YOUR TEST NUMBER IS THE 5-DIGIT NUMBER AT THE TOP OF EACH PAGE.

1. An electron is moving at $3.6 \times 10^6$ m/s perpendicular to a uniform magnetic field. If the radius of the motion is 18 mm, what is the magnitude of the magnetic field?

   (1) 1.14 mT  
   (2) 70 mT  
   (3) 9.3 mT  
   (4) 1.6 $\mu$T  
   (5) 8.9 nT

2. A proton cyclotron has a magnetic field of 0.20 T between its poles and a radius of 0.40 m. What is the maximum energy for the protons from this machine?

   (1) $4.9 \times 10^{-14}$ J  
   (2) $3.2 \times 10^{-13}$ J  
   (3) $4.9 \times 10^{-13}$ J  
   (4) $3.2 \times 10^{-14}$ J  
   (5) $1.6 \times 10^{-13}$ J

3. In a velocity selector for ions, when the velocity of the ions is double the value for which the selector is set, how do the magnetic force $F_M$ and the electric force $F_E$ compare?

   (1) $F_M = 2F_E$  
   (2) $F_M = 4F_E$  
   (3) $F_M = F_E/2$  
   (4) $F_M = F_E/4$  
   (5) $F_M = 1.414F_E$

4. A 3.0 cm section of a horizontal wire carrying a 6.7 A current from east to west is placed in a north to south 0.42 T magnetic field in the lab. What is the magnitude and the direction of the force on the 3.0 cm section of the wire? (In a 3-d world, north and up are not the same.)

   (1) 0.084 N, Up  
   (2) 0.17 N, Down  
   (3) 0.25 N, Up  
   (4) 0.0017 N, Down  
   (5) 0.0025 N, Up

5. One wire, lying on the x-axis, carries a current of 8.0 A in the positive x-direction. Another wire, lying on the y-axis, carries a current of 12 A in the positive y-direction. What is the magnitude of the magnetic field at (x, y) = (8.0 cm, 12.0 cm)?

   (1) $1.7 \times 10^{-5}$ T  
   (2) $3.0 \times 10^{-5}$ T  
   (3) $1.3 \times 10^{-5}$ T  
   (4) $4.3 \times 10^{-5}$ T  
   (5) $4.0 \times 10^{-10}$ T

6. A 0.40 H inductor has a current that rises from zero to 3.0 A in 6.0 s. What is the average power required to accomplish this?

   (1) 0.30 W  
   (2) 9.0 W  
   (3) 1.5 W  
   (4) 0.60 W  
   (5) 15 W
7. The remnants of a red giant star form a ring around a black hole of mass \( M = 2 \times 10^{32} \text{kg} \), just like the rings of rock and ice around Saturn. Our home planet lies in the plane of rotation of the ring; the material on one side moves towards us, the material on the other side moves away from us. The diameter of the ring is \( D = 2.4 \times 10^{13} \text{m} \). The Hubble space telescope observes the emission from hydrogen atoms inside the ring. Hydrogen atoms at rest emit light at 410 nm. What is the frequency difference (in \(10^{9}\text{Hz}=\text{GHz}\)) between the light emitted by Hydrogen atoms flying away from us and the light emitted by Hydrogen atoms flying towards us in the ring? Assume that the relative velocity between the black hole and earth can be neglected. Hint: Recall that the gravitational force between two masses is \( F_G = \frac{Gm_1m_2}{r^2} \).

(1) 163 (2) 282 (3) 230 (4) 203 (5) 247

8. A conducting bar can slide with no friction along two conducting rails separated by distance \( L = 1.2 \text{ m} \). The rails are interconnected via a resistor \( R = 6\Omega \). A uniform 2.5 Tesla magnetic field points into the page, as indicated by crosses. At what speed should the bar be moved to produce a power dissipation of 1.5 W in the resistor?

(1) 1.0 m/s (2) 2.0 m/s (3) 3.0 m/s (4) 1.5 m/s (5) 2.5 m/s

9. 9.3 ms after switch \( S \) is closed in the circuit shown, the current through the resistor \( R = 5.2\Omega \) reaches 0.87 A. The emf of the battery is 9.0 V. What is the inductance \( L \) of the coil [in H], whose resistance is negligible?

(1) 6.9 \times 10^{-2} (2) 3.5 \times 10^{-2} (3) 1.9 \times 10^{-2} (4) 9.7 \times 10^{-3} (5) 4.8 \times 10^{-3}

10. One hundred turns of insulated copper wire are wrapped around an iron core of cross-sectional area 0.100m\(^2\). The circuit is completed by connecting the coil to a 10Ω resistor. As the magnetic field along the coil axis changes from 1.00T in one direction to 1.00T in the other direction, the total charge that flows through the resistor is:

(1) 2C (2) 10mC (3) 20mC (4) 1C (5) 0.20C

11. From her police car running at 70 mi/h, officer K sends a radar signal of a 28.5 mm wavelength to an SUV in front of her. The frequency of the signal, as measured on the SUV, is found to be lower by 94 Hz than the original. What is the speed of the SUV [in mi/h]?

(1) 76 (2) 82 (3) 70 (4) 64 (5) 58

12. People with pacemakers are warned to stay away from magnetic fields stronger than 5 gauss (\( 5 \times 10^{-4} \text{T} \)). If a bolt of lightning can reach a current of approximately 25,000 A for a short time, what is the minimum distance that a person wearing a pacemaker can be from the lightning bolt to stay within the B field safety threshold? (Ignore the fact that the magnetic field from a lightning bolt is the least of his concerns.)

(1) 10 m (2) 20 m (3) 30 m (4) 40 m (5) 250 m

13. A linearly polarized beam of light (vertically polarized) is incident upon a group of three polarizing sheets which are arranged so that the transmission axis of each sheet is rotated by \( \theta = 45^\circ \) with respect to the preceding sheet starting from the vertical polarizer as shown in the figure. What fraction of the incident intensity is transmitted?

(1) 0.25 (2) 0.13 (3) 0.38 (4) 0.75 (5) 0
14. If light has a wavelength of 600 nm in a vacuum, what is its wavelength in a material with an index of refraction of 1.50?

(1) 400 nm  (2) 900 nm  (3) 600 nm  (4) $1.35 \times 10^3$ nm  (5) 267 nm

15. What is the intensity of the electromagnetic radiation at a distance of 2.00 m from a 100 W isotropic source?

(1) 1.99 W/m$^2$  (2) 6.25 W/m$^2$  (3) 4.00 W/m$^2$  (4) 25.0 W/m$^2$  (5) 1.00 W/m$^2$