Constants:

e = 1.6 \times 10^{-19} \text{ C}
\n\text{m}_e = 9.11 \times 10^{-31} \text{ kg}

1) (20 pts) An electron moves through a uniform magnetic field given by
\[ \vec{B} = B_x \hat{i} + (2B_x) \hat{j}. \]
At a particular instant, the electron has a velocity
\[ \vec{v} = 3\hat{i} - 5\hat{j} \text{ m/s} \]
and the magnetic force acting on it is \( 7 \times 10^{-19} \hat{k} \) N. What is \( B_x \)?
2) (15 pts) What uniform magnetic field, applied perpendicular to a beam of electrons moving at $2 \times 10^6$ m/s, is required to make the electrons travel in a circular arc of radius 0.3 m?
3) (20 pts) This figure represents a simplistic optical fiber: a plastic core \((n_1=1.45)\) is surrounded by a plastic sheath \((n_2=1.40)\). A light ray is incident on one end of the fiber at angle \(\theta\). The ray is to undergo total internal reflection at point A, where it encounters the core-sheath boundary. (Thus there is no loss of light through that boundary.) What is the maximum value of \(\theta\) that allows total internal reflection at A?
4) (20 pts) In this figure, a 3-m long vertical pole extends from the bottom of a swimming pool to a point 100 cm above the water. Sunlight is incident at an angle \( \theta = 45 \) degrees. What is the length of the shadow of the pole on the level bottom of the pool? (the index of refraction for water is 1.3)
5) (15 pts) In this figure, a real inverted image I of an object O is formed by a certain lens (not shown); the object-image separation is 60.0 cm, measured along the central axis of the lens. The image is just half the size of the object.

a) What kind of lens must be used to produce this image?

b) How far from the object must the lens be placed?

c) What is the focal length of the lens?
6) (10 pts) This figure shows an overhead view of a corridor with a plane mirror, M, mounted at one end. A burglar, B, sneaks along the corridor directly toward the center of the mirror. If \( d = 5 \text{ m} \), how far from the mirror will the burglar be when the security guard, S, can first see her in the mirror?