Year 1 Assessed Problems

Semester 1

Assessed Problems 7

SOLUTIONS TO BE SUBMITTED ON CANVAS BY

Wednesday 20th November at 17:00

Classical mechanics and Relativity
Problem Sheet 4

A block of weight $mg = 300$ N is sitting on a horizontal floor. The coefficient of kinetic friction is $\mu_k = 0.3$.

1. With how much force do I need to pull the block horizontally in order to keep it moving at a constant non-zero velocity? [1 mark]

2. How much work will I need to do in order to move the block by 10 m in a straight horizontal line, while pulling horizontally and moving the block at a constant velocity? [2 marks]

3. At what angle θ from the horizontal should I pull the block in order to minimise the total work I need to do in order to move the block by 10 m in a straight horizontal line at a constant non-zero velocity, and what will that work be? [7 marks]

Quantum Mechanics 1 – Problem 6

Molybdenum is commonly used as a target material in commercial X-ray tubes. The average ionisation energies of the K, L and M electron shells in molybdenum are 20,002 eV, 2,573 eV, and 284 eV, respectively.

a) If electrons are accelerated toward the target through a potential difference of 35 kV, what is the cutoff wavelength in the Bremsstrahlung spectrum? [2 marks]

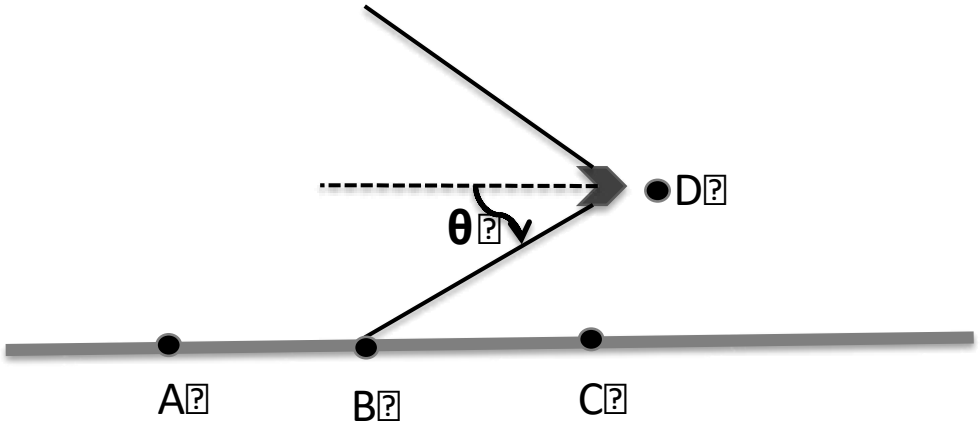
b) Use the data provided to calculate the wavelengths of any discrete lines that may appear in the spectrum. [3 marks]

c) Use the information gathered in parts (a) and (b) to draw a reasonably accurate diagram of the wavelength spectrum of X-rays that will be produced in a 35 kV molybdenum X-ray tube. Label the key features in the spectrum. [3 marks]

d) How would the X-ray spectrum change if the acceleration potential difference is lowered to 19.8 kV? [2 marks]

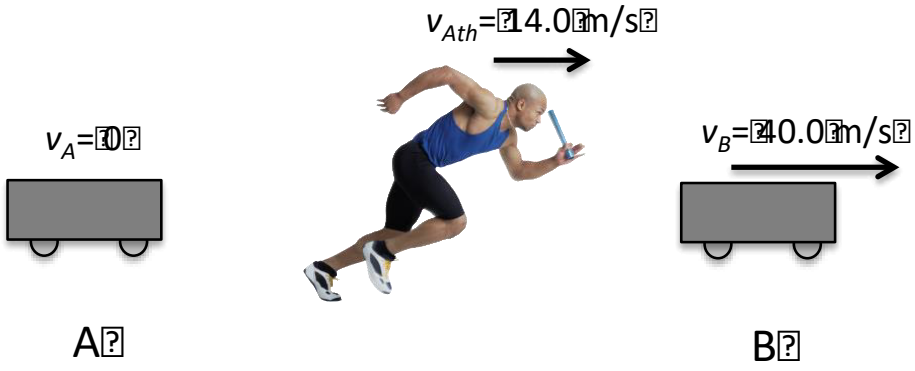
Optics and Waves (Week 7)

(a) An airplane is flying at a constant altitude at a steady speed *u* which is greater than the speed of sound. At one instant in time, the shock wave arrives at point B. In the diagram below, θ is the Mach cone angle.



For the moment an observer at point B heard the sonic boom, what did observers at A, C and D hear? Explain your reasoning. Just in case that you get worried about the observer at point D, I can assure you that the observer at point D can move out of the way with super-supersonic speed and hence would not cause unnecessary damage to the airplane due to a potential head-on collision. [4]

(b) Two train whistles, A and B, each has a frequency of 390 Hz. A is stationary and B is moving away towards the right at a speed of 40.0 m/s. An athlete is running after train B at a speed of 14.0 m/s. What is the frequency from A heard by the athlete? What is the frequency from B heard by the athlete? (Speed of sound in air is 340m s^{-1}) [4]



The athlete also hears an echo of whistle A from the back of train B. What frequency is this echo? [2]