STONY BROOK
STATE UNIVERSITY OF NEW YORK

**PHY251 Modern Physics, Homework 1**
**30 Jan - 6 Feb** Lecturer: Urs Achim Wiedemann

e-mail: wiedemann@tonic.physics.sunysb.edu Tel: 631-632-4489 Fax: 631-632-9718

**Problems:**

1. How far does light travel in a nanosecond? How long does it take for light to travel one nanometer? And how long does it take light to travel a millimeter?
   The average distance of mars from the sun is 227,936,637 km. Pluto is 5,906,376,272 km away from the sun, the earth is 147,098,074 km away. How long does it take light to travel these distances?

2. A train passes Stony Brook station with a speed $v_{\rm train} = 30$ m/s. Inside the train, a passenger moves with $v_{\rm pass} = 5$ m/s. The passenger carries a box of length $L = 1$ m and a very precise watch. He is well-trained and finds that his heart beats exactly once per second. Consider an observer standing on the platform of Stony Brook station: what is the length of the box and the velocity of the passenger measured by this observer? What is the frequency of the passengers heart beat, measured by the observer?
   Reconsider the same situation in the year 2200, when the Port Jeff space ship passes Stony Brook with 3/4 of the speed of light in order to make the intergalactic connection at JFK. A self-propelled passenger on this space ship moves in between compartments with 1/2 the velocity of light, carrying the same antique box of length $L = 1$ m. What does the observer on the platform of Stony Brook station observe now? (length, speed and heart beat of passenger).

3. A reckless driver argues that he did not stop at the red light on Nicholls Road, since it appeared Doppler-shifted green to him. Also, he did not stop when he saw a police car with blue light chasing him, since he viewed it as a green light. Calculate for the judge the velocity of the driver, when he approached the traffic light and when he tried to escape the police car. [wavelengths are 700 nm (red), 550 nm (green) and 450 nm (blue)]

4. A puzzled observer sees that a broom stick of proper length $L_0$ flies past him with a speed $v$ along the horizontal direction. A witch riding on the broom stick measures an angle of $\Theta_0$ of the broom stick with respect to the $x'$-axis.
   (a) Show that the length of the broom stick as measured by the puzzled observer is given by $L = L_0\sqrt{1 - (v^2/c^2)\cos^2\Theta_0}$.
   (b) Show that the angle that the rod makes with the $x$-axis of the stationary observer is given by $\tan\Theta = \gamma\tan\Theta_0$.
   These results show that the broom stick is both contracted and rotated. Take the lower end of the broom-stick to be at the origin of the primed coordinate system.

5. *Speed of light in a moving medium:* In a transparent liquid, light travels with a speed which is smaller than the vacuum speed of light by a factor $1/n$, $n > 1$ the index of refraction. Consider light passing through a horizontal column of water moving with a speed $v$.

(a) Show that if the beam travels in the same direction as the flow of water, the speed of light measured in the laboratory frame is

$$u = \frac{c}{n}\left(\frac{1 + nv/c}{1 + v/nc}\right) .$$

What is the result if the beam travels opposite to the flow of water?
(b) Show that for $v \ll c$, the preceding expression is in good agreement with $u \approx \frac{c}{n} + v - \frac{v}{n^2}$, first found by Fizeau in the 1850s.

6. In 2200, a physics professor at Stony Brook has a student in PHY251, who has to travel with a speed $v$ for a family reunion to Alpha Centauri when the mid-term exam is due. The moment the space ship passes Stony Brook, the professor signals that the examen starts and that he wishes the student to have time $T_0$ (spaceship time) to complete the exam. Show that the professor should wait a time (Earth time) of

$$T = T_0\sqrt{\frac{1 - v/c}{1 + v/c}}$$

before sending a light signal telling the student to stop.