Physics 101
Midterm 2

1. A car of mass m is initially moving with velocity v, and collides with a second car of mass $2m$ that is initially at rest. The cars are locked together after the collision.

(a) (10 points) What fraction of the original speed v does the combined wreck have just after the collision?

(b) (15 points) What fraction of the initial kinetic energy of the moving car is converted to heat and other forms of energy during the collision?

2. (15 points) Three charges are placed along a line a distance d apart. From left to right, the charges are $-Q$, $+Q$, and $-2Q$. Find a formula for the magnitude of the force on the leftmost charge $-Q$. Give the direction of the force.

3. (20 points) What fundamental discovery about the structure of the atom did Ernest Rutherford make in 1909? Briefly describe what experimental measurement he made, and how the result was interpreted in terms of the structure of the atom.

4. (20 points) How did Niels Bohr's model of the hydrogen atom explain the atom's stability and the spectral lines predicted by Balmer's formula? You don't need to give any formulas, but state the main ideas.

5. (20 points) Explain why Einstein's special theory of relativity predicts that events that are simultaneous to one observer are not simultaneous to another observer moving relative to the first.

"Cheat Sheet"

Velocity and Acceleration

$$\Delta t = t_f - t_i, \quad \Delta x = x_f - x_i, \quad \Delta v = v_f - v_i. \quad etc.$$

$$v = \lim_{\Delta t \to 0} \frac{\Delta x}{\Delta t},$$
$$a = \lim_{\Delta t \to 0} \frac{\Delta v}{\Delta t}.$$

Constant acceleration

$$\Delta v = a\Delta t,$$
$$\Delta x = v_i \Delta t + \frac{1}{2} a \Delta t^2$$

Newton's laws of Motion

$$F_{\text{net}} = ma$$
$$F_{\text{on A due to B}} = -F_{\text{on B due to A}}.$$

Circular Motion

$$a_{\text{in}} = \frac{v^2}{r}.$$

Newton's law of Gravity

$$F_{\text{grav}} = G_{\text{N}} \frac{m_A m_B}{r^2}, \qquad G_{\text{N}} = 6.7 \times 10^{-11}\ \text{N} \cdot \text{m}^2/\text{kg}^2$$

Momentum and Energy

$$p = mv$$
$$E = \tfrac{1}{2} m v^2 + mgh + E_{\text{other}}$$

Electromagnetism

$$F_{\text{elec}} = k \frac{Q_A Q_B}{r^2}, \qquad k = 9 \times 10^9\ \text{N} \cdot \text{m}^2/\text{Coul}^2$$

Bohr Atom

$$E_n = -\frac{2\pi^2 e^4 m_e k^2}{n^2 h^2}, \qquad h = 6.7 \times 10^{-34}\ \text{J} \cdot \text{s}$$