PHYS1220 Final Exam **December 12, 2016**

Multiple choice. Please select only one answer.

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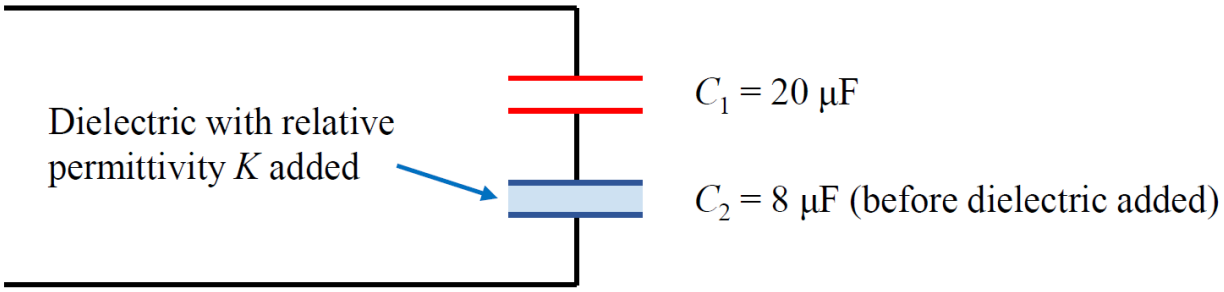
1. We are trying to determine the resistance, *R*, of a rectangular bar of length, *L*, by carefully measuring resistivity, ρ. The cross-sectional area is defined by a width, *a*, and height, *b*. If the error in ρ and *L* are both 3% and *a* and *b* are both 2%, what is the estimated error in *R*?

A) 4% B) 5% C) 6% D) 8% E) 10% F) 12%

2. We have two capacitors in series with initial capacitances $C_1 = 20$ μF and $C_2 = 8$ μF. An unknown dielectric material with a relative permittivity of *K* (where $\epsilon = K\epsilon_0$) is slid between the plates in the second capacitor (see figure). The measured effective capacitance of the entire system is now $\frac{40}{3}$ μF. What is the value of *K*?



A) 2 B) 4 C) 5 D) 10 E) 50

3. A non-conducting sphere of radius *R* has a charge density of $\rho(r) = C_0 + C_1 r$, where *r* is the radial distance from the center of the sphere and C_0 and C_1 are constants. What is the form of the electric field inside the sphere ($r \leq R$)?

A) $\frac{1}{\epsilon_0}\left[C_0 r + \frac{C_1 r^2}{2}\right]$ B) $\frac{1}{3\epsilon_0}[C_0 r^3 + C_1 r^4]$ C) $\frac{1}{4\epsilon_0 r^2}[C_0 + C_1 r]$

D) $\frac{1}{\epsilon_0}\left[\frac{C_0 r}{3} + \frac{C_1 r^2}{4}\right]$ E) $\frac{1}{3\epsilon_0}[C_0 r + C_1 r^2]$

4. Just like an atomic gas, electrons in a metal can be (approximately) modelled as an ideal gas. If an electron has a kinetic energy of $1.6*10^{-18}$ J, what is its velocity?

A) $3.4*10^{-5}$ m/s B) $5.2*10^{3}$ m/s C) $8.5*10^{4}$ m/s D) $1.9*10^{6}$ m/s E) $4.5*10^{7}$ m/s

5. We have two ideal gases, one with an average atomic mass of m_1 and the other with an average atomic mass of m_2. If both are at the same temperature, the ratio of gas 1's kinetic energy to gas 2's kinetic energy is:

A) $\frac{1}{10}$ B) $\frac{1}{\sqrt{10}}$ C) 1 D) $\sqrt{10}$ E) 10

6. Although often overshadowed by other effects, nearly all materials have this type of magnetism:

A) Diamagnetism B) Paramagnetism C) Ferromagnetism
D) Flux expulsion E) Superconductivity

7. We have a conducting sphere with a surface charge density of 10 $\mu C/cm^2$ and a radius of 2 cm. We put an electron right at the center of the sphere. How much work is done by the field to move the electron from the center to the surface of the sphere?

A) 0 J B) $3.2*10^{-21}$ J C) $4.5*10^{5}$ J D) $2.3*10^{8}$ J E) $8.2*10^{10}$ J

8. Water has a dipole moment magnitude of $6.2*10^{-30}$ C-m. If we have an electric field, from a laser for example, of $5*10^{3}$ V/cm, what is the *maximum* potential energy change possible in one water molecule?
A) 0 J B) $3.1*10^{-26}$ J C) $6.2*10^{-26}$ J D) $3.1*10^{-24}$ J E) $6.2*10^{-24}$ J

9. We have a steel wall that has an area of 50 m^2 sandwiched between two concrete walls, all initially at 20°C. The steel wall has hot water tubes going through it, which raise the steel wall temperature to 25°C. If the coefficient of linear expansion of the steel is $1.2*10^{-5}$ K^{-1} and the Young's modulus, *Y*, is 200 GPa, what is the force exerted on one of the concrete walls?

