Name: Keys

Circle on your choices of answers clearly. Be sure to write down proper SI units. You must show your work for numeric problems to obtain any credit. Zero credit will be given if you just write down the answer. Some useful formulae and constants are at provided on a separate sheet. There are a total of 20 problems, of which 5 are numeric. All multiple choice problems are 5 points each. The maximum scores for points for numeric problems are specified to each problem. The maximum score is 105 points.

1. When a 20.0 ohm resistor is connected across the terminals of a 12.0-V battery, the terminal voltage of the battery falls 0.30 V. What is the internal resistance of this battery?

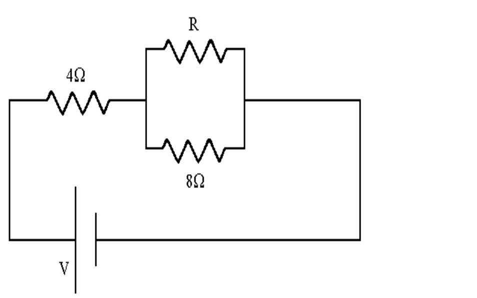
a. 0.30 Ω **b. 0.51 Ω**
c. 0.98 Ω d. 3.60 Ω

2. What is the maximum current that can be drawn from a 1.50-V battery with an internal resistance of 0.30 ohm?

a. 0.20 A b. 0.45 A
c. 4.5 A **d. 5.0 A**

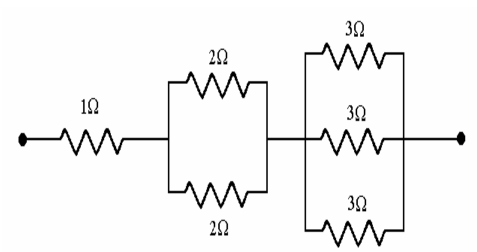
3. What per cent of the initial current remains 10 time constants after the switch is closed in an RC circuit without a source of emf but with a fully charged capacitor?

a. 0.0045 b. 0.069
c. 6.9 d. 10



4. If the current through the 8 Ω resistor is 2 A, what is V if R is not zero?

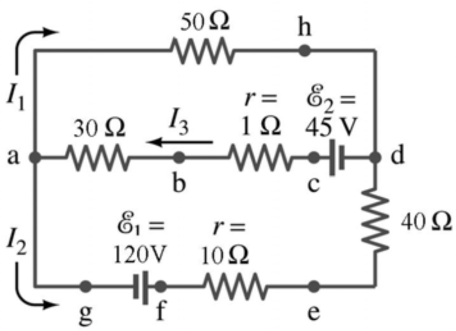
a. 8 V b. 16 V
c. more than 24 V d. less than 8V



5. What is the resistance of the combination in the figure left?

a. 1.8 Ω **b. 3.0 Ω**
c. 6.0 Ω d. 14 Ω

Turn Over



6. Calculate the currents I1, I2 and I3 in each of the branches of the circuit in the figure left, using Kirchhoff's rules. (3 points each, totaling 9 points)

Ans] From Kirchhoff's junction rule, we obtain $I_3 = I_1 + I_2$.
Now, using the loop rule, we can write the potential drop through the bottom and top loops separately:

$$120 - 10I_2 - 40I_2 + 45 - I_3 - 30I_3 = 165 - 50I_2 - 31I_3 = 0$$
$$-50I_1 + 45 - I_3 - 30I_3 = 45 - 50I_1 - 31I_3 = 0$$

We can then solve the three equations for I_1, I_2 and I_3.

$$I_2 = \frac{165 \cdot 81 - 31 \cdot 45}{(81)^2 - (31)^2} = +2.1A;\ I_1 = \frac{165 - 81 \cdot 2.1}{31} = -0.16A;\ \text{ and }\ I_3 = I_1 + I_2 = -0.16 + 2.1 = +1.94A$$

7. What does the earth's northern magnetic pole acts like?

a. the north pole of a magnet
b. the south pole of a magnet
c. it has positive charge
d. it has negative charge

8. If the earth's magnetic field is 0.52 gauss, what is this field in SI units?

a. 0.52 SI units
b. 0.52×10^{-4} SI units
c. 0.52×10^{4} SI units
d. 2.04 SI units

9. A circular loop of wire has a current I flowing around it. The radius of the loop is R. What is the magnitude of the net force on the loop?

a. 0
b. 2 IBR
c. 4 IBR
d. which depends on the angle between the loop and the field.

10. An alpha particle is moving at a speed of 5×10^5 m/s in a direction perpendicular to a uniform magnetic field of strength 4×10^{-2} T. The charge on an alpha particle is 3.2×10^{-19} C and its mass is 6.6×10^{-27} kg. What is the radius of the path of the alpha particle?

a. changing
b. 0.26 m
c. 0.52 m
d. 3.9 m

11. A fifteen turn rectangular loop of wire of width 10 cm and length 20 cm has a current of 2.5 A flowing through it. Two sides of the loop are oriented parallel to a uniform magnetic field of strength 0.037 T, while the other two sides being perpendicular to the magnetic field. What is the magnetic moment of this coil?

a. 0.025 A-m^2
b. 0.050 A-m^2
c. 0.75 A-m^2
d. 7.5 A-m^2

12. Using what of the following can isotopes of different mass be separated?
    a. Hall probe **b. mass spectrometer**
    c. periodic table meter d. chemical reaction

