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

DIRECTIONS
(1) Code your test number on your answer sheet (use 76–80 for the 5-digit number). Code your name on your answer sheet. DARKEN CIRCLES COMPLETELY. Code your student number on your answer sheet.
(2) Print your name on this sheet and sign it also.
(3) Do all scratch work anywhere on this exam that you like. At the end of the test, this exam printout is to be turned in.
(4) Blacken the circle of your intended answer completely, using a #2 pencil or blue or black ink. Do not make any stray marks or the answer sheet may not read properly.
(5) The answers are rounded off. Choose the closest to exact. There is no penalty for guessing.

>>>►►►► WHEN YOU FINISH <<<<<<<<<<<
Hand in the answer sheet separately.

Constants: \( e = 1.6 \times 10^{-19} \text{ C} \) \( m_p = 1.67 \times 10^{-27} \text{ kg} \) \( m_e = 9.1 \times 10^{-31} \text{ kg} \) \( c = 3 \times 10^8 \text{ m/s} \) micro = \( 10^{-6} \) \( \epsilon_o = 8.85 \times 10^{-12} \text{ C}^2/\text{N} \cdot \text{m}^2 \) \( k = 1/(4\pi\epsilon_o) = 9 \times 10^9 \text{ N} \cdot \text{m}^2/\text{C}^2 \) \( \mu_o = 4\pi \times 10^{-7} \text{ T} \cdot \text{m/A} \) nano = \( 10^{-9} \)

Coulomb’s Law: \( \vec{F} = \frac{|q_1| |q_2|}{4\pi\epsilon_o r^2} \) (point charge)

Electric field: \( \vec{E} = \frac{\vec{F}}{q} \) \( \vec{E} = \frac{q}{4\pi\epsilon_o r^2 \hat{r}} \) (point charge) \( \vec{E} = \int \frac{dq}{4\pi\epsilon_o r^2 \hat{r}} \) (general) \( E = \frac{\sigma}{2\epsilon_o} \) (plane)

Gauss’ law: \( \Phi = \hat{n} \cdot \vec{E} \cdot dA = \frac{q_{enc}}{\epsilon_o} \)

Energy: \( W = \int \vec{F} \cdot d\vec{s} = \frac{1}{2}mv_f^2 - \frac{1}{2}mv_i^2 = K_f - K_i \)

For conservative forces \( U_f - U_i = -\int \vec{F} \cdot d\vec{s} \rightarrow K_i + U_i = K_f + U_f \)

Electric potential: \( V = \frac{U}{q} \) \( V = \frac{q}{4\pi\epsilon_o r} \) (point charge) \( V = \int \frac{dq}{4\pi\epsilon_o r} \) (general)

\( V_b - V_a = -\int_a^b E_x dx = -\int_a^b \vec{E} \cdot d\vec{s} \) \( E_x = -\frac{\partial V}{\partial x} \) \( E_y = -\frac{\partial V}{\partial y} \) \( E_z = -\frac{\partial V}{\partial z} \)

Capacitors: \( q = CV \) \( C = \frac{K\epsilon_o A}{d} \) (parallel-plate) \( C = C_1 + C_2 \) (parallel)

\( U = \frac{q^2}{2C} \) \( u = \frac{1}{2} \epsilon_o E^2 \) \( \frac{1}{C} = \frac{1}{C_1} + \frac{1}{C_2} \) (series)

Resistors: \( i = \frac{dq}{dt} = jA \) \( R = \frac{V}{i} \) \( R = \frac{\rho L}{A} \) (wire) \( P = iV \) \( R = R_1 + R_2 \) (series)

\( q = CV(1 - e^{-t/RC}) \) (charging) \( q = q_0 e^{-t/RC} \) (discharging) \( \frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2} \) (parallel)

Magnetism: \( \vec{F} = q\vec{v} \times \vec{B} \) \( \vec{F} = i\vec{L} \times \vec{B} \) \( \mu = NiA \) \( \tau = \vec{\mu} \times \vec{B} \) \( U = -\vec{\mu} \cdot \vec{B} \)

\( d\vec{B} = \frac{\mu_o}{4\pi} \frac{d\vec{s} \times \hat{r}}{r^2} \) \( \oint \vec{B} \cdot d\vec{s} = \mu_o i_{enc} \) \( B = \frac{\mu_o i}{2\pi R} \) (wire) \( \frac{\mu_o i}{2R} \) (loop center) \( \frac{\mu_o i N}{L} \) (solenoid)
1. A satellite telescope orbiting the earth can resolve objects that are 1.1 m apart (Raleigh criterion) from a height of 400 km using 550 nm light. What is the approximate minimum diameter of the telescope?

