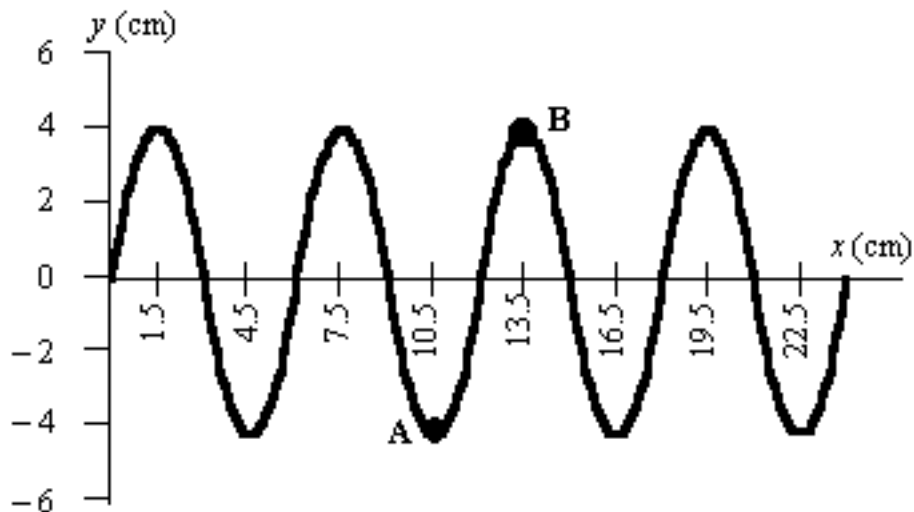


Use the following to answer question 1:

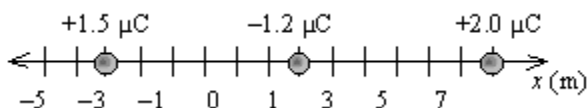
The displacement of a vibrating string versus position along the string is shown in the figure. The periodic waves have a speed of 10.0 cm/s. **A** and **B** are two points on the string.



1. What is the wavelength of the wave?
 - A) 3.0 cm
 - B) 6.0 cm
 - C) 9.0 cm
 - D) 12 cm
 - E) 15 cm

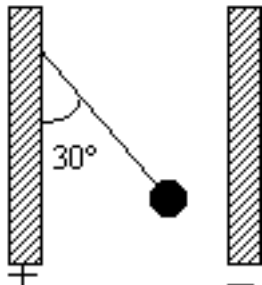
2. Two boys are whispering in the library. The radiated sound power from one boy's mouth is 1.2×10^{-9} W and it spreads out uniformly in all directions. What is the minimum distance the boys must be away from the librarian so that she will not be able to hear them? The threshold of hearing for the librarian is 1.00×10^{-12} W/m².
 - A) 100 m
 - B) 35 m
 - C) 23 m
 - D) 16 m
 - E) 9.8 m

3. A 4.00-m long string, clamped at both ends, vibrates at 2.00×10^2 Hz. If the string resonates in six segments, what is the speed of transverse waves on the string?
- A) 100 m/s
 B) 133 m/s
 C) 267 m/s
 D) 328 m/s
 E) 400 m/s
4. Some of the lowest pitches attainable on a musical instrument are achieved on the world's largest pipe organs. What is the length of an organ pipe that is open on both ends and has a fundamental frequency of 8.75 Hz when the speed of sound in air is 341 m/s?
- A) 9.83 m
 B) 19.5 m
 C) 21.2 m
 D) 29.3 m
 E) 32.4 m
5. Three charges are located along the x axis as shown in the drawing. The mass of the $-1.2 \mu\text{C}$ charge is 4.0×10^{-9} kg. Determine the magnitude and direction of the acceleration of the $-1.2 \mu\text{C}$ charge when it is allowed to move if the other two charges remain fixed.