A) $1.2*10^{10}$ N B) $6.0*10^{11}$ N C) $3.7*10^{9}$ N D) $9.1*10^{11}$ N E) $3.4*10^{12}$ N

10. An ideal gas is at a pressure $2.8*10^{5}$ N/m^2 and occupies a volume 2.00 m^3. If the gas is compressed to a volume 0.50 m^3 while the temperature remains constant, what will be the new pressure in the gas?

A) The answer depends on the mass of the gas particles.
B) $7.0*10^{4}$ N/m^2
C) The answer depends on the temperature and the mass of the gas particles.
D) $1.1*10^{6}$ N/m^2
E) $6.5*10^{6}$ N/m^2

11. If we use 112 W of power to heat 194 g of water, how long will it take to raise the temperature of the water from 15°C to 30°C? The specific heat of water is 4190 J/kg-K.

A) 83 s B) 109 s C) 11 s D) 1070 s E) 22 s

12. A proton (mass = $1.67*10^{-27}$ kg) moving at 10^{3} m/s in the +*x* direction enters a uniform magnetic field of 1 T magnetic field in the +*y* direction. The magnetic force moves the proton 1 cm in the +*z* direction before hitting a wall. How much work is done on the proton?
A) 0 J B) $1.6*10^{-18}$ J C) $9.6*10^{8}$ J D) $-1.6*10^{-18}$ J

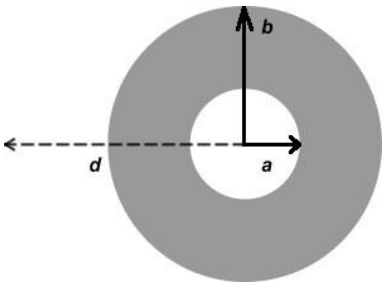
13. The compression stroke in an engine undergoes adiabatic ($Q = 0$) compression. Let's assume that the cylinder contains a diatomic gas (like N_2 or O_2) that is initially at a pressure of $1.0*10^{5}$ Pa. We can model the *PV* curve of a diatomic gas as P^5V^7 = constant. If the initial volume of $2*10^{-3}$ m^3 is compressed by a factor of 10, then how much work is done by the gas?

A) $-7.8*10^{9}$ J B) $8.4*10^{4}$ J C) $-5.8*10^{7}$ J D) $2.3*10^{7}$ J E) $9.2*10^{2}$ J

14. Calculate the current through a 5.0-m long 22 gauge (having radius 0.321 mm) copper wire if it is connected to a 9.0-V battery. The resistivity of copper is $1.68*10^{-8}$ Ω • m.

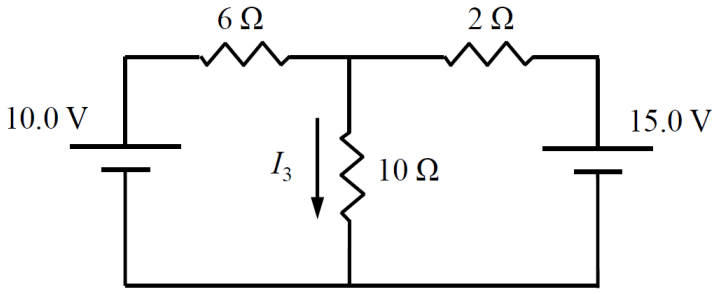
A) 376 mA B) 17.3 A C) 202 A D) 134 A E) 34.7 A

15. The figure shows the cross-section of a hollow cylinder of inner radius a = 2.0 cm and outer radius b = 5.0 cm. A uniform current density of 5.0 A/cm^2 flows through the cylinder parallel to its axis. Calculate the magnitude of the magnetic field at a distance of d = 8.0 cm from the axis of the cylinder.