   (1) 3.5 m  (2) 2.5 m  (3) 6.9 m  (4) 0.85 m  (5) 0.24 m

2. In the Figure 12.0 V is applied to the network of capacitors where the capacitance values are in µF. The charge on the positive plate of the upper 10µF capacitor (in µC) is:

   (1) 52.4  (2) 37.5  (3) 40.5  (4) 9.2  (5) 27.8

3. In a sinusoidally driven series RLC circuit the current lags the applied emf. The power dissipated in the resistor can be increased by:

   (1) decreasing the amplitude of the driving emf (making no other changes)
   (2) increasing the capacitance (making no other changes)
   (3) increasing the driving frequency (making no other changes)
   (4) decreasing the inductance (making no other changes)
   (5) increasing the inductance (making no other changes)
4. The magnetic flux exiting the circular bottom face of a right circular cylinder is $23.4 \text{ T} \cdot \text{m}^2$ and the magnetic flux entering the sidewall of the cylinder is $63.9 \text{ T} \cdot \text{m}^2$. The magnetic flux on the top face must be

1. $87.4 \text{ T} \cdot \text{m}^2$, exiting
2. $40.5 \text{ T} \cdot \text{m}^2$, entering
3. $2.73 \text{ T} \cdot \text{m}^2$, exiting
4. $87.4 \text{ T} \cdot \text{m}^2$, entering
5. $40.5 \text{ T} \cdot \text{m}^2$, exiting

5. A beam of light polarized along the $y$ axis and moving along the $+z$ axis passes through two polarized sheets with axes of polarization oriented $30^\circ$ and $70^\circ$ relative to the $y$ axis. The final intensity of the beam is measured to be $61 \text{ W/m}^2$. What is the initial beam intensity?

1. $139 \text{ W/m}^2$
2. $92 \text{ W/m}^2$
3. $27 \text{ W/m}^2$
4. $695 \text{ W/m}^2$
5. $195 \text{ W/m}^2$

6. Two isotropic point sources emit identical radio waves in phase at wavelength $\lambda$. The sources are separated by a distance $d$ on the $x$–axis, and a receiver moves around on a circle of large radius centered on the midpoint between them. It detects 14 points of zero intensity, including two on the $x$–axis, one to the left of the sources and one to the right. What is $d$?

1. $3 \lambda$
2. $3.5 \lambda$
3. $14 \lambda$
4. $28 \lambda$
5. $7 \lambda$

7. Parallel rays sent along the central axis of diverging lens are extrapolated to converge 15 cm from the lens. An object placed 20 cm from the lens can only appear:

1. On the opposite side from the object, 8.6 cm from the lens
2. On the opposite side from the object, 51.4 cm from the lens
3. On the opposite side from the object, 60 cm from the lens
4. On the same side as the object, 8.6 cm from the lens
5. On the same side as the object, 60 cm from the lens

8. Costume jewelry beads are made of glass with index of refraction 1.55. To make them more reflective, they are coated with a layer of material with index of refraction 1.90. What is the minimum coating thickness needed to ensure that light of wavelength 540 nm and perpendicular incidence will be reflected with maximum constructive interference?

1. 142 nm
2. 213 nm
3. 87 nm
4. 71 nm
5. 174 nm

9. In the figure the magnetic flux through the loop changes according to the relation $\Phi_B = 60 - 36t - 3t^2 + t^3$, where $\Phi_B$ is in milliwebers and $t$ is in seconds. What is the magnitude of the emf (in millivolts) induced in the loop when $t = 1 \text{ s}$ and the direction of the induced current? (cw = clockwise, ccw = counterclockwise)

1. 33, cw
2. 39, cw
3. 30, cw
4. 39, ccw
5. 30, ccw

10. An object is reflected in a concave spherical mirror. The object distance $p$ is less than the focal length $f$ ($p < f$). The image can be (the correct answer contains only true statements from the following list of possibilities):