- A) $2 \times 10^5 \text{ m/s}^2$, to the right
 B) $1 \times 10^5 \text{ m/s}^2$, to the left
 C) $7 \times 10^4 \text{ m/s}^2$, to the right
 D) $3 \times 10^5 \text{ m/s}^2$, to the left
 E) $4 \times 10^6 \text{ m/s}^2$, to the right

6. A small sphere of mass 1.0×10^{-6} kg carries a total charge of 2.0×10^{-8} C. The sphere hangs from a silk thread between two large parallel conducting plates. The excess charge on each plate is equal in magnitude, but opposite in sign. If the thread makes an angle of 30° with the positive plate as shown, what is the magnitude of the charge density on each plate?



- A) 2.5×10^{-9} C/m²
- B) 5.2×10^{-9} C/m²
- C) 1.0×10^{-9} C/m²
- D) 2.1×10^{-8} C/m²
- E) 4.2×10^{-8} C/m²

Use the following to answer question 7:

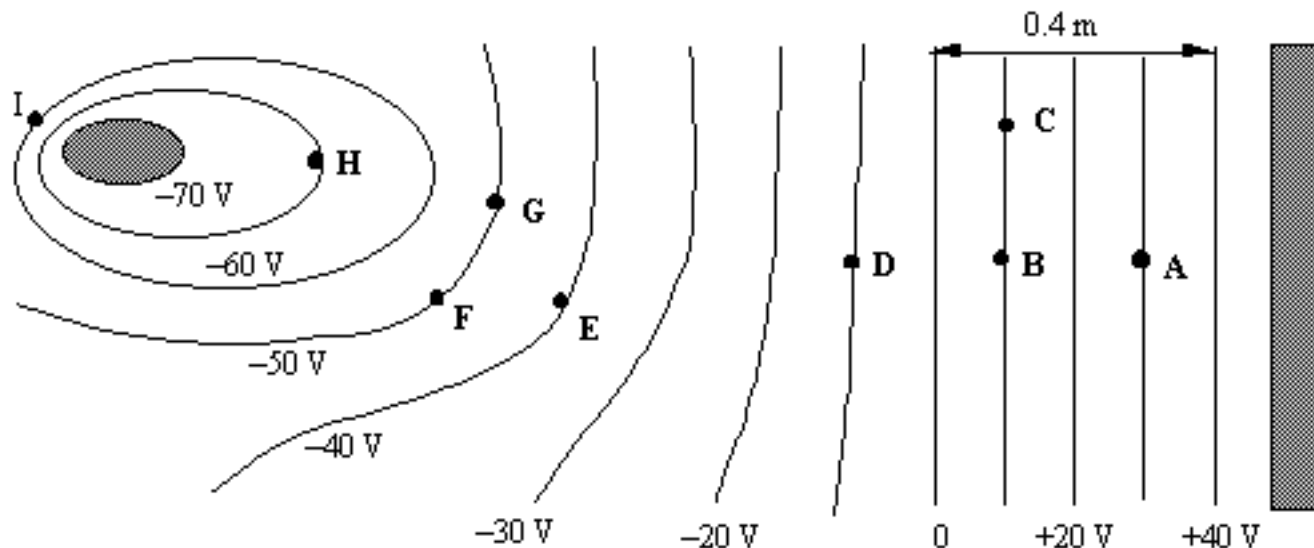
Two point charges are held at the corners of a rectangle as shown in the figure. The lengths of sides of the rectangle are 0.050 m and 0.150 m. Assume that the electric potential is defined to be zero at infinity.



7. What is the potential difference, $V_B - V_A$, between corners **A** and **B**?
- A) -8.4×10^5 V
 - B) -7.8×10^5 V
 - C) -7.2×10^5 V
 - D) -6.0×10^5 V
 - E) zero volts

Use the following to answer question 8:

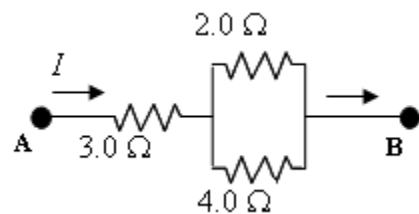
The sketch below shows cross sections of equipotential surfaces between two charged conductors that are shown in solid black. Various points on the equipotential surfaces near the conductors are labeled **A**, **B**, **C**, ..., **I**.



