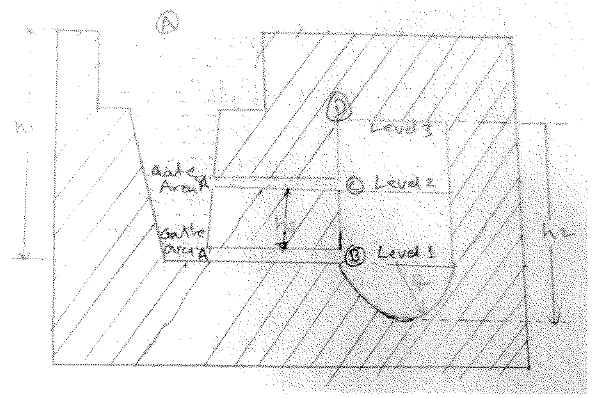
Qualifier 2023, January MFG1- Time 180 mins.

Self-hand-written notes are allowed, no photo copies or books

1. Derive an expression for the pouring time for the following casting assuming that the pour cup is always full. (expression must be in terms of the given parameters: h_1, h_2, h_3, R, A, g, where g is the gravitational acceleration) **[15]**



2. Arrange the following casting in an increase order of solidification time. **[5]**
   a. Spherical casting of radius R Thermally exposed throughout from outer surface
   b. Spherical casting of radius R with Thermally insulation at lower hemisphere
   c. Cubic casting of side R Thermally exposed throughout from its outer surface
   d. Cubic casting of side R with thermal insulation at lower surface

3. In a nucleation and growth process, two nuclei are born in a 2D rectangular box [bounded by x=0, x=2d, y= d/2, y= -d/2] at locations A (d/2,0) and B (3d/2,0) and time =0. Both nuclei grow at a uniform radial speed of G. find out the following: **[10]**
   a. Time time (t_1) when they will meet
   b. Phase fraction transformed at t_1
   c. The time t_2 for the complete phase transformation
   d. How t_1 will change if the nuclei growth rates are G and 2G respectively
   e. Referring to case (d), at which location they will meet

4. A single pass full penetration weld is made in steel using the following parameters: $E = 25$ V, $I = 300$ A, $\eta = 0.9$, $v = 10$ mm/sec, $T_o = 25°C$, $T_{preheat} = 200°C$, $T_m = 1510°C$, $\rho C_p = 0.0044$ J/mm^{3}K, $k = 0.028$ J/mm-sec-^{0}C, t = 6 mm
   a. Identify if it is a thick or thin plate for cooling rate estimation at a temperature, $T_c = 550°C$ [3]
   b. Calculate the cooling rate. **[3]**
   c. Suggest two methods to change the cooling rate, without varying E & I. **[4]**
   d. Show calculations for 50% increase in cooling rate by two methods in (c) **[10]**

Hint:

Relative plate thickness factor, $\tau = t\left\{\frac{\rho C_p(T_c - T_o)}{H_{net}}\right\}^{0.5}$

For thick plates, $R = \frac{2\pi k(T_c - T_o)^2}{H_{net}}$; For thin plates, $R = 2\pi k\rho C_p(T_c - T_o)^3\left(\frac{t}{H_{net}}\right)^2$

5. A single pass full penetration weld is made in steel using the following parameters:

$E = 25$ V, $I = 120$ A, $v = 4$ mm/sec, $T_o = 25°C$, $T_m = 1510°C$, $\rho C_p = 0.0044$ J/mm^3, $t =$ 4 mm, $\eta = 0.8$, $T_{recrystalization} = 720°C$

a. Calculate width of heat affected zone (HAZ). **[2]**

b. Calculate width of HAZ if the plate was preheated at 120°C. **[1.5]**

c. Calculate width of HAZ if the plate was tempered at 420°C (without preheating) **[1.5]**

d. For preheating at 120°C (not tempered plates), calculate the % change in weld speed to achieve the HAZ width of (a) **[2.5]**

e. For plates tempered at 420°C (without preheating), calculate the % change in weld speed to achieve the HAZ width of (a). **[2.5]**

6. In a metallic material, strains of 0.002 and 0.30 correspond to stress of 380 MPa and 600 MPa respectively. Young's modulus and Poisson's ratio are 190 GPa and 0.34, respectively. Find the components of the elastic strain, the plastic strain and the total strain and the magnitude of the equivalent plastic strain at $\sigma_x = 600$ MPa in uniaxial tensile deformation. Assume von Mises plasticity. **[20]**

7. Explain mathematically and graphically, why the yield surface does not evolve to be a perfect ellipse. Assume plane stress condition. [10]

8. For a perfect plastic material, show analytically, which deformation will be more expensive energetically - uniaxial compression or plane strain compression? [10]