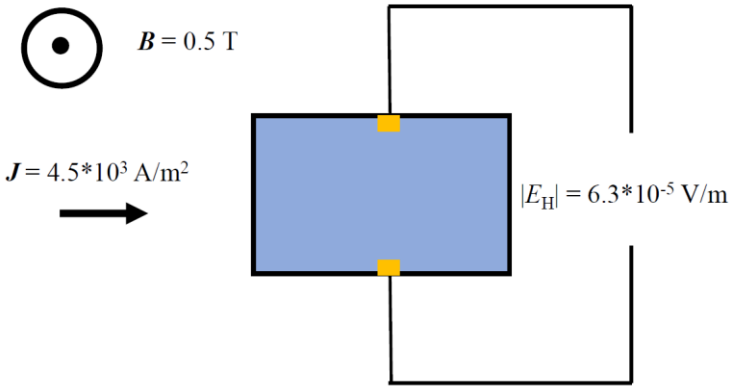


A) 0.0 T
B) 1.6*10^{-4}T
C) 1.0*10^{-3} T
D) 1.3*10^{2} T
E) 16 T

16. For the circuit below, what is I_3?
A) -2.3 A B) -1.2 A C) -0.25 A D) 0.25 A E) 1.2 A F) 3.1 A



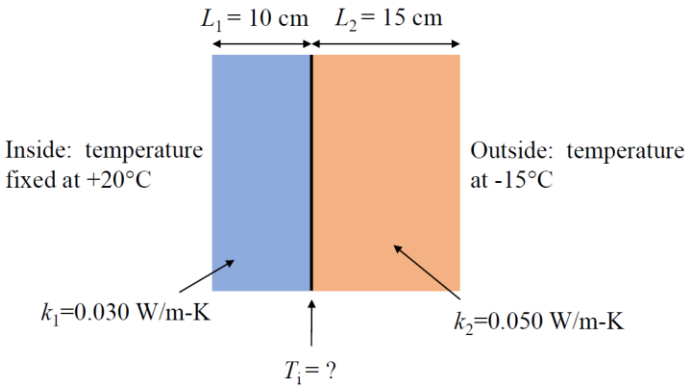
17. We have a Hall bar on an unknown material pictured below. We are sourcing 4.5*10^3 A/cm^2 in the +x-direction in a uniform magnetic field of 0.5 T in the +z-direction. If the magnitude of the electric field between A and B is measured to be 6.3*10^{-5} V/m, what is the carrier concentration of the material, n?



A) 1.5*10^{28} m^{-3} B) 2.2*10^{26} m^{-3} C) 8.3*10^{20} m^{-3}

D) 6.5*10^{25} m^{-3} E) 3.8*10^{30} m^{-3}

18. We have a 25 cm thick wall made of two materials with different thermal conductivities, as shown in the figure below. If the outside temperature is -15°C and the inside temperature is 20°C, what is the steady-state temperature, T_i, where the two materials meet?



A) -5°C B) 0°C C) 1.6°C D) 4°C E) 15°C

19. A closed loop conductor that forms a circle with a radius of 0.5 m is located in a uniform but changing magnetic field. If the maximum emf induced in the loop is -100.0 V, what is the maximum rate at which the magnetic field strength is changing if the magnetic field is oriented perpendicular to the plane in which the loop lies?

A) 400 T/s B) 4000 T/s C) 0.054 T/s D) 127 T/s E) 13 T/s

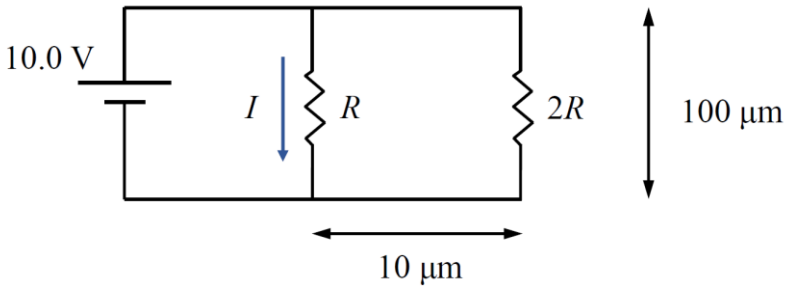
20. A capacitor, with an initial electric field at 10^6 V/m, completely discharges in 2 ps. If the radius of this capacitor is 1 cm, what is the measured magnetic field between the plates at a radius of 1 cm?

A) 2.8 T B) 0.028 T C) 56 T D) $8.7*10^3$ T E) $6.7*10^{-5}$ T

21. A lightning bolt can have up to 300 kA of current flowing during a strike. What is the magnetic field a radial distance of 0.5 m away from the (very long) lightning bolt?

A) $3.5*10^{-3}$ T B) 23 T C) 0.12 T D) 3.7 T E) 0.6 T

22. Two wires in parallel are on a circuit board, as pictured below. A 10.0 V source produces 1.0 N of force on the wire that has a 2*R* resistance causing it to be dislodged. From that observation, what is *R*?



