

Exam 2

Physics 140, 9:45-11:20 Tuesday November 13 2018

You may use a 3"x5" card of notes, both sides, and a calculator. NO PHONES.

Do simple integrals. Leave complex ones unevaluated.

You're expected to do integrals like $\int cz^n dz$, $\int ce^{kx} dx$, $\int c \ln(ky) dy$, $\int \frac{1}{(a+r)} dr$, $\int c \cos(k\theta) d\theta$, or $\int c \sin(k\phi) d\phi$.

Don't do the integration on anything more complex. Instead, move all constants out of the integral, reasonably simplify all terms, specify limits, and clearly write the integral.

PERIODIC TABLE OF THE ELEMENTS

<div style="display: flex; justify-content: space-around; align-items: center;"> <div style="text-align: center;"> <p>■ Non-metal</p> <p>■ Alkali metal</p> <p>■ Alkaline earth metal</p> <p>■ Transition metal</p> </div> <div style="text-align: center;"> <p>■ Metal</p> <p>■ Metalloid</p> <p>■ Halogen</p> </div> <div style="text-align: center;"> <p>■ Noble gas</p> <p>■ Lanthanide</p> <p>■ Actinide</p> </div> </div>																																
1 H HYDROGEN 1.0079																	2 He HELIUM 4.0026															
3 Li LITHIUM 6.941	4 Be BERYLLIUM 9.0122																	5 B BORON 10.811	6 C CARBON 12.011	7 N NITROGEN 14.007	8 O OXYGEN 15.999	9 F FLUORINE 18.998	10 Ne NEON 20.1797									
11 Na SODIUM 22.9897	12 Mg MAGNESIUM 24.305																	13 Al ALUMINUM 26.981	14 Si SILICON 28.085	15 P PHOSPHORUS 30.974	16 S SULFUR 32.066	17 Cl CHLORINE 35.453	18 Ar ARGON 39.948									
19 K POTASSIUM 39.098	20 Ca CALCIUM 40.078	21 Sc SCANDIUM 44.955	22 Ti TITANIUM 47.867	23 V VANADIUM 50.9415	24 Cr CHROMIUM 51.9961	25 Mn MANGANESE 54.938	26 Fe IRON 55.845	27 Co COBALT 58.933	28 Ni NICKEL 58.6934	29 Cu COPPER 63.546	30 Zn ZINC 65.38	31 Ga GALLIUM 69.723	32 Ge GERMANIUM 72.63	33 As ARSENIC 74.921	34 Se SELENIUM 78.971	35 Br BROMINE 79.904	36 Kr KRYPTON 83.796															
37 Rb RUBIDIUM 85.463	38 Sr STRONTIUM 87.62	39 Y YTTORIUM 88.9058	40 Zr ZIRCONIUM 91.224	41 Nb NIOBIUM 92.9063	42 Mo MOLYBDENUM 95.95	43 Tc TECHNETIUM 98	44 Ru RUTHENIUM 101.07	45 Rh RHODIUM 102.90	46 Pd PALLADIUM 106.42	47 Ag SILVER 107.8682	48 Cd CADMIUM 112.414	49 In INDIUM 114.818	50 Sn TIN 118.710	51 Sb ANTIMONY 121.760	52 Te TELLURIUM 127.60	53 I IODINE 126.90	54 Xe XENON 131.29															
55 Cs CAESIUM 132.905	56 Ba BARIUM 137.327	57-71**	72 Hf HAFNIUM 178.49	73 Ta TANTALUM 180.94	74 W TUNGSTEN 183.84	75 Re RHENIUM 186.207	76 Os OSMIUM 190.23	77 Ir IRIDIUM 192.227	78 Pt PLATINUM 195.084	79 Au GOLD 196.96	80 Hg MERCURY 200.59	81 Tl THALLIUM 204.38	82 Pb LEAD 207.2	83 Bi BISMUTH 208.98	84 Po POLONIUM 209	85 At ASTATINE 210	86 Rn RADON 222															
87 Fr FRANCIUM 223	88 Ra RADIUM 226	89-103**	104 Rf RUFENIUM 261	105 Db DUBNIUM 262	106 Sg SEABORGIUM 271	107 Bh BOHRIUM 272	108 Hs HASSIUM 277	109 Mt MEITNERIUM 276	110 Ds DARMSTADIUM 281	111 Rg ROENTGIUM 280	112 Cn COPECIUM 285	113 Uut UNUNTRIUM 288	114 Fl FLEROVIUM 288	115 Uup UNUNPENTIUM 288	116 Lv LIVERMORIUM 293	117 Uus UNUNSEPTIUM 294	118 Uuo UNUNOCTIUM 294															
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1. We consider lattice vibrations even at absolute zero. Why? Use the Heisenberg uncertainty principle and include a calculation to support your answer.
 2. We often use the simple harmonic oscillator to model lattice vibrations. Why? Provide text, a diagram and one or two relevant equations.
When is the harmonic approximation *not* valid?
 3. What's the frequency of lattice vibrations? We addressed this with two models.
 - (a) The first uses $3N$ independent oscillations. How do we determine ω ?
