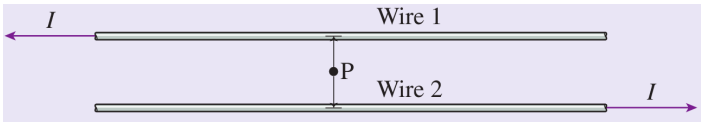
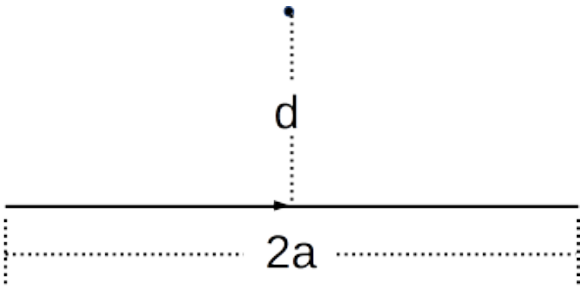
Matter and Motion – Tue. March 13, 2018
Final Exam – Revision Edition Name:_____

80 points total

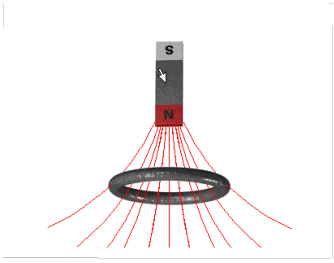
1. [2 points] Why, for a Carnot engine with 33% efficiency and T_c = 30°C, is T_h approximately 450 K?
2. [2 points] The electric field in a certain region of space is given by $\vec{E} = \left(+2.0\ \frac{V}{m} - 1.0\ \frac{V}{m^2}x\right)\hat{\imath}$. Wh is the change in potential when moving from *x=2.0* m to *x=0.0* m equal to +2.0 V?
3. [2 points] A positively-charged rod is brought close to a Styrofoam ball, and the Styrofoam ball is attracted to the rod. Why could the charge on the Styrofoam ball be either negative or zero?
4. [2 points] From what height above the surface of the earth should an object be dropped from rest to initially experience an acceleration of 0.9200*g*? The radius of the earth is 6.38×10^6 m.
5. [2 points] Two long, parallel wires each carry the same current I, but the two currents are anti-parallel. The two wires are a distance d apart. (Recall that the magnetic field at a distance *r* from an infinitely long wire has magnitude $B = \frac{\mu_0 I}{2\pi r}$). Why are the magnitude and direction of the magnetic field, B, at a point that is at the midpoint, P, between the two wires, given by $B = \frac{2\mu_0 I}{\pi d}$ directed out of the page?



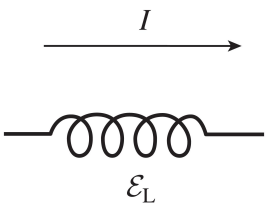
6. [2 points] Consider a finite, straight piece of wire (length = 2*a*) running along the *x* axis carrying a current *I* in the +*x* direction. You need to calculate the magnetic field due to this piece of wire at a point *P* in the *x*-*y* plane a distance *d* from the center of the wire. Why is the correct integral $B_z = +\frac{\mu_0}{4\pi}\int_{x=-a}^{a} \frac{Id}{(x^2+d^2)^{\frac{3}{2}}}dx$



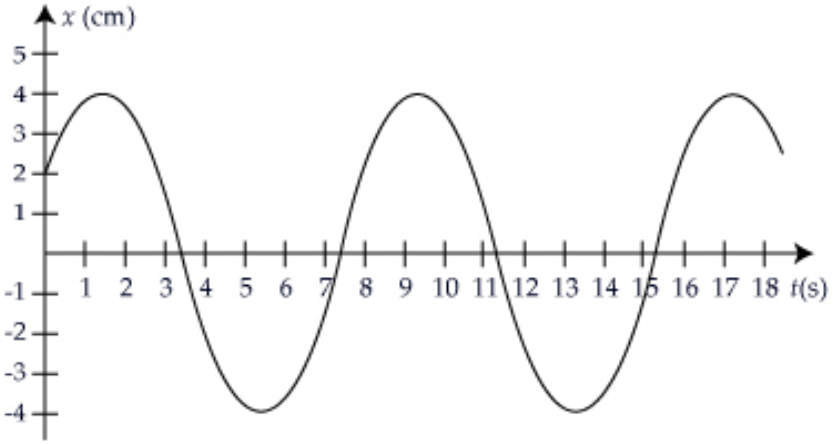
7. [2 points] A 200 nF capacitor discharges through a 1.0 MΩ resistor. If the initial potential across the capacitor was 10 V, why will the potential across the capacitor be 3.7 V at t=2.0 s?
8. [2 points] Consider an ideal parallel plate capacitor, with plates of area *A* separated a distance *d*, an initial charge *Q* and a potential difference across the plates *V*. Why will, taken alone, doubling *A* or halving *d* double capacitance, while, despite the equation $C = \frac{Q}{V}$, is it not true that doubling *Q* or halving *V* would double the capacitance?
9. [2 points] A permanent magnet oriented with the north pole downward falls through a conducting ring, as shown. As it falls through the ring, why does the current in the ring start counterclockwise as seen from above, go to zero, then go clockwise? (Recall that you saw in lab the emf produced by a magnet falling through a coil.)



