PHYS-3203 Homework 8 Due 21 March 2024

This homework is due to `https://uwcloud.uwinnipeg.ca/s/Re9qoZBqcD8F5oe` by 10:59PM on the due date. Your file(s) must be in PDF format; they may be black-and-white scans or photographs of hardcopies (all converted to PDF), PDF prepared by LaTeX, or PDF prepared with a word processor *using an equation editor.*

1. **Rocket Science**

   Consider a rocket of initial velocity v_0 and initial total mass (including fuel) m_0 moving linearly in outer space. Recall from class that its velocity at a later time t is $v = v_0 + u\ln(m_0/m)$, where u is the exhaust speed relative to the rocket and m is the mass at time t.

   (a) *from Thornton & Marion* What is the ratio m/m_0 when the momentum of the rocket is maximized? *Hint:* Remember that the mass of the rocket is changing as it burns and exhausts fuel.

   (b) *from Cline 2.10* Assume the rocket exhausts fuel at a constant rate $\dot{m} = -k$ (until the fuel runs out). Find the displacement as a function of time.

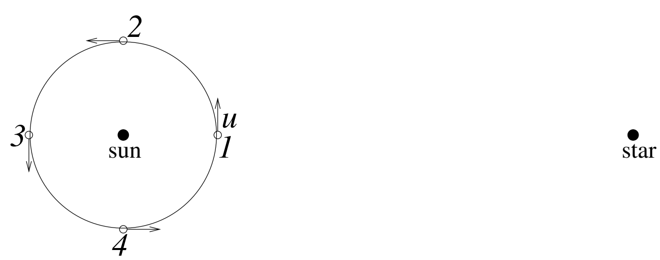
   (c) Finally, assuming that the relative exhaust speed u is constant, what is the mass of the rocket as a function of time if its acceleration a is constant?

2. **Stellar Aberration**

   In this problem we will explore more the aberration of starlight that was measured as far back as 1725. In this problem, all speeds of objects are small compared to the speed of light, so you are free to use Newtonian/Galilean relativity. You may want to recall that the speed of light is approximately $c = 3 \times 10^8$ m/s.

   (a) First, to get a feel for how this works, consider the following situation. You're driving in a car, and it's raining. Relative to the fixed earth, the rain falls straight down with speed w, and you drive at speed u. At what angle from the vertical do you see the rain falling?

   (b) Now, suppose there is a star straight overhead compared to your telescope. However, the earth is at position 1 in its orbit around the sun (see the figure below), where the orbital speed of the earth is approximately $u = 30,000$ m/s. At what angle from the vertical must I, standing on the earth, aim my telescope so that light from the star falls down the telescope tube? You may ignore the rotational speed of the earth's surface, which is much smaller than the earth's orbital speed. *Hint:* Recall that $\tan\theta \approx \sin\theta \approx \theta$ for small angles θ.



   Note that the figure is not to scale; the star is far enough away that it is effectively directly overhead (at the appropriate time of day) no matter where the earth is in its orbit. Give the angle in arc-seconds, where 3600 arcsec equal 1 degree.

   (c) At which point(s) as labeled in the figure above is this angle of aberration maximized? At which points is it minimized?