This is an open notes test lasting 50 minutes.

There are two problems, divided into subsections. The points for each part are marked. **The total is 20 points.**

**Bold face letters denote vectors.**

Begin each problem on a fresh sheet of paper. Use only one side of a sheet of paper.

Put your name, the problem number, and the page number in the upper right hand corner of each sheet.

To receive partial credit you must explain what you are doing. Carefully labeled figures are important. Randomly scrawled equations aren't helpful.

Draw a box around important results.

Some constants which may be useful:

Magnetic permeability of free space \( \mu_0 = 4\pi \times 10^{-7} \) tesla.meter/ampere

electronic charge \( e = 1.6 \times 10^{-19} \) C

electronic mass \( m = 9.1 \times 10^{-31} \) kg

Boltzmann’s constant \( k_B = 1.38 \times 10^{-23} \) J/K

**There are 3 pages including this page. Do not forget to look at all parts of the problems.**
Problem 1.

An electromagnetic wave entering a conducting metal surface is damped and reduces in amplitude by a factor $1/e$ in a distance $\delta$. $\delta$ depends on how good the conductor is i.e. the conductivity ($\sigma = l/RA$), the frequency of the electromagnetic wave ($f$), and the magnetic permeability ($\mu$).

a) Using dimensional analysis express $\delta$ in terms of $\sigma$, $f$, and $\mu$. (6 points)

b) How does $\delta$ change as the conductivity of the metal increases (i.e. does it increase or decrease)? (1 point)

c) If the frequency of the incident radiation is doubled, what is the change in $\delta$? (3 points)

Problem 2.

The figure shows a cube with side $h$. The point O is the origin of the coordinate system. The points P1, P2 and P3 are the centers of the respective square faces of the cube as shown in the figure.

a) Represent the vectors $a_1$, $a_2$, and $a_3$ in terms of unit vectors in the direction of the x, y and z axes and the length of the side h. (2 points)
b) Find the volume of the parallelepiped described by the vectors \( \mathbf{a}_1, \mathbf{a}_2, \) and \( \mathbf{a}_3 \), in terms of \( h \). (2 points)

c) Find the area of the triangle defined by the points P1, P2, and P3 and show that it is an equilateral triangle. (4 points)

d) Show that the body diagonal of the cube passing through the origin O is perpendicular to the surface of the triangle described in part (c). (2 points)