1. Determine the longitudinal growth of a 24-in-long free-standing grain with a linear thermal coefficient of expansion of $7.5 \times 10^{-5}/°F$ for temperature limits of -40 to 140°F.
   Answer: 0.32 in.

2. The following data are given for an internally burning solid propellant grain with inhibited end faces and a small initial port area:

Length	40 in
Port area	27 in^2
Propellant weight	240 lb
Initial pressure at front end of chamber	1,608 psi
Initial pressure at nozzle end of chamber	1,412 psi
Propellant density	0.060 lb/in^3
Vehicle acceleration	21.2 g_0

   Determine the initial forces on the propellant supports produced by the pressure differential and vehicle acceleration.
   Answers: 19,600 lbf; 5090 lbf.

3. A fuel-rich solid propellant gas generator propellant is required to drive a turbine of a liquid propellant turbopump. Determine its mass flow rate. The following data are given:

Chamber pressure	$P_1 = 5$ MPa
Combustion temperature	$T_1 = 1,500$ K
Specific heat ratio	$k = 1.25$
Required pump input power	970 kW
Turbine outlet pressure	10 psia
Turbine efficiency	65%
Molecular weight of gas	22 kg/kg-mol
Pressure drop between gasgenerator and turbine nozzle inlet	0.10 MPa

   Windage and bearing friction is 10 kW. Neglect start transients.
   Answer: $\dot{m} = 0.92$ kg/s.

4. The propellant for this gas generator has these characteristics:

Burn rate at standard conditions	4.0 mm/s
Burn time	110 s
Chamber pressure	5.1 MPa
Pressure exponent n	0.55
Propellant specific gravity	1.47
Mass flow rate	0.257 kg/s

Determine the size of an end-burning cylindrical grain.

Hint: Use $r = r_{ref} (p \times p_{ref}^{-1})^n e^{\sigma_p (T - T_{ref})}$

Answer: Single end-burning grain is 27.2 cm in diameter and 31.9 cm long, or two end-burning opposed grains (each 19.6 cm diameter × 31.9 cm long) in a single chamber with ignition of both grains in the middle of the case.