Two point charges, $A$ and $B$, lie along a line separated by a distance $L$. The point $x$ is the midpoint of their separation.

1. Which combination of charges would yield the greatest repulsive force between the charges?
   A) $-2q$ and $-4q$
   B) $+1q$ and $-3q$
   C) $-1q$ and $-4q$
   D) $-2q$ and $+4q$
   E) $+1q$ and $+7q$

A solid, conducting sphere of radius $a$ carries an excess charge of $+6 \mu C$. This sphere is located at the center of a hollow, conducting sphere with an inner radius of $b$ and an outer radius of $c$ as shown. The hollow sphere also carries a total excess charge of $+6 \mu C$.

2. Determine the excess charge on the inner surface of the outer sphere (a distance $b$ from the center of the system).
   A) zero coulombs
   B) $-6 \mu C$
   C) $+6 \mu C$
   D) $+12 \mu C$
   E) $-12 \mu C$
3. Which one of the following statements best explains why it is possible to define an electrostatic potential in a region of space that contains an electrostatic field?
   A) Work must be done to bring two positive charges closer together.
   B) Like charges repel one another and unlike charges attract one another.
   C) A positive charge will gain kinetic energy as it approaches a negative charge.
   D) The work required to bring two charges together is independent of the path taken.
   E) A negative charge will gain kinetic energy as it moves away from another negative charge.

4. Two point charges are arranged along the $x$ axis as shown in the figure. At which of the following values of $x$ is the electric potential equal to zero?
   Note: At infinity, the electric potential is zero.

   A) +0.05 m
   B) +0.29 m
   C) +0.40 m
   D) +0.54 m
   E) +0.71 m

5. Which one of the following circuits has the largest resistance?
6. A 220-Ohm resistor is connected across an ac voltage source $V = (150 \text{ V}) \sin [2\pi (60 \text{ Hz})t]$. What is the average power delivered to this circuit?
   A) 51 W  
   B) 110 W  
   C) 280 W  
   D) 320 W  
   E) 550 W  

Use the following to answer question 7.

The figure shows a simple RC circuit consisting of a 100.0-V battery in series with a 10.0-$\mu$F capacitor and a resistor. Initially, the switch S is open and the capacitor is uncharged. Two seconds after the switch is closed, the voltage across the resistor is 37 V.

7. How much charge is on the capacitor 2.0 s after the switch is closed?
   A) $1.1 \times 10^{-3}$ C  
   B) $2.9 \times 10^{-3}$ C  
   C) $3.7 \times 10^{-4}$ C  
   D) $5.2 \times 10^{-4}$ C  
   E) $6.6 \times 10^{-4}$ C

8. Which one of the following statements best explains why a constant magnetic field can do no work on a moving charged particle?
   A) The magnetic field is conservative.  
   B) The magnetic force is a velocity dependent force.  
   C) The magnetic field is a vector and work is a scalar quantity.  
   D) The magnetic force is always perpendicular to the velocity of the particle.  
   E) The electric field associated with the particle cancels the effect of the magnetic field on the particle.
9. An electron enters a region that contains a magnetic field directed into the page as shown. The velocity vector of the electron makes an angle of 30° with the +y axis. What is the direction of the magnetic force on the electron when it enters the field?

A) up, out of the page  
B) at an angle of 30° below the positive x axis  
C) at an angle of 30° above the positive x axis  
D) at an angle of 60° below the positive x axis  
E) at an angle of 60° above the positive x axis

10. Two long, straight wires are perpendicular to the plane of the paper as shown in the drawing. Each wire carries a current of magnitude \( I \). The currents are directed out of the paper toward you. Which one of the following expressions correctly gives the magnitude of the total magnetic field at the origin of the \( x, y \) coordinate system?

