Prof. Anchordoqui

Problems set # 7 **Physics 131** November 13, 2018

1. *(i)* The distance to the North Star, Polaris, is approximately 6.44×10^{18} m. If Polaris were to burn out today, in what year would we see it disappear? *(ii)* How long does it take for sunlight to reach the Earth? *(iii)* How long does it take for a microwave radar signal to travel from the Earth to the Moon and back? *(iv)* How long does it take for a radio wave to travel once around the Earth in a great circle, close to the planet's surface? *(v)* How long does it take for light to reach you from a lightning stroke 10 km away?

2. *(i)* As a result of his observations, Roemer concluded that eclipses of Io by Jupiter were delayed by 22 min during a 6 month period as the Earth moved from the point in its orbit where it is closest to Jupiter to the diametrically opposite point where it is farthest from Jupiter. Using 1.5×10^8 km as the average radius of the Earths orbit around the Sun, calculate the speed of light from these data; see Fig. 1. *(ii)* The Apollo 11 astronauts set up a panel of efficient corner-cube retroreflectors on the Moon's surface. The speed of light can be found by measuring the time interval required for a laser beam to travel from Earth, reflect from the panel, and return to Earth. If this interval is measured to be 2.51 s, what is the measured speed of light? Take the center-to-center distance from Earth to Moon to be 3.84×10^8 m, and do not ignore the sizes of the Earth and Moon. The Earth radius is $R_\oplus = 3,959$ miles and $R_{\rm moon} = 1,079$ miles.

3. The light beam shown in Fig. 2 makes an angle of 20.0° with the normal line NN' in the linseed oil. Determine the angles θ and θ'. (The index of refraction of air is 1.00029, the one of water is 1.33, and that of linseed oil is 1.48.)

4. A (thin) converging lens of focal length 10 cm forms images of objects placed at *(i)* 30 cm, *(ii)* 10 cm, *(iii)* 5 cm from the lens. In each case, find the image distance and describe the image characteristics. A (thin) diverging lens of focal length 10 cm forms images of objects placed at *(iv)* 30 cm, *(v)* 10 cm, *(vi)* 5 cm from the lens. Repeat the calculations to find the image distance and describe the image.

5. Faraday's law states that the induced voltage in a coil is proportional to the product of its number of loops, the cross-sectional area of each loop, and the rate at which the magnetic field lines change within those loops. For example, when one end of a magnet is repeatedly plunged into and back out of a coil of wire, the direction of the induced voltage alternates. As the magnetic field strength inside the coil is increased (as the magnet enters the coil), the induced voltage in the coil is directed one way. When the magnetic field strength diminishes (as the magnet leaves the coil), the voltage is induced in the opposite direction. The frequency ν of the alternating voltage that is induced equals the frequency of the changing magnetic field within the loops. It is more practical to induce voltage by moving a coil than by moving a magnet. This can be done by rotating the coil in a stationary magnetic field, as shown in Fig. 3. This arrangement is called a generator. The voltage induced in the loop of area A when it is rotated in the magnetic field B varies with time t

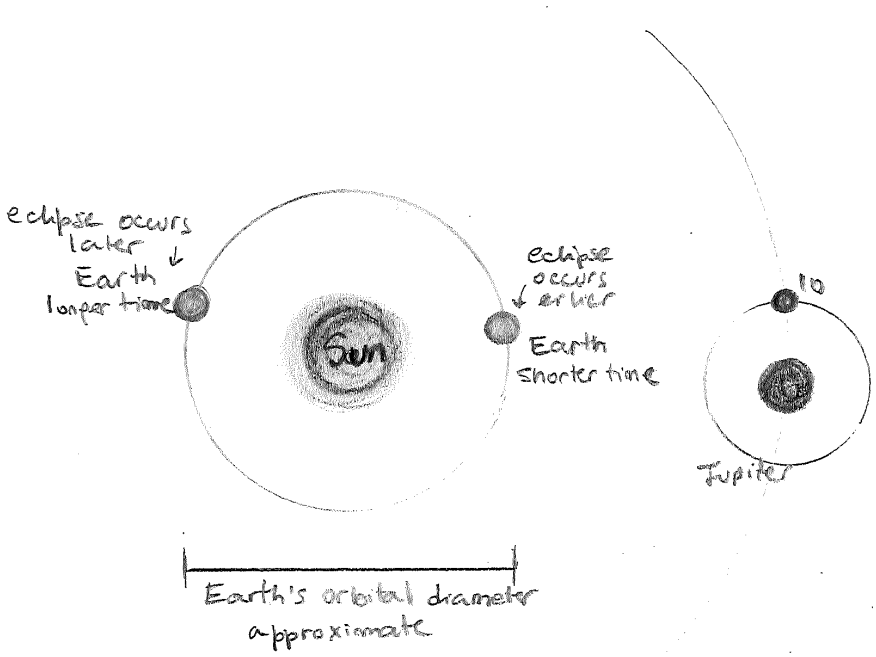

Figure 1: Earth's orbital diameter causes the eclipse of Io to occur at different times because of the extra distance the light must travle when Earth is farthest from Jupiter.

