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Laser Physics (Physics 464)
Homework I, due Wednesday, September 6, 2023

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Transverse Doppler shift

Year 202?, the Artemis NASA mission is on the moon with a high resolution wavemeter. Jan Hall's one micron wavelength laser with one Herz bandwidth is beamed at that detector. Is that sufficiently narrow bandwidth? If not, what is the minimum bandwidth required? How long do you have to track the detector on the moon with your laser beam in order to do this measurement? Assume a circular orbit for the moon around the earth.

Longitudinal Doppler shift

The orbit of the moon is not circular, but has a fairly large excentricity of 13%. The moon-earth distance varies periodically. Take that variation to be sinusoidal. What is the Doppler shift at the point(s) where the longitudinal component of the velocity is maximum. maximum?

Spacecraft

In the 70's at the peak of excitement about space exploration, a propulsion scheme was proposed to visit another galaxy. Since it is extremely costly to bring up fuel to a spacecraft, it was proposed to attach huge reflectors to the spacecraft, and to "push" it with a powerful light beam. Another approach is to "beam up" energy with a powerful laser, which is then collected by solar panels, and converted into energy to power an ionic engine to propel the satellite or spacecraft.

1. To get a comparison between the two approaches, assume that the energy conversion is 10% efficient (from laser light to propulsion). Assume a continuous laser beam of 1 MW power, being completely collected by solar panels of 100 m diameter, and applied for 200 seconds. Assuming a mass of 1000 kg, what will be the velocity increase of the spacecraft after 200 s or irradiation?

2. For comparison, replace the solar panels by perfectly reflecting mirrors. The laser beam is now used to push the spacecraft by radiation pressure. What will be the velocity after 200 seconds (still a 1 MW laser beam)?

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Note that the authors of the article had also an answer to the question: "how do you stop the spacecraft". Simple, answered the authors: the space travelers have to attempt communication with a more advanced civilization, screaming "help" in all possible language and form as they are pushed into space!