (D) volt/meter²
 (E) volt \cdot meter \cdot coulomb

65. Particle I has charge Q and mass M , and particle II has charge $2Q$ and mass $3M$. Both particles are at rest. If F is the magnitude of the force exerted on I by II, then the magnitude of the force exerted on II by I is

(A) F
 (B) $2F$
 (C) $3F$
 (D) $5F$
 (E) $6F$

66. A particle with charge 2×10^{-12} coulombs moves from a point where the electric potential is 5 volts to a point where the electric potential is 9 volts. The change in electric potential energy in joules (J) of the charge is

(A) 0
 (B) 8×10^{-12} J
 (C) 10×10^{-12} J
 (D) 18×10^{-12} J
 (E) $2 \times 10^{+12}$ J

67. A circuit element has resistance R when the voltage across it is V and the current in it is I . If the voltage is $2V$ and the current is $2I$, then the resistance is

(A) $R/4$
 (B) $R/2$
 (C) R
 (D) $2R$
 (E) $4R$

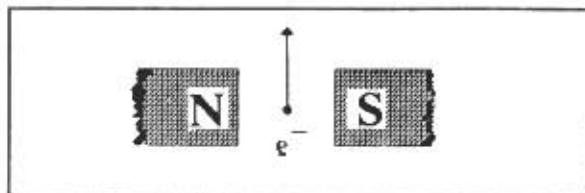


Figure for question 68.

68. An electron moves in the plane of the page between the poles of a magnet as shown above. The direction of the magnetic force on the electron in the position shown is

(A) the same as the direction of its velocity
 (B) opposite the direction of its velocity
 (C) toward the north pole of the magnet
 (D) toward the south pole of the magnet
 (E) perpendicular to the plane of the page

End of Section D

No test material on this page.

Part II • Section E • Modern Physics

12 Questions – 15 Minutes

69. In the Bohr model of the hydrogen atom, an electron in an initial level of higher energy can change to a final level of lower energy by

(A) emitting a photon
 (B) absorbing a photon
 (C) emitting a neutrino
 (D) absorbing a neutrino
 (E) emitting an antineutrino

70. Electrons are emitted from a certain metal if light of frequency greater than 6.0×10^{14} hertz is incident on the surface. However, no electrons are emitted if light of lower frequency is used. The minimum energy in joules (J) necessary to free an electron from this metal is most nearly

(A) 0
 (B) 1.1×10^{-48} J
 (C) 6.6×10^{-34} J
 (D) 1.3×10^{-27} J
 (E) 4.0×10^{-19} J

71. The masses of an electron, a proton, and a neutron compare as $m_e < m_p < m_n$. If an electron, a proton, and a neutron all have the same momentum, then they also have the same

(A) speed
 (B) de Broglie wavelength
 (C) rest-mass energy
 (D) kinetic energy
 (E) half-life

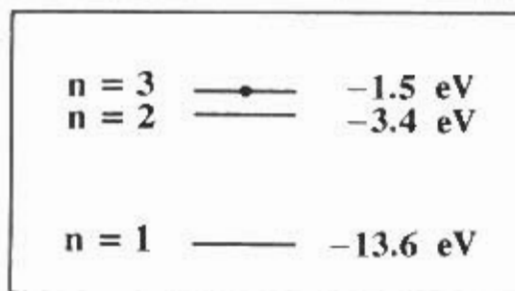


Figure for question 72.

72. The three lowest energy levels of atomic hydrogen are shown in the diagram above. If the electrons in a collection of atoms are initially in the $n = 3$ level, then possible energies of photons emitted from this collection include which of the following?

I 1.9 eV
 II 10.2 eV
 III 12.1 eV

- (A) I only
 (B) III only
 (C) I and II only
 (D) I, II, and III
 (E) none of the choices
73. The Heisenberg uncertainty principle implies that
- (A) all material particles travel at less than the speed of light
 (B) quantum mechanics and classical mechanics merge in the limit of large quantum numbers
 (C) an electron's position and momentum cannot both be known precisely at the same time
 (D) no more than two electrons can be in the same atomic orbital
 (E) momentum is not necessarily conserved in atomic processes
74. The rest-mass energy equivalent in joules (J) of a proton is most nearly
- (A) 0
 (B) 1.9×10^{-44} J
 (C) 5.0×10^{-19} J
 (D) 1.5×10^{-10} J
 (E) 940 J

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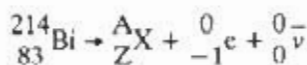
75. In atomic mass units (u), the proton rest mass is 1.0073 u and the neutron rest mass is 1.0087 u. The deuteron, formed from a proton and a neutron, has a rest mass that is between

(A) 0.0014 u and 0.0028 u
 (B) 2.0135 u and 2.0159 u
 (C) 2.0161 u and 2.0184 u
 (D) 2.0185 u and 2.0208 u
 (E) 2.0209 u and 4.0320 u

76. In alpha decay, an unstable nucleus decays into a daughter nucleus and

(A) a ${}^4_2\text{He}$ nucleus
 (B) a ${}^2_1\text{H}$ nucleus
 (C) a neutron
 (D) a neutrino
 (E) an electron

77. In the nuclear decay process



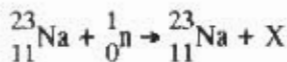
${}^A_Z\text{X}$ represents

(A) ${}^{213}_{82}\text{X}$
 (B) ${}^{213}_{84}\text{X}$
 (C) ${}^{214}_{82}\text{X}$
 (D) ${}^{214}_{83}\text{X}$
 (E) ${}^{214}_{84}\text{X}$

78. The half-life of magnesium 23 is about 12 seconds. A sample initially contains 72 micrograms (μg) of this isotope. How much magnesium 23 is present after 36 seconds?

(A) $2\mu\text{g}$
 (B) $6\mu\text{g}$
 (C) $9\mu\text{g}$
 (D) $24\mu\text{g}$
 (E) $36\mu\text{g}$

79. In the nuclear process



X represents

(A) a proton
 (B) an electron
 (C) a neutron
 (D) a neutrino
 (E) a photon

80. In the current standard model of elementary particles, the neutron is composed of

(A) a proton and an electron
 (B) an electron, a neutrino, and an antineutrino
 (C) a neutrino and an antineutrino
 (D) three quarks
 (E) three photons

End of Section E

End of Part II