10. [2 points] Current flows from left to right through the inductor shown. A voltmeter connected across the inductor gives a constant reading, and shows that the left end of the inductor is positive. How can you tell that the current in the inductor is decreasing?

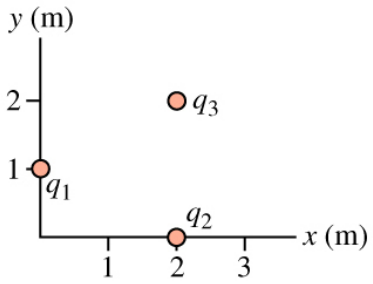


11. [4 points] An object of mass *m* is released from rest very far away from the surface of a planet of mass *M* and radius *R*. Find an expression for its speed when it strikes the surface of the planet (neglecting the effects of any atmosphere).
12. [6 points total] An object is in simple harmonic motion, as depicted by the graph below. Write a formula for its *acceleration* as a function of time. Include correct units for all necessary quantities.



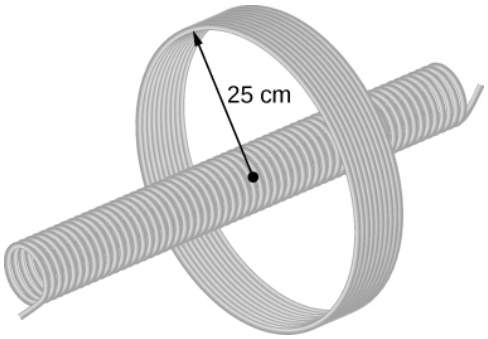
13. [4 points] A very long wire carries a current of *I*=250 A along the *x* axis in the +x direction. (Recall that the magnetic field at a distance *r* from an infinitely long wire has magnitude $B = \frac{\mu_0 I}{2\pi r}$). What is the magnetic force on an electron (q_e=-1.6 x 10^{-19} C) when it reaches the point *x*=0 cm, *y*=1.0 cm if the electron's velocity is $\vec{v} = 300\frac{m}{s}\hat{\imath} - 400\frac{m}{s}\hat{\jmath}$?

14. [6 points] What is the net force on charge q_1 if q_1=-5.0 nC, q_2=+3.0 nC, and q_3= -2.0 nC? Be sure to express this as a vector in correct units!



15. [10 points] Two +5.0 nC point charges, each of mass *m*=2.0 x 10^{-6} kg, are connected by a 15 cm long, massless thread. The system is at rest in space (and we assume there is nothing else around; ignore gravity). The thread suddenly breaks. How fast will each charge be moving when it is very far away (you may assume infinitely far) from its original location?

16. [10 points] A long solenoid of cross-sectional area 5.0 cm^2 is wound with 25 turns of wire per centimeter. It is placed in the middle of a closely wrapped coil of 10 turns and radius 25 cm, as shown below. What is the emf induced in the coil when the current through the solenoid is decreasing at a rate $\frac{dI}{dt} = -0.20\ A/s$?



17. [10 points] A 1900 kg electric car traveling at 30.0 m/s begins braking and comes to a full stop after 20.0 seconds. The regenerative braking system feeds energy back into the 300 V battery. If the regenerative braking system is 50% efficient at converting kinetic energy into electric power, what average current did the brakes deliver to the battery as the car slowed down?

18. [10 points] A 3-step cycle using 8.0 mol of a monatomic ideal gas consists of an isothermal expansion at *T*=500 K, then an isobaric compression at p_B=*200* kPa, then an adiabatic compression back to the original state. Call the key locations on the p-V diagram points A, B and C (relevant pressure, volume and temperature values are in the table). How much net work per cycle, in J, would a heat engine based on these steps perform? Sketch this process on a p-V diagram, indicating clearly the points *A, B* and *C* and the "direction" of the cycle. The ideal gas law constant is *R*=8.314 J/(mol K).

Point	*p* (Pa)	*V* (m^3)	*T* (K)
A	1.66×10^6	2.00×10^{-2}	500
B	2.00×10^5	1.66×10^{-1}	500
C	2.00×10^5	7.12×10^{-2}	?