Name: ______________________________

SID: ______________________________

Section: ______________________

Physics 7B Lecture 3 Final - Fall 2018
Professor A. Lanzara

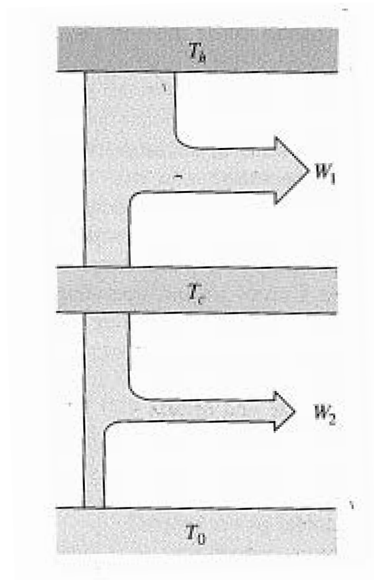
This exam is out of 100 points. Show all your work and take particular care to explain your steps. Partial credit will be given. Use symbols defined in problems and define any new symbols you introduce. If a problem requires that you obtain a numerical result, first write a symbolic answer and then plug in numbers. Label any drawings you make. **Good luck!**

Problem 1 (15 pts.) Consider a Carnot engine operating between temperatures T_h and T_c, where T_c is above the ambient temperature T_0. A second Carnot engine is set up that operates between T_c and the ambient temperature T_0, as shown in the figure below. The heat output of the first engine acts as the asborbed heat of the second engine.

a) Draw the P-V diagram for the two-stage engine

b) Draw the P-V diagram for the equivalent engine

c) Calculate the efficiency of the equivalent engine. What is the role of T_c?



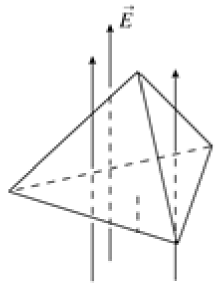
Problem 2 (10 pts.) A pan contains 500 g of water at 20 °C. What heat flow does it require to raise the temperature of the water to 100 °C and vaporize it at 1 atm?Take the specific heat of water to be $c_w = 4000$ J/kg$\cdot$ C° and the latent heat of vaporization to be $L_w = 2200$ kJ/kg.

Proble 3 (15 pts.)

a) The figure below depicts a tetrahedron immersed in a uniform electric field with magnitude E. Assume that each face is an equilateral triangle with edge length L.

(i) What is the total flux through the tetrahedron?

(ii) Calculate the electric flux through the top three faces.

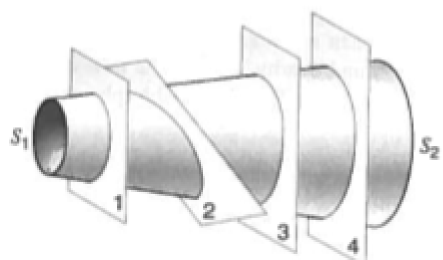


b) A constant current flows through a conical conductor as shown below. End surfaces S_1 and S_2 are equipotential surfaces that are not at the same potential. The metal has a uniform conductivity σ. Assume the electric field is confined to the interior of the conductor.

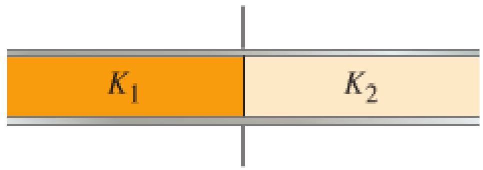
(i) Through which plane does the greatest current flow?

(ii) Through which plane is the greatest electric flux?

(iii) How does the magnitude of the electric field E vary along the central axis moving from S_1 to S_2?

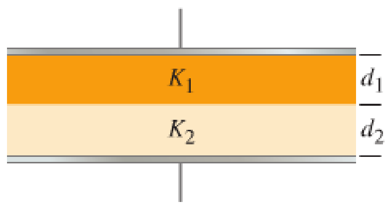


Problem 4 (15 pts.) For all the capacitors and dielectric configurations below, assume that the top plate has a charge +Q and the bottom plate has a charge -Q. Take the separation between the plates to be d and the area of the plates to be A.

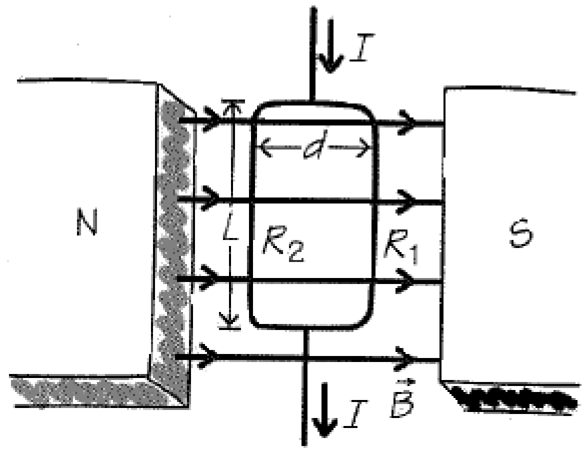


(a) Calculate the effective capacitance of the capacitor above.The space between the capacitor plates is completely filled with two blocks of dielectrics with dielectric constants K_1 and K_2.

(b) Repeat part (a) for the new capacitor below, which also is filled with two dielectrics with dielectric constants K_1 and K_2. Note that $d_1 + d_2 = d$.



Problem 5 (15 pts.) A wire carrying a current I splits into two channels of resistance R_1 and R_2, respectively, forming a circuit. The loop is fixed and cannot be translated, but is free to rotate. The wire enters the space between the two poles of a magnetic with a uniform magnetic field that runs from one pole piece to the other, as shown below. What is the torque on the circuit about the wire axis, given that the wires are a distance d apart and that the length of the split is L?