8. How much work is required to move a $-1.0 \mu\text{C}$ charge from **B** to **D** to **C**?
- A) $+2.0 \times 10^{-5} \text{ J}$
 - B) $-2.0 \times 10^{-5} \text{ J}$
 - C) $+4.0 \times 10^{-5} \text{ J}$
 - D) $-4.0 \times 10^{-5} \text{ J}$
 - E) zero joules

Use the following to answer question 9:

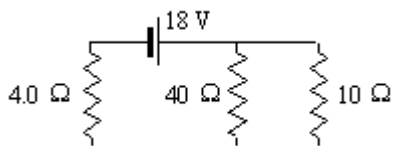
Three resistors are connected as shown in the figure. The potential difference between points **A** and **B** is 26 V.



9. How much current flows through the 3-Ω resistor?

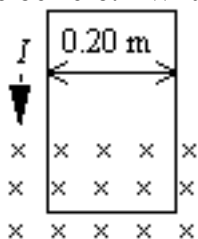
- A) 2.0 A
- B) 4.0 A
- C) 6.0 A
- D) 8.7 A
- E) 10.0 A

10. Determine the power dissipated by the 40-Ω resistor in the circuit shown.



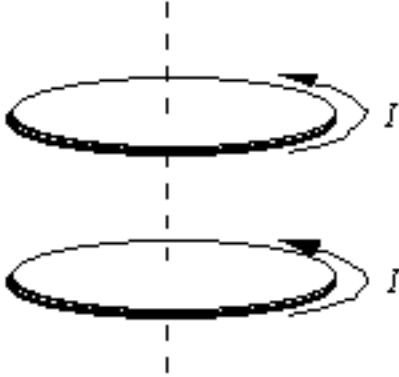
- A) 3.6 W
- B) 4.5 W
- C) 9.0 W
- D) 14 W
- E) 27 W

11. A loop of wire with a weight of 1.47 N is oriented vertically and carries a current $I = 1.75$ A. A segment of the wire passes through a magnetic field directed into the plane of the page as shown. The net force on the wire is measured using a balance and found to be zero. What is the magnitude of the magnetic field?



- A) zero tesla
- B) 0.51 T
- C) 0.84 T
- D) 1.5 T
- E) 4.2 T

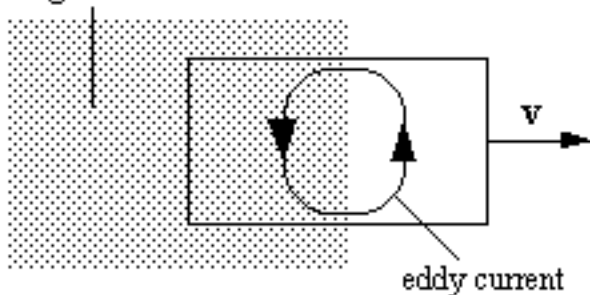
12. Two loops carry equal currents I in the same direction. The loops are held in the positions shown in the figure and are then released. Which one of the following statements correctly describes the subsequent behavior of the loops?



- A) Both loops move to the left.
 B) The loops remain in the positions shown.
 C) The top loop moves to the right; the bottom loop moves to the right.
 D) The loops repel each other.
 E) The loops attract each other.
13. A circular copper loop is placed perpendicular to a uniform magnetic field of 0.50 T. Due to external forces, the area of the loop decreases at a rate of $1.26 \times 10^{-3} \text{ m}^2/\text{s}$. Determine the induced emf in the loop.
- A) $3.1 \times 10^{-4} \text{ V}$
 B) $6.3 \times 10^{-4} \text{ V}$
 C) $1.2 \times 10^{-3} \text{ V}$
 D) $7.9 \times 10^{-3} \text{ V}$
 E) 3.1 V

14. A sheet of copper is pulled at constant velocity v from a region that contains a uniform magnetic field. At the instant shown in the figure, the sheet is partially in and partially out of the field. The induced emf in the sheet leads to the eddy current shown. Which one of the following statements concerning the direction of the magnetic field is true?

