Theoretische Physik I: Klassische Mechanik - Übungsblatt

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TECHNISCHE UNIVERSITÄT DARMSTADT

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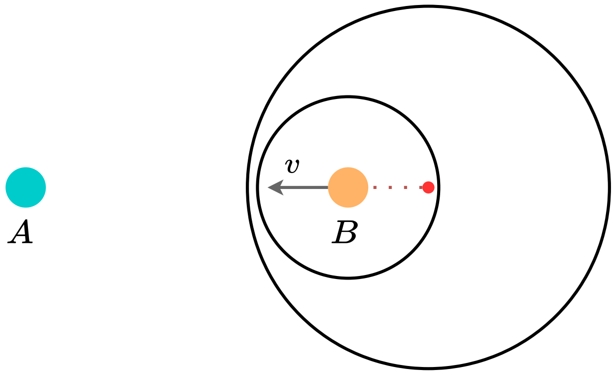
Übungsblatt 12

Deadline: 08.07. 23 Uhr online

Aufgabe 12.1: Lights. 10p.

Observer A will receive light from Observer B, who is moving towards A (from A's perspective) with a velocity of v. Do *not* approximate $v/c \ll 1$.

From A's perspective, B emits two "wavecrests" of light. The first wave crest is emitted (according to A) when the separation between A and B is r and the time is $t = 0$. From B's perspective, the two "wavecrests" are separated by a time T_B and so the light has a frequency $f_B = 1/T_B$. We want to find the frequency which A observes.



12.1a)

(1p) What is the time when the second burst of light is emitted?

12.1b)

(2p) What is the separation between A and B at the instant when the second burst of light is emitted?

12.1c)

(2p) What are the times when the first and second bursts reach A?

12.1d)

(2p) What is the time difference T_A between the wave crests as seen by A, and what is the frequency $f_A = 1/T_A$? What is the ratio f_A/f_B?

12.1e)

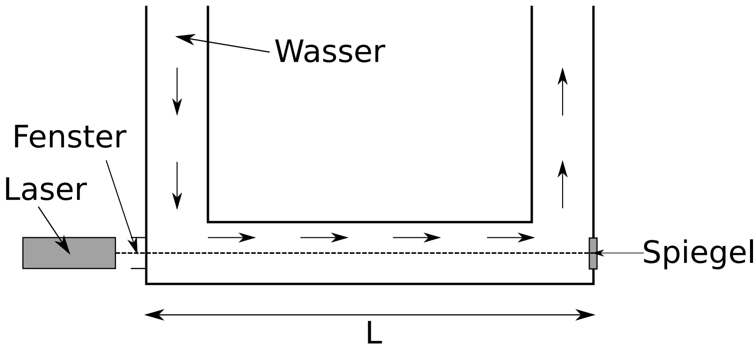
(3p) Suppose that A holds up a mirror to send the light back to B. From B's perspective, with what velocity is A approaching? Using the result from a) to d), determine what frequency B measures the reflected light to have. You should not need to repeat all steps.

Aufgabe 12.2: Light in water. 10p.

Let us consider an experiment which helped clarify how the addition of velocities works.

Water flows in a pipe with velocity v. Because water has an *index of refraction* of $n = 4/3$, light moves with the velocity $c_w = c/n = 3c/4$ in the water – in the reference frame in which the water is at rest.

The pipe is designed with a straight segment of length L, with right-angle bends at each end of the segment. At each end, there is a glass window which allows light to enter and leave the pipe. At one end, there is a pulsed laser and a photodetector. At the opposite end there is a mirror.



12.2a)

(2p) What is the speed of the light, in the laboratory frame, as it moves down the pipe -with- the flow of the water?

12.2b)

(2p) What is the speed of the light, in the laboratory frame, as it moves down the pipe -against- the flow of the water?

12.2c)

(3p) What is the total time that it takes for the light to go from the laser to the mirror and back? How much slower is the light's travel time if the pipe is of length 10 meters and the water flows with a velocity of 100 m/s, compared to the water being at rest?

12.2d)

(3p) Compare your answer to the "clumsy" approximation that the velocities add linearly, that is, that the light travels forward with a velocity $v + c/n$ and returns with a velocity $-v + c/n$. Show that the true answer differs from this approximation. For the same values as above, 10 meters and 100 m/s, how different are the two answers?

In completing c) and d) you are allowed to expand in small v^2/c^2, but c/n should be treated as an order-1 number.