Problem 6 (20 pts.) A wire is bent into a circular arc of radius r, as shown below. An additional straight length of wire, OP, is free to pivot about O and makes sliding contact with the arc at P. Finally, another straight length of wire, OQ, completes the circuit. All the wires have cross-sectional area A and resistivity ρ. The entire arangement is located in a magnetic field B that is directed out of the plane of the figure.

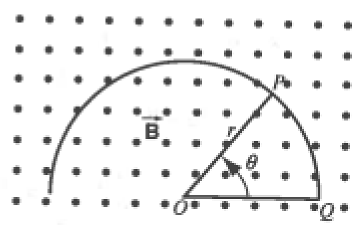
(a) Find the resistance of the loop OPQO as a function of θ.

(b) Find the magnetic flux through the loop as a function of θ. Hint: Think of the area for certain values of θ.

We now consier the case where the straight wire OP starts from rest at $\theta = 0$ and has a constant angular acceleration of α.

(a) Find the induced emf in the loop as a function of time in terms of α, B, and other given constants.

(b) For what value of $\theta(t)$ is the induced current in the loop a maximum?



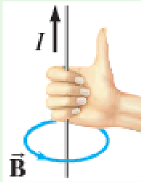
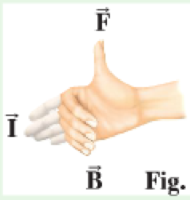
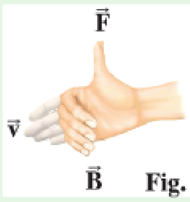
Problem 7 (10 pts.)

a) Consider two inductors L_1 and L_2 that are in series. Derive the equivalent inducatance.

b) Consider two inductors L_1 and L_2 that are in parallel. Derive the equivalent inductance.

Thermodynamics and Mechanics	Electromagnetism	Constants and Formulas
$\Delta l = \alpha l_0 \Delta T$	$\oiint \vec{E} \cdot d\vec{A} = \frac{Q_{encl}}{\epsilon_0}$	$k_B = 1.38 \times 10^{-23}$ J/K
$\frac{dQ}{dt} = -kA\frac{dT}{dx}$	$C = KC_0$	$\frac{1}{4\pi\epsilon_0} \sim 10^{10}\ \mathrm{N \cdot m^2/C^2}$
$dS = \frac{dQ}{T}$	$P = IV$	$q = 1.6 \times 10^{-19}$ C $\sim 10^{-19}$ C
$\Delta S_{syst} + \Delta S_{env} > 0$	$R = \frac{\rho l}{A}$	$\sqrt{2} \sim 1.4$
$\oint dS = 0$	$\Delta V = -\int \vec{E} \cdot d\vec{l}$	$\sqrt{3} \sim 1.7$
$\Delta V = \beta V_0 \Delta T$	$\vec{E} = -\nabla V$	$\ln(2) \sim 0.69$
$e = \frac{W_{net}}{Q_{in}}$	$\oiint \vec{B} \cdot d\vec{A} = 0$	$\ln(3) \sim 1.09$
$C_p - C_V = R = N_A k_B$	$\oint \vec{E} \cdot d\vec{l} = -\frac{d\Phi_B}{dt}$	$\cos(x) = 1 - \frac{x^2}{2} + \frac{x^4}{24} \cdots$
$\mathrm{COP} = \frac{\text{Heat from low temp. resevoir}}{\text{Work}}$	$\vec{B} = \frac{\mu_0}{4\pi} \int \frac{I d\vec{l} \times \hat{r}}{r^2}$	$\sin(x) = x - \frac{x^3}{6} + \cdots$
$\mathrm{COP_{ideal}} = \frac{T_L}{T_H - T_L}$	$\vec{\mu} = NI\vec{A}$	$e^x = 1 + x + \frac{x^2}{2} + \cdots$
$\lvert \vec{F}_{cent} \rvert = \frac{mv^2}{r}$	$L = N\frac{\Phi_B}{I}$	$\ln(1+x) = x - \frac{x^2}{2} + \frac{x^3}{3} + \cdots$
$v = \frac{dx}{dt}$	$\oint \vec{B} \cdot d\vec{l} = \mu_0 I_{encl}$	$\int \frac{1}{(a^2+x^2)^{1/2}} dx = \ln\left(x + \sqrt{a^2+x^2}\right) + C$
$a = \frac{dv}{dt}$		$\int \frac{1}{(a^2+x^2)^{3/2}} dx = \frac{x}{a^2\sqrt{a^2+x^2}} + C$
$\omega = \frac{d\theta}{dt}$		$\int \frac{x}{(a^2+x^2)^{1/2}} dx = \sqrt{a^2+x^2} + C$
$\alpha = \frac{d\omega}{dt}$		$\int \frac{x}{(a^2+x^2)^{3/2}} dx = -\frac{1}{\sqrt{a^2+x^2}} + C$

TABLE 27–1 Summary of Right-hand Rules (= RHR)

Physical Situation	Example	How to Orient Right Hand	Result
1. Magnetic field produced by current (RHR-1)	 **Fig. 27–8c**	Wrap fingers around wire with thumb pointing in direction of current I	Fingers point in direction of $\vec{\mathbf{B}}$
2. Force on electric current I due to magnetic field (RHR-2)	 **Fig. 27–11c**	Fingers point straight along current I, then bend along magnetic field $\vec{\mathbf{B}}$	Thumb points in direction of the force $\vec{\mathbf{F}}$
3. Force on electric charge $+q$ due to magnetic field (RHR-3)	 **Fig. 27–15**	Fingers point along particle's velocity $\vec{\mathbf{v}}$, then along $\vec{\mathbf{B}}$	Thumb points in direction of the force $\vec{\mathbf{F}}$