Modern Physics
Problem Set 1

JC-1) **Star Wars**
In episode 5 of Star Wars the Empire's space ships launch probe droids throughout the galaxy to seek the base of the Rebel Alliance. Suppose a space ship moving at 2.3 x 10^8 m/s toward Hoth (site of the rebel base) launches a probe droid toward Hoth at 2.1 x 10^8 m/s relative to the space ship. According to *Galilean relativity:*

a) *(5 points)* What is the speed of the droid relative to Hoth?
b) *(5 points)* If rebel astronomers are watching the approaching spaceship through a telescope, will they see the probe before it lands on Hoth?

JC-2) **Michelson-Morley Revisited**
(10 points) A shift in one fringe in the Michelson-Morley experiment corresponds to a change in the round-trip travel time along one arm of the interferometer by one period of vibration of light (about 2.0 x 10^{-15} s) when the apparatus is rotated by 90°. What velocity through the ether would be deduced from a shift of one fringe? (Take the length of the interferometer arm to be 11 m).
Hint: You may find the following expansions helpful for this problem and problems you will see later in the class.

$$\frac{1}{1-\frac{u^2}{c^2}} \approx 1 + \frac{u^2}{c^2} + \ldots \qquad \text{and} \qquad \frac{1}{\sqrt{1-\frac{u^2}{c^2}}} \approx 1 + \frac{1}{2}\frac{u^2}{c^2} + \ldots$$

JC-3) **Binomial Expansion**
(10 points) In the previous problem it was suggested to use the binomial approximation

$$(1-x)^n \approx 1 - nx$$

which olds for any number *n* and any *x* much smaller than 1 (that is $|x| << 1$). Make a table showing $(1 - x)^n$ and its approximation $(1 - nx)$ for the case $n = -1/2$ and $x = 0.5, 0.1, 0.01$, and 0.001. In each case find the percentage by which the approximation differs from the exact result. Hint: In this case neglect significant figures and use enough digits so that you can actually see a difference.

JC-4) **Galilean Invariance**
a) *(10 points)* Show that the form of Newton's second law is invariant under a Galilean transformation.
b) *(10 points)* Is the definition of of linear momentum ($p = mv$) invariant under a Galilean transformation? What about the change in momentum?