Region containing magnetic field



- A) The magnetic field points to the right.
 B) The magnetic field points to the left.
 C) The magnetic field points into the paper.
 D) The magnetic field points out of the paper.
 E) The direction of the magnetic field cannot be determined from the information given.
15. A convex mirror has a radius of curvature of 0.50 m. Where must an object be placed in front of the mirror such that the image is formed 0.15 m behind the mirror?
- A) 0.38 m
 B) 0.19 m
 C) 0.77 m
 D) 0.093 m
 E) 0.57 m

Use the following to answer question 16:

A 3.0-cm object is placed 8.0 cm in front of a mirror. The virtual image is 4.0 cm further from the mirror when the mirror is concave than when it is planar.

16. Determine the image height in the concave mirror.
- A) 0.5
 B) 1.5
 C) 2.0
 D) 3.0
 E) 4.5

17. A light ray is traveling in a diamond ($n = 2.419$). If the ray approaches the diamond-air interface, what is the minimum angle of incidence that will result in all of the light being reflected back into the diamond? The index of refraction for air is 1.000.
- A) 24.42°
 - B) 32.46°
 - C) 54.25°
 - D) 65.58°
 - E) 77.54°

Use the following to answer question 18:

A diverging lens has a focal length of -10 cm. A 3-cm object is placed 25 cm from the lens.

18. What is the magnification of the image?
- A) +0.3
 - B) -0.3
 - C) +0.7
 - D) -0.7
 - E) +0.8
19. A lens that has an index of refraction of 1.61 is coated with a non-reflective coating that has an index of refraction of 1.45. Determine the minimum thickness for the film if it is to be non-reflecting for light of wavelength 5.60×10^2 nm.
- A) 1.93×10^{-7} m
 - B) 3.86×10^{-7} m
 - C) 4.83×10^{-8} m
 - D) 9.66×10^{-8} m
 - E) 8.69×10^{-8} m
20. A meter stick is observed to be only 0.900 meters long to an inertial observer. At what speed, relative to the observer, must the meter stick be moving?
- A) 0.44×10^8 m/s
 - B) 0.57×10^8 m/s
 - C) 0.95×10^8 m/s
 - D) 1.31×10^8 m/s
 - E) 2.70×10^8 m/s

21. The average power output of a nuclear power plant is 5.00×10^2 MW. In one minute, what is the change in the mass of the nuclear fuel due to the energy being taken from the reactor? *Assume 100% efficiency.*
- A) 9.3×10^{-17} kg
 - B) 9.3×10^{-11} kg
 - C) 3.3×10^{-13} kg
 - D) 3.3×10^{-7} kg
 - E) 9.3 kg
22. When ultraviolet photons with a wavelength of 3.45×10^{-7} m are incident on an unknown metal surface in a vacuum, electrons with a maximum kinetic energy of 1.52 eV are emitted from the surface. What is the work function of the metal?
- A) 3.60 eV
 - B) 3.11 eV
 - C) 2.59 eV
 - D) 2.08 eV
 - E) 1.98 eV
23. The speed of a bullet with a mass of 0.050 kg is 420 m/s with an uncertainty of 0.010 %. What is the minimum uncertainty in the bullet's position if it is measured at the same time as the speed is measured?
- A) 2.5×10^{-31} m
 - B) 5.0×10^{-32} m
 - C) 7.5×10^{-33} m
 - D) 2.5×10^{-34} m
 - E) 6.0×10^{-36} m
24. Determine the energy of the photon emitted when the electron in a hydrogen atom undergoes a transition from the $n = 8$ level to the $n = 6$ level.
- A) 0.17 eV
 - B) 0.21 eV
 - C) 0.36 eV
 - D) 0.57 eV
 - E) 13.4 eV

