

1. (10%) Assume that the sound emission frequency of a bat is 39 kHz. During one fast swoop directly toward a flat wall surface, the bat is moving at 0.025 times the speed of sound in air. What frequency does the bat hear reflected off the wall?
2. (10%) A plane transmission grating disperses white light so that red wavelength  $\lambda = 650 \text{ nm}$  appears in the 2nd-order pattern at  $\theta = 20^\circ$ . Find the grating constant, i.e., the number of slits per centimeter. [ $\sin 20^\circ = 0.3420$ .]
3. (10%) An ideal gas undergoes a reversible isothermal expansion from volume  $V_1$  to volume  $V_2$ . What is the change in entropy of the gas?
4. (10%) A  $2 \mu\text{F}$  parallel-plate capacitor is charged to an initial potential difference  $V = 100 \text{ V}$  and then isolated. The dielectric material between the plates is mica of dielectric constant  $K = 5$ . What is the minimum work required to withdraw the mica sheet?
5. (15%) A 140 kg cannon, which fires a 70.0 kg shell with a speed of  $556 \text{ m/s}$  relative to the muzzle, is set at an elevation angle of  $37.0^\circ$  above the horizontal. The cannon is mounted on frictionless rails, so that it recoils freely. At what angle with ground is the shell projected? [ $\sin 37^\circ = 0.60$ ;  $\cos 37^\circ = 0.80$ .]
6. (15%) A bowling ball ( $I_0 = \frac{2}{5}MR^2$ ) is released from rest and rolls without sliding down a ramp inclined at an angle of  $30^\circ$  to the horizontal. How far will it roll in two seconds?
7. (15%) A long wire carries a current of uniform density. Let  $I$  be the total current carried by the wire, find the magnetic energy per unit length stored within the wire.

8. (15%) An open hemispherical tank of radius  $0.80\text{ m}$ , initially filled with water is drained through a hole of radius  $1.0\text{ cm}$  at the lowest point in the tank. How much time is required to drain the tank completely?