13. The magnetic field due to a current I in a long straight wire at a distance d is B. What is the magnetic field at 2d from this wire?
    a. B b. 2B
    c. B/2 d. B/4

14. Two parallel wires carry currents in the same direction. What is the direction of the force on one wire?
    a. toward the other wire b. away from the other wire
    c. perpendicular to the plane of the wires d. along the wire

15. Two parallel wires carry currents in the same direction. The current in one wire doubles while the current in the other also doubles and the distance between the wires doubles. What happen to the force between the wires?
    a. remains the same **b. doubles**
    c. halves d. quadruples

16. Cutting a bar magnet near its north end results in a smaller mostly north pole magnet and a larger mostly south pole magnet. True or false?
    a. True **b. False**

17. A superconducting wire has a mass of 0.15 g per meter of length. If it is under a weak horizontal magnetic field of magnitude 0.5×10^{-4} T, what current would the wire have to carry if the magnetic force on the wire equals the gravitational force? (5 points)
    Ans] The gravitational force must be balanced by the magnetic force exerted on the wire by the field which is perpendicular to the wire. Thus we can establish the equation $\frac{F_g}{l}=\frac{mg}{l}=\frac{F_M}{l}=IB$. Solving the equation for the current I, we obtain
    $$I=\frac{mg}{lB}=\frac{\left(1.5\times10^{-4}\,kg/m\right)\cdot\left(9.8\,m/s^2\right)}{0.5\times10^{-4}\,T}$$

18. A ten loop coil of area 0.23 m^2 is in a 0.047 T uniform magnetic field oriented so that the maximum flux goes through the coil. (a) What is the total magnetic flux? (b) The coil is then rotated so that the flux through it goes to zero in 0.34 s. What is the average emf induced in the coil during the 0.34 s? (3 points each, totaling 6 points)
    Ans] (a) Since the orientation of the uniform magnetic field is perpendicular to the surface of the coil, the flux is maximum. Thus, the flux is
    $$\Phi_B=\vec{B}\cdot\vec{A}=BA=\left(0.23m^2\right)\cdot\left(0.047T\right)=0.0108T\cdot m^2=0.0108W$$
    (b) From the Faraday's law of induction, we obtain the induced emf on the coil as:
    $$\varepsilon=-N\frac{\Delta\Phi_B}{\Delta t}=-10\cdot\frac{-0.0108T\cdot m^2}{0.34s}=0.32V.$$

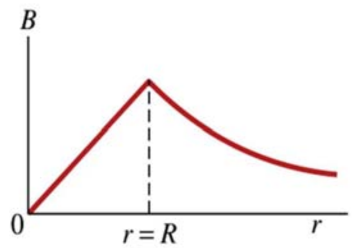
19. A long straight cylindrical wire conductor of radius R carries a current I of uniform current density in the conductor. Determine the magnetic field at (a) points outside the conductor (r>R) and (b) points inside the conductor (r<R). Assume that r, the radial distance from the axis, is much less than the length of the wire. (c) Draw the graph of the magnitude of the magnetic field as a function of the distance, r, from the center of the wire. (3 points each, totaling 9 points)

Ans] (a) The total current I_{encl}=I for r>R. Thus, from Ampere's law, we obtain:

$\oint \vec{B}\cdot d\vec{l} = 2\pi rB = \mu_0 I_{encl} = \mu_0 I$. Thus the field is $B = \dfrac{\mu_0 I}{2\pi r}$.

(b) The total enclosed current I_{encl} for r<R is $I_{encl} = I\dfrac{\pi r^2}{\pi R^2} = I\dfrac{r^2}{R^2}$. Thus again using Ampere's law, we obtain

$\oint \vec{B}\cdot d\vec{l} = 2\pi rB = \mu_0 I_{encl} = \mu_0 I\dfrac{r^2}{R^2}$. Thus the field is $B = \dfrac{\mu_0 Ir}{2\pi R^2}$.



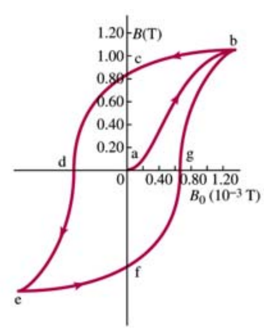
(c) From the results above, we see that the magnetic field is linearly proportional to the distance inside the wire and then inversely proportional to the distance outside the wire. Thus we can draw the plot on the right:

20. (a) What happens to the total magnetic field strength if a ferromagnetic material, such as iron, is put inside a solenoid, increase or decrease compared to the solenoid with air? (b) What happens to the total magnetic field of the iron core solenoid if the direction of the current goes through an entire loop from $0A \rightarrow +IA \rightarrow 0A \rightarrow -IA \rightarrow 0A$? (c) Draw an example picture of the total magnetic field (B) as a function of the magnetic field without an iron core (B_0). (d) What is the name of this loop? (6 points)

Ans] (a) The magnetic field strength increases when a ferromagnetic material is put in the core of a solenoid since the total magnetic field becomes the field of the solenoid with air core only plus the field by the ferromagnetic material.

(b) The total magnetic field strength will gradually increase to one direction but will not go back to origin as the current reduces and eventually changes the direction. When the current returns to +I, however, the field strength returns to the original position at +I.

(c) The picture on the right without the last leg (point g to b).



(d) Hysteresis curve