according to

$$V = B\ A\ \omega\ \ \sin(\omega t)\,, \tag{1}$$

where $\omega = 2\pi\nu$ is known as the angular frequency. Assume the circular loop of Fig. 3 (with radius of $r = 0.25$ meters) is rotated about the axis at a constant rate of 120 revolution per minute in a uniform magnetic field that has a magnitude of 1.3 Tesla. *(i)* Calculate the maximum value of the emf induced in the loop. *(ii)* Determine the times for which the voltage will be at the maximum. *(iii)* This is another example of periodic motion. What is the period?

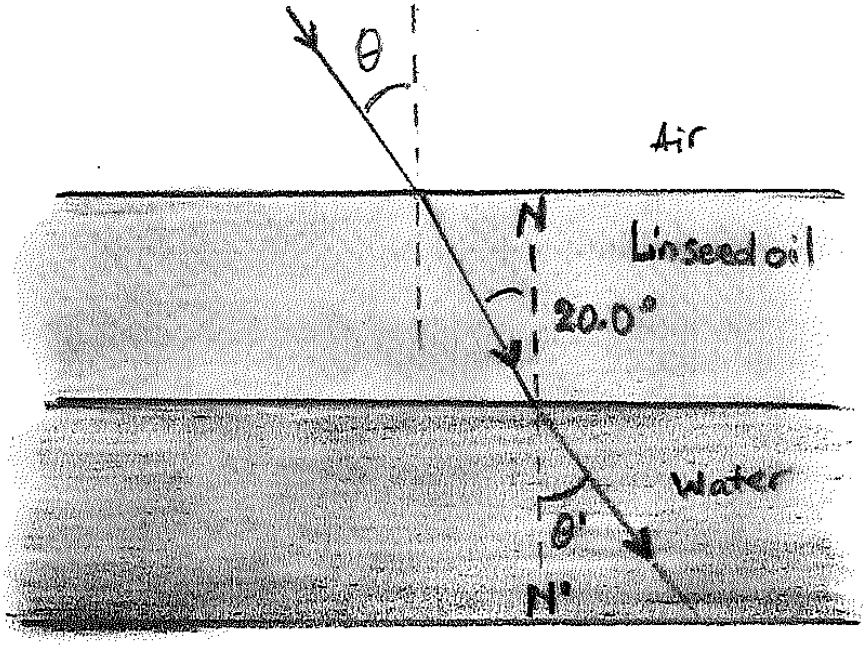

Figure 2: The situation in question 3.

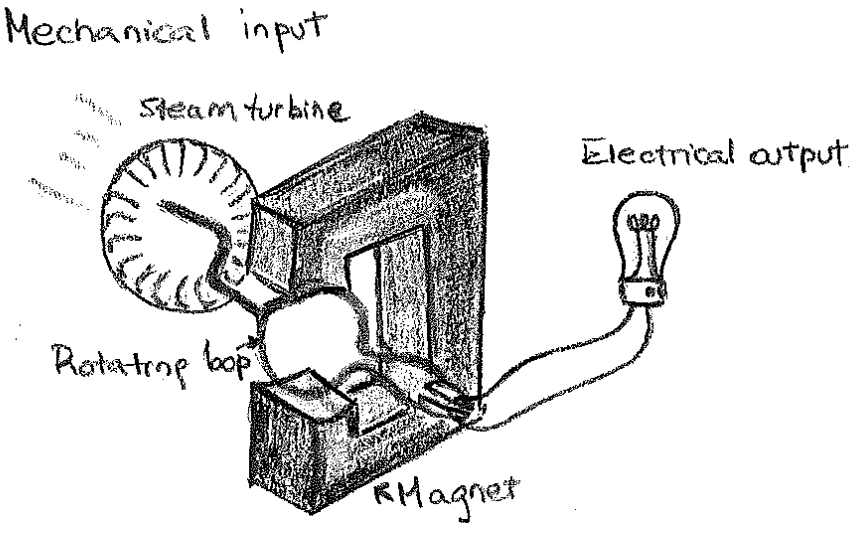

Figure 3: A simple generator. Voltage is induced in the loop when it is rotated in the constant magnetic field. Steam drives the turbine, which provides the mechanical input.