25. Determine the maximum number of electron states with principal quantum number $n = 3$?
- A) 2
 - B) 3
 - C) 6
 - D) 9
 - E) 18
26. How much energy is required to split a ${}^{52}_{24}\text{Cr}$ atom of mass 51.940 509 u into two identical ${}^{26}_{12}\text{Mg}$ atoms? The mass of this isotope of magnesium is 25.982 59 u.
- A) 22.98 MeV
 - B) 14.20 MeV
 - C) 0.0247 MeV
 - D) 0.6936 MeV
 - E) 0.1562 MeV
27. Which particle(s) is(are) emitted when ${}^{40}_{19}\text{K}$ decays into ${}^{40}_{20}\text{Ca}$?
- A) a photon
 - B) a proton
 - C) an alpha particle
 - D) a positron and a neutrino
 - E) an electron and an antineutrino
28. Consider the nuclear decay process: ${}^{90}_{39}\text{Y} \rightarrow {}^{90}_{38}\text{Sr} + ?$ What is(are) the missing product(s)?
- A) a photon
 - B) a proton
 - C) an alpha particle
 - D) a positron and a neutrino
 - E) an electron and an alpha particle

29. Tritium is an isotope of hydrogen that has two neutrons in addition to its proton. Tritium undergoes β^- decay with a half-life of 12.3 years. What percentage of an initially pure sample of tritium will remain undecayed after 35 years?

A) 2.9 %
 B) 6.0 %
 C) 7.0 %
 D) 14 %
 E) 19 %

30. Consider the following nuclear reaction: ${}^4_2\text{He} + {}^{10}_5\text{B} \rightarrow {}^{13}_6\text{C} + X$.

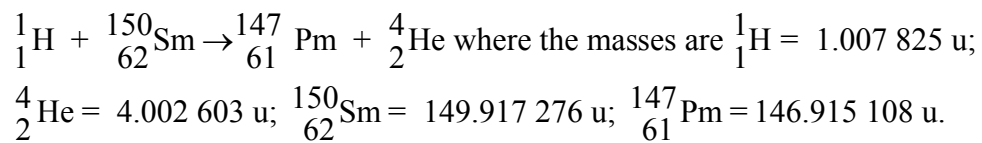
Which one of the following correctly identifies X and represents the reaction?

A) ${}^{10}_5\text{B}(\alpha, \beta^+){}^{13}_6\text{C}$
 B) ${}^{13}_6\text{C}(p, a){}^{10}_5\text{B}$
 C) ${}^{13}_6\text{C}(a, p){}^{10}_5\text{B}$
 D) ${}^{10}_5\text{B}(a, p){}^{13}_6\text{C}$
 E) ${}^{10}_5\text{B}(a, n){}^{13}_6\text{C}$

31. Complete the following nuclear reaction: ${}^4_2\text{He} + {}^{12}_6\text{C} \rightarrow {}^1_0\text{n} + {}^A_Z\text{X} ?$

A) ${}^{16}_8\text{O}$
 B) ${}^{15}_8\text{O}$
 C) ${}^{14}_7\text{N}$
 D) ${}^{14}_9\text{F}$
 E) ${}^{15}_7\text{N}$

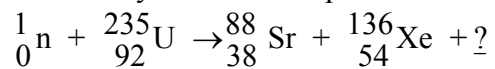
32. Consider the reaction:



How much energy is released in the reaction?

- A) 3.14 MeV
- B) 6.88 MeV
- C) 12.6 MeV
- D) 19.8 MeV
- E) 36.2 MeV

33. How many neutrons are produced in the following reaction:



- A) 11
- B) 12
- C) 22
- D) 24
- E) 48

Answer Key

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