OPTI 421/521 – Introductory Opto-Mechanical Engineering

Homework 9

1.) Material properties

1a) Consider the materials below for use in an optical system. For ***each material***:

- List at least one outstanding property for this material (What makes this material special?) Give the values for relevant material constants where appropriate.
- List at least one other property of this material that provides difficulty. (Why don't we use this for everything?) Give the values for the relevant material constants where appropriate.
- List wavelength range and refractive index for the optical materials. For each material, list density, Young's modulus, CTE, and thermal conductivity.
- Name one application for optical systems where this material may be optimal.

Optical Materials	Structural materials
BK7	Aluminum (6061T6)
Fused Silica	Steel (A36)
Calcium Fluoride	Stainless steel (17-4 CRES)
P-PK53	Beryllium (S-200F)
Acrylic (PMMA)	Titanium (6Al4V)
Sapphire	Copper
ZnSe	Invar 36
N-SF-57	Graphite epoxy (CFRP)
Germanium	Silicon Carbide
Magnesium Fluoride	Teflon™ (polytetrafluoroethylene)

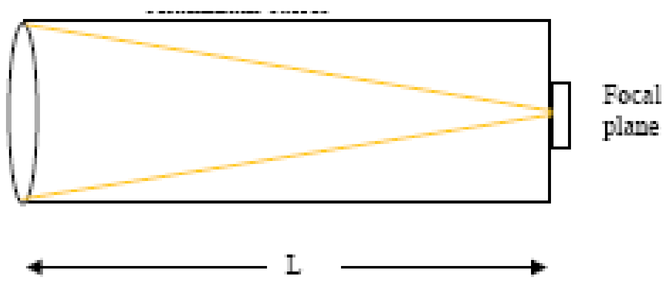
- You need to present the information in a coherent way, but it is not necessary to write this as a report.
- THINK about the results you show. You are expected to remember each of these materials and the approximate values of their outstanding characteristics.

1b) Find a specification sheet for at least 3 aluminum alloys, including 6061-T6, give modulus, yield strength, density, and ultimate strength values for each. Comment on the applications for each of these alloys.

1c) Find at least two stock lenses made from different materials that are used for IR applications. List the part number, material, wavelength range, size, and cost. Note the special issues with the material.

2) Thermal defocus

Consider a 50 mm focal length lens and housing, both made from PMMA plastic. The aperture is 10 mm.



Find CTE, dn/dT for PMMA

Find the effect of a 25°C temperature change:

a) Find CTE, *n*, d*n*/dT
b) Find the change in focal length of the lens
c) Find the change in length of the tube (lens to focal plane distance)
d) Show the resulting focus error from the combined effect
e) Find the thermal defocus for a system with the same geometry, but lens made of BK7 and the mount made of aluminum.

<u>3.) Shock Loading</u>

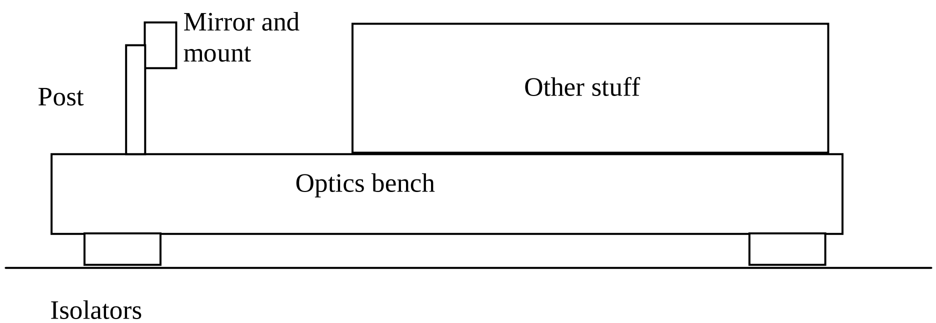
You built a high performance spectrograph that needs to be shipped to the factory in Zihuatanejo. The system is approximately cubical 10 inches on a side, and weighs 10 lb. You need to mount your system into the shipping box. You can expect this box to be dropped by 20 inches in any direction, and you must limit the shock loading of your system to 5 G's. Specify the support of your spectrograph that will provide adequate isolation.

<u>4. Vibration analysis</u>

Provide solution in the form of a brief technical memo. Submit this attached to your regular assignment.

Calculate the vibration of a mirror as mounted and determine if it meets requirements. If not, provide guidance for an improvement to the system.

This mirror is used for manufacturing holograms, so it is important that the mirror motion is less than lambda/40 for 488 nm light. Will this system meet the requirements? If not, what design changes are necessary?



The mirror is mounted on a 20 cm long, 15 mm diameter steel post

The mass of the mirror and mount together is about 1 kg
The Q for the mounted mirror on the bench is estimated at 40

(What is the resonant frequency for the mounted mirror as a cantilever? Do you need to include the mass of the post?)

The entire assembly is 100 kg and when it is placed on the isolated bench, the isolators deflect 2 mm.

(What is the resonant frequency for the system on isolators? Assume isotropic behavior.)

The isolators are made of rubber with damping $C_R = 0.05$.

(Evaluate the transmissibility of the isolators at the resonant frequency of the mirror.)

The system is in a lab on the ground floor of a busy building, the PSD is estimated at 10^{-8} G^2/Hz in the direction that will excite the mirror.

Does this meet spec with ample margin? If not, use scaling laws to adjust the design and improve performance.

<u>5. Rules of Thumb</u>

Provide three rules of thumb using the standard format.