A) \( \frac{\mu_0 I}{2d} \)  
B) \( \frac{\mu_0 I}{\sqrt{2d}} \)  
C) \( \frac{\mu_0 I}{2\pi d} \)  
D) \( \frac{\mu_0 I}{\pi d} \)  
E) \( \frac{\mu_0 I}{\sqrt{2\pi d}} \)
Use the following to answer questions 11-12.
A circuit is pulled with a 16-N force toward the right to maintain a constant speed \( v \). At the instant shown, the loop is partially in and partially out of a uniform magnetic field that is directed into the paper. As the circuit moves, a 6.0-A current flows through a 4.0-\( \Omega \) resistor.

11. Which one of the following statements concerning this situation is true?
   A) The temperature of the circuit remains constant.
   B) The induced current flows clockwise around the circuit.
   C) Since the circuit moves with constant speed, the force \( F \) does zero work.
   D) If the circuit were replaced with a wooden loop, there would be no induced emf.
   E) As the circuit moves through the field, the field does work to produce the current.

12. With what speed does the circuit move?
   A) 1.5 m/s
   B) 3.0 m/s
   C) 6.4 m/s
   D) 9.0 m/s
   E) 12 m/s

Use the following to answer question 13.
The graph shows the voltage across and the current through a single circuit element connected to an ac generator.
13. Identify the circuit element.
   A) The element is a 25-Ohm resistor.
   B) The element is a 35-Ohm resistor.
   C) The element is a 0.45-H inductor.
   D) The element is a 360-µF capacitor.
   E) The element is a 510-µF capacitor.

14. A 7.70-µF capacitor and a 1250-Ohm resistor are connected in series to a generator operating at 50.0 Hz and producing an rms voltage of 208 V. What is the average power dissipated in this circuit?
   A) 346 W
   B) 31.2 W
   C) 19.7 W
   D) 1.66 W
   E) zero watts

15. Electromagnetic waves are radiated uniformly in all directions from a source. The rms electric field of the waves is measured 35 km from the source to have an rms value of 0.42 N/C. Determine the average total power radiated by the source.
   A) 4.1 \times 10^5 W
   B) 8.3 \times 10^5 W
   C) 3.0 \times 10^6 W
   D) 7.2 \times 10^6 W
   E) 1.7 \times 10^7 W

16. A concave mirror in an amusement park has a radius of curvature of 4.0 m. A child stands in front of the mirror so that she appears 2.5 times taller than her actual height. If the image is upright, how far is she standing from the mirror?
   A) 1.2 m
   B) 3.5 m
   C) 2.8 m
   D) 4.0 m
   E) 7.0 m

17. Which one of the following statements concerning a virtual image produced by a mirror is true?
   A) A virtual image is always larger than the object.
   B) A virtual image is always smaller than the object.
   C) A virtual image is always upright relative to the object.
   D) A virtual image is always inverted relative to the object.
   E) A virtual image can be photographed or projected onto a screen.
18. A beam of light passes from air into water. Which is necessarily true?
   A) The frequency is unchanged and the wavelength increases.
   B) The frequency is unchanged and the wavelength decreases.
   C) The wavelength is unchanged and the frequency decreases.
   D) Both the wavelength and frequency increase.
   E) Both the wavelength and frequency decrease.

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 $5.60 \times 10^2$ nm.
   A) $1.93 \times 10^{-7}$ m
   B) $3.86 \times 10^{-7}$ m
   C) $4.83 \times 10^{-8}$ m
   D) $9.66 \times 10^{-8}$ m
   E) $8.69 \times 10^{-8}$ m

20. Light of wavelength 600 nm is incident upon a single slit with width $4 \times 10^{-4}$ m. The figure shows the pattern observed on a screen positioned 2 m from the slits.

   ![Diagram of diffraction pattern](image)

   Determine the distance $s$.
   A) 0.002 m
   B) 0.003 m
   C) 0.004 m
   D) 0.006 m
   E) 0.008 m
21. A photon has a collision with a stationary electron \((h/mc = 2.43 \times 10^{-12} \text{ m})\) and loses 5.0\% of its energy. The photon scattering angle is 180°. What is the wavelength of the incident photon in this scattering process?

