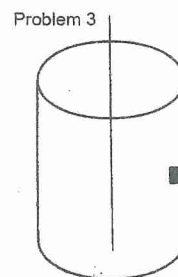


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Note: Please write down all your numerical answers with at least 2 significant digits.

- (10pts total) A optical grating has 300 lines/mm. What is the angular difference in the first-order principle minima between the spectral lines at 434 nm and 486 nm emitted by a hydrogen source? You can use the small-angle approximation for trigonometric functions.
- (15pts total) A 440-Hz wave (pitch 'A' in music) travels at 2000 m/s along a string. (a) (8pts) At a given time, what is the distance between points on the string that differ in phase by 0.2 rad? (b) (7pts) At a given position on the string, what is the change in phase during an time interval of 2 ms?
- (15pts total) A hollow cylinder of radius 1 m is rotating about a vertical axis (the rotating period is 3 s). A small block is found rotating without slipping along with the cylinder. The block does not have any other support except that from the cylinder. Assume that the block is in full contact with the cylindrical surface (i.e., there is no contact angle). (a) (10pts) Find the minimum coefficient of friction for a block not to slide down. (b) (5pts) Is it the static or kinetic coefficient of friction? Explain why.



- (15pts total) (a) (8pts) What is the definition of the shear modulus? (b) (7pts) And what is the physical dimension of the shear modulus?
- (15pts total) The interactions between a pair of neutral atoms can often be described by the Lennard-Jones potential:

$$U_{LJ}(r) = 4\epsilon \left[ \left( \frac{\sigma}{r} \right)^{12} - \left( \frac{\sigma}{r} \right)^6 \right],$$

where  $r$  is the distance between the two atoms. Let's use  $\epsilon = 1$  and  $\sigma = 1$  (in dimensionless units).

- (a) (5pts) Within which range is the potential repulsive? (b) (5pts) At which distance  $r$  is the value of potential equal to zero? (c) (5pts) At which distance  $r$  is the magnitude of force equal to zero?
- (15pts total) A  $10\mu\text{F}$  capacitor is connected in series with a 15V battery and a resistor (assuming all the other devices have negligible resistance). At time  $t = 0\text{s}$  the battery gets connected and the initial current is found to be 5 mA. (a) (5pts) What is the resistance of the resistor? (b) (5pts) What is the time constant of the circuit? (c) (5pts) Please plot the current of the circuit versus time.
- (15pts total) (a) (5pts) The water molecule has a permanent electric dipole moment of  $6.16 \times 10^{-30} \text{C}\cdot\text{m}$ . Assume this arises from net charges of  $+e$  and  $-e$  in two point-like regions of the molecule, what is their separation in distance? (b) (5pts) If a water molecule is in an external electric field of  $2 \times 10^6 \text{N/C}$ , please find the magnitude of torque on the molecule if its dipole moment is parallel to the field. (c) (5pts) Please find the potential energy of the molecule due to the presence of external electric field for the case of (b).