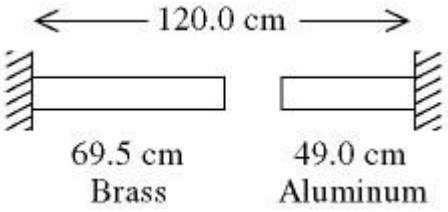
A) 10^{-5} Ω B) 10^3 Ω C) 10^1 Ω D) 10^0 Ω E) 10^{-2} Ω

23. A solid metal sphere is 15.0 cm in diameter and has surface of uniform color. When its surface is at 112°C, you measure that it radiates energy at a rate of 71.3 W. What is the emissivity of the surface of this object? Any heat that enters the sphere from the outside environment is negligible.
A) 0.17 B) 0.35 C) 0.54 D) 0.81 E) 1.0

24. A circular coil of radius 5.0 cm and resistance 0.20 Ω is placed in a uniform magnetic field perpendicular to the plane of the coil. The magnitude of the field changes with time according to $B = 0.50e^{-20t}$ T. What is the magnitude of the current induced in the coil at the time t=2.0 s?

A) 9.2 mA B) 2.6 mA C) 1.3 mA D) 4.2 mA E) 7.5 mA

25. A brass rod is 40.1 cm long and an aluminum rod is 79.3 cm long when both rods are at an initial temperature of 0°C. The rods are placed in line with a gap of 0.60 cm between them, as shown in the figure. The distance between the far ends of the rods is maintained at 120.0 cm throughout. The temperature of both rods is raised until the two rods are barely in contact. The coefficients of linear expansion of brass and aluminum are $2.0*10^{-5}$ K^{-1} and $2.4*10^{-5}$ K^{-1}, respectively. The temperature at which contact of the rods barely occurs is closest to



A) 240°C B) 220°C C) 230°C D) 210°C E) 200°C

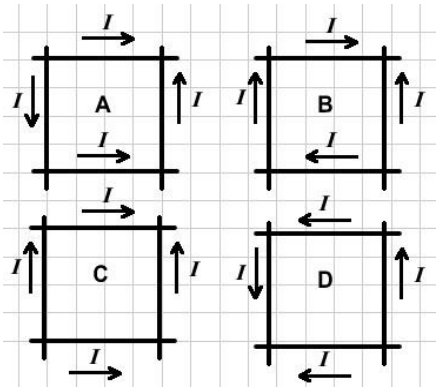
26. How many grams of ice at -13°C must be added to 711 grams of water that is initially at a temperature of 87°C to produce water at a final temperature of 10.0°C? Assume that no heat is lost to the surroundings and that the container has negligible mass. The specific heat of liquid water is 4190 J/kg • C° and of ice is 2050 J/kg • C°. For water the normal melting point is 0.00°C and the heat of fusion is $334*10^3$ J/kg. The normal boiling point is 100°C and the heat of vaporization is $2.26*10^6$ J/kg.

A) 57 g B) 1200 g C) 130 g D) 720 g E) 570 g

27. Three resistors having resistances of 4.0 Ω, 6.0 Ω, and 3.0 Ω are connected in parallel. If the combination is connected in series with an ideal 15-V battery and a 2.0-Ω resistor, what is the current through the 4.0-Ω resistor?

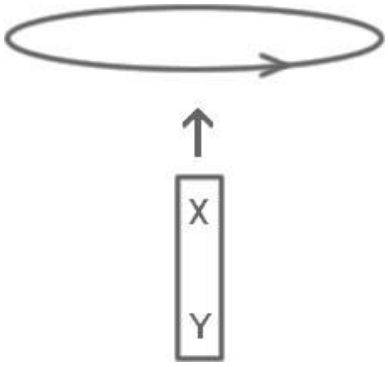
A) 1.5 A B) 2.5 A C) 15 A D) 0.25 A E) 0.5 A

28. The figure shows four different sets of insulated wires that cross each other at right angles without actually making electrical contact. The magnitude of the current is the same in all the wires, and the directions of current flow are as indicated. For which (if any) configuration will the magnetic field at the center of the square formed by the wires be equal to zero?



A) A B) B C) C
D) D E) The field is not equal to zero in any of these cases.

29. The figure shows a bar magnet moving vertically upward toward a horizontal coil. The poles of the bar magnets are labeled X and Y. As the bar magnet approaches the coil it induces an electric current in the direction indicated on the figure (counter-clockwise as viewed from above). What are the correct polarities of the magnet?



A) X is a south pole, Y is a north pole.
B) Both X and Y are north poles.
C) Both X and Y are south poles.
D) X is a north pole, Y is a south pole.
E) The polarities of the magnet cannot be determined from the information given.

30. An ideal gas in a balloon is kept in thermal equilibrium with its constant-temperature surroundings. How much work is done by the gas if the outside pressure is slowly reduced, allowing the balloon to expand to 6.0 times its original size? The balloon initially has a pressure of 645.0 Pa and a volume of 0.10 m^3.

A) 6.0 J B) 390 J C) -330 J D) 120 J E) -120 J