 - (b) The second uses an *infinite* chain of atoms. How do we determine ω ?
 - (c) Compare the two results for ω . How are they different?
 - (d) We can usually modify the second to address a *finite* chain of identical atoms. Why do we do this? How does this change ω ? Outline how this comes about.
 4. What are *phonons*?
 5.
 - (a) What is heat capacity C ?
 - (b) What's typically experimentally observed for C at room temperature? As temperature decreases?
 - (c) Calculate values C from macroscopic quantities (temperature and heat).
 6. We considered three models for the heat capacity contribution from the lattice.
 - (a) Why do we use lattice vibrations in explaining heat capacity?
 - (b) Determine C from the energy of a system.
 - (c) For the classical model: How energy is calculated? What's predicted for C and how does it match experimental observations?
 - (d) Repeat (c) for the Einstein model
 7.
 - (a) What are the Debye model's assumptions? You can discuss this in terms of how its ideas are similar to or different from the Einstein model.
 - (b) The Debye model uses the density of states $g(\omega)$. What does $g(\omega)$ describe? Where is it used in the Debye model?
 8.
 - (a) What's thermal conductivity κ ?
 - (b) Calculate values of κ from macroscopic quantities (temperature gradient and heat transfer).
 - (c) What is the microscopic model for κ ? Refer to mean free path, the speed of sound, and a diagram in your answer.
 - (d) Why do we use lattice vibrations (phonons) in explaining κ ?
 9. Explain why a solid undergoes thermal expansion in a microscopic model.
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10.
 - (a) Describe the basic assumptions of the Drude model for metals. Explain relaxation time and the mean free path in your answer.
 - (b) What determines how fast electrons move in the Drude model?
 - (c) Calculate thermal speed, relaxation time and mean free path.
 11.
 - (a) Where does electrical resistance come from in the Drude model?
 - (b) When an electric field is applied, how does the electron drift speed compare with their thermal speed? Calculate drift speed.
 - (c) What is the microscopic version of Ohm's law? Outline how to derive the microscopic version of Ohm's law with the Drude model.
 - (d) Calculate values of conductivity of a metal based on the Drude model.
 12. From an energy band schematic,
 - (a) Determine if a material is a conductor, insulator or semiconductor.
 - (b) Identify the conduction band and the valence band. Which electrons can participate in conduction?
 - (c) Identify the Fermi level
 13. Describe the basic assumptions of the free electron model.
 14. The Fermi energy is given by $E_f = \frac{\hbar^2}{2m_e}(3\pi^2n)^{2/3}$.
 - (a) What does the Fermi energy describe? Do all electrons have an energy equal to E_f ?
 - (b) Outline how to arrive at this expression.
 - (c) Calculate values of the Fermi energy and Fermi velocity.
 15.
 - (a) What does the Fermi-Dirac distribution describe?
 - (b) Calculate the total number of electrons with energy $E \rightarrow (E+\Delta E)$ at some temperature T . This is an integral. Identify each of the terms. Leave it as an integral.
 16.
 - (a) What happens to the F-D distribution when temperature increases? What is the soft-zone and how is affected by T ?
 - (b) Only electrons in the soft-zone can participate in conduction. Calculate the density of these electrons. Leave your answer as an integral.
 - (c) Typically, what percentage of the valence electrons can actually participate in conduction?