Year 1 Assessed Problems

Semester 1

Assessed Problems 5

SOLUTIONS TO BE SUBMITTED ON CANVAS BY

Wednesday 6th November

at 17:00

Classical mechanics and Relativity
Problem Sheet 3

1. A train is traveling at constant speed u and is approaching two people, A and B, who are at rest along the train tracks.

As measured by an observer at rest with respect to the train tracks, the distance between A and B is the same as the length of the train. As measured by an observer at rest with respect to the train, A and B are separated by a distance which is equal to 16/25 of the length of the train. At what fraction of the speed of light is the train traveling? [4 marks]

2. A transmitter on the train sends radio signals of frequency 100 MHz, as measured by a passenger at rest on the train. What is the radio frequency measured by person A? [2 marks]

3. The transmitter is located at the back of the train. In the train's reference frame a radio pulse is sent exactly at the time at which the front of the train is at the location of person A. In A's reference frame, is the radio signal sent before, at the same time or after the front of the train is at A's location? If the two events – (i) signal is sent, and (ii) front of the train is at A's location – are not simultaneous, what is the time difference (as measured in A's reference frame)? In the train's reference frame, the train's length is 100 m. [4 marks]

Quantum Mechanics 1 – Problem 4

The energy levels of the hydrogen atom are well described by the expression

$$E_n = -\frac{A}{n^2}$$

where *A* is a constant and *n* is a positive integer. Hydrogen atoms absorb UV radiation of wavelength λ = 103 nm when they are excited from the ground state to the *n* = 3 energy level.

a) Use this information to calculate the energy required to ionize an atom of hydrogen from its ground state. Explain your reasoning and express your answer in electron volts. [7 marks]

b) Calculate the possible photon energies that may be emitted when hydrogen atoms excited to the *n* = 3 energy level decay to the ground state. Express your answers in electron volts. [3 marks]

A 75.0 cm long string stretched between two fixed supports has harmonic frequencies of 420.0 and 315.0 Hz, with no intermediate harmonic frequencies. What is
(a) the fundamental frequency and (b) the wave speed?

[4]

(c) Find the maximum kinetic energy contained in this system if the string is oscillating in its fundamental mode with a standing wave amplitude 0.50 cm. The mass of the string is 10.0 g. Treat the string as a large number of harmonic oscillators, each oscillator with a mass μdx. Write down the expression for the energy contained within x to $x + dx$, then integrate to find the total energy carried by the whole string. Remember that the amplitude of each oscillator is a function of x.

[4]

(d) For the above-mentioned system, if the tension of the string were to increase by 50%, what would be the new frequency of the fundamental mode?

[2]