A) real, B) virtual, C) upright, D) inverted, E) larger, F) smaller

1. B, D, E
2. B, D, F
4. A, D, E
5. A, C, E
11. At time \( t = 0 \) an ideal 12.00 V power supply is connected to an uncharged series RC circuit in which the resistor is 120\( \Omega \) and the capacitor is 47.0 pF. The charge accumulated on the positive plate of the capacitor at a time \( t = 10RC \) is closest to,

(1) 5.64 nC  (2) 2.82 nC  (3) 282 pC  (4) 564 pC  (5) 28.2 nC

12. The resistor network in the diagram has 8V across its end terminals labeled A and B. The current through, and voltage drop across, the 6k\( \Omega \) resistor are, respectively:

(1) 3 mA, 6V  (2) 3mA, 2V  (3) 6mA, 1V  (4) 1mA, 6V  (5) 2mA, 3V

13. A 1.0\( \mu \)m-wide slit is illuminated by light of wavelength 530 nm. Consider a point on a viewing screen that is 9° from the center of the central maximum. What is the phase difference between the waves arriving from the top of the slit to the waves coming from the bottom?

(1) 180°  (2) 135°  (3) 90°  (4) 106°  (5) 45°

14. A proton traveling along the x axis (toward increasing x) has a speed of \( 1.0 \times 10^5 \) m/s. At time \( t = 0 \) it enters a region of space in which there is an electric field of 100.0 N/C \( \hat{j} \). At a time \( t = 14 \mu s \) later the proton’s velocity makes an angle with respect to the +x axis that is:

(1) \(-36°\)  (2) \(-53°\)  (3) \(+36°\)  (4) \(+53°\)  (5) much less than 1°

15. A double slit arrangement produces interference fringes for 465 nm laser light that are 2.2 mm apart on a screen located 5.0 m from the slits. What is the separation of the slits?

(1) 0.26 mm  (2) 2.5 mm  (3) 5.8 mm  (4) 1.06 mm  (5) 0.12 mm

16. Three wires are equally spaced along a line (perpendicular to the page) as shown in the Figure. Wires A and B each carry current \( i \) into the page. When wire C carries no current, wire B experiences a force \( F \). With no other currents changed, in order for wire B to experience a force \( 4F \) in the same direction as the original \( F \), the current in wire C must be set equal to

(1) 3\( i \), out  (2) \( i/2 \), out  (3) 4\( i \), in  (4) 3\( i \), in  (5) 4\( i \), out

17. Two rectangular glass plates with \( n = 1.65 \) (see Figure) of length 4.0 cm are in contact along the left edge and are separated by 0.1 mm at the right edge. The air between the plates acts as a thin film. If light of 540 nm is incident normally from above, what is the distance between fringes as seen from above?

(1) 0.176 mm  (2) 0.131 mm  (3) 0.108 mm  (4) 0.216 mm  (5) 0.065 mm

18. The two lenses in the Figure (not to scale) are identical, converging lenses of 15 cm focal lengths. A 2.0 cm tall object is 30 cm away from lens 1. Lens 2 is 50 cm from lens 1. How tall is the image of the object appearing to the right of lens 2?

(1) 0.67 cm  (2) 6.0 cm  (3) 3.0 cm  (4) 4.0 cm  (5) 2.0 cm
19. An electron moves at a speed of $v = 3 \times 10^7$ m/s parallel to and a distance $d = 20$ cm from a conducting wire carrying a current of $I = 40$ A. If the directions of the electron and current are as shown in the figure, what is the magnitude (in N) and direction of the force experienced by the electron?

(1) $3.1 \times 10^{-17}$ toward the wire
(2) $9.1 \times 10^{-17}$ away from the wire
(3) $1.3 \times 10^{-16}$ toward the wire
(4) $1.9 \times 10^{-16}$ toward the wire
(5) $3.8 \times 10^{-16}$ away from the wire

20. A 2.0 cm tall object sits 30 cm from a concave spherical mirror along its central axis. The mirror has a radius of curvature of 25 cm. The magnification of the object is

(1) $-0.71$  (2) $-1.2$  (3) $+0.71$  (4) $+1.2$  (5) $-0.83$