A) \(2.4 \times 10^{-12} \text{ m}\)  
B) \(4.6 \times 10^{-11} \text{ m}\)  
C) \(9.2 \times 10^{-11} \text{ m}\)  
D) \(1.9 \times 10^{-10} \text{ m}\)  
E) \(3.1 \times 10^{-12} \text{ m}\)

22. What is the de Broglie wavelength of an electron \((m = 9.11 \times 10^{-31} \text{ kg})\) in a \(5.0 \times 10^{3}\)-volt X-ray tube?

A) 0.007 nm  
B) 0.014 nm  
C) 0.017 nm  
D) 0.028 nm  
E) 0.034 nm

23. Complete the following statement: For the ground state of the hydrogen atom, the Bohr model correctly predicts

A) only the energy.  
B) only the angular momentum.  
C) only the angular momentum and the spin.  
D) the angular momentum and the energy.  
E) the energy, the angular momentum, and the spin.

24. Determine the maximum wavelength of incident radiation that can be used to remove the remaining electron from a singly ionized helium atom He⁺ \((Z = 2)\). Assume the electron is in its ground state.

A) 6.2 nm  
B) 12.4 nm  
C) 22.8 nm  
D) 45.6 nm  
E) 54.4 nm
25. Which one of the following sets of quantum numbers is not possible?

<table>
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<tr>
<td>B)</td>
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<td>E)</td>
<td>5</td>
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Use the following to answer question 26.

Consider the following nuclear decay: \( ^{236}_{92}U \rightarrow ^{232}_{90}Th + X \)

26. What is X?
   A) \( \alpha \)
   B) p
   C) ?^+
   D) ?^-
   E) n
27. This question refers to the figure shown. Which one of the following concepts explains why heavy nuclei do not follow the $N = Z$ line (or trend) in the figure?

![Diagram showing N=Z line]

A) transmutation
B) Coulomb repulsion
C) particle-wave duality
D) Pauli exclusion principle
E) Heisenberg uncertainty principle

28. What is the mass defect of $^{120}_{50}$Sn (atomic mass = 119.902 200 u)? The hydrogen atom has a mass of 1.007 83 u; and the neutron has a mass of 1.008 67 u.

A) $6.9175 \times 10^{-28}$ kg
B) $8.0024 \times 10^{-28}$ kg
C) $2.2391 \times 10^{-27}$ kg
D) $1.0687 \times 10^{-27}$ kg
E) $1.8202 \times 10^{-27}$ kg

29. A radiologist absorbs $3.6 \times 10^{-5}$ J of radiation. Determine the absorbed dose if his mass is 70.0 kg.

A) $1.9 \times 10^{-7}$ Gy
B) $2.3 \times 10^{-7}$ Gy
C) $2.6 \times 10^{-7}$ Gy
D) $3.6 \times 10^{-7}$ Gy
E) $5.1 \times 10^{-7}$ Gy
30. What is the importance of thermal neutrons in nuclear processes?
   A) Thermal neutron capture results in uranium fission.
   B) Thermal neutrons are released in radioactive decay.
   C) Thermal neutrons are necessary in the fusion of deuterium.
   D) Thermal neutrons are commonly released in fusion reactions.
   E) Thermal neutrons are sources of gamma rays.

31. How many neutrons are produced in the reaction: \( \frac{1}{0}n + \frac{235}{92} U \rightarrow \frac{144}{56} Ba + \frac{89}{36} Kr + 2 \frac{1}{0}n \)?
   A) 1
   B) 2
   C) 3
   D) 4
   E) 5

32. Of the reactions listed below, which \textit{will not} proceed via the strong interaction?
   \begin{align*}
   (a) & \quad n + p \rightarrow e^- + \bar{\nu}_e & \quad \text{(d)} & \quad \pi^- + p \rightarrow n + \gamma \\
   (b) & \quad p + p \rightarrow \Sigma^+ + \bar{\Sigma}^+ & \quad \text{(e)} & \quad \bar{K}^- + p \rightarrow \bar{K}^+ + \bar{\Xi}^-
   (c) & \quad \pi^- + p \rightarrow \Sigma^0 + \bar{\Sigma}^0
   \end{align*}