HT Lab Experiment-1: Estimating the Convective Heat Transfer coefficient

Group-2

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Preliminaries

Pump Power → 80%

Bath Temperature (T_∞) → 62^oC

Material	Shape	Dimensions (mm)	Density (kg/m^3)	Thermal Conductivity (W/m-K)	Specific Heat Capacity (J/kg-K)
Brass	Sphere	40 (D)	8500	111	380
SS	Cylinder	14 (D), 150 (L)	8000	14	490
Aluminium	Rectangular Slab	150*40*10	2700	190	890

Questions

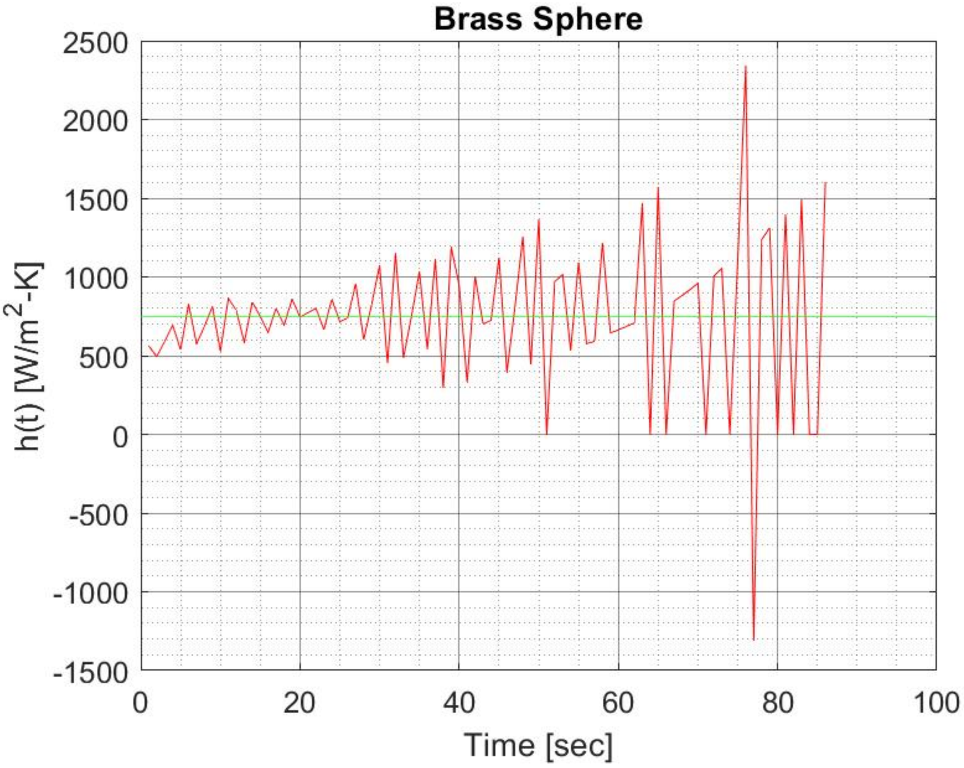
Q. Estimate and plot the instantaneous heat transfer coefficient *h*(*t*) by considering the instantaneous rate of heat transfer to the object:

$$\dot{Q} = \rho V c_p \frac{dT(t)}{dt} = h(t)A(T_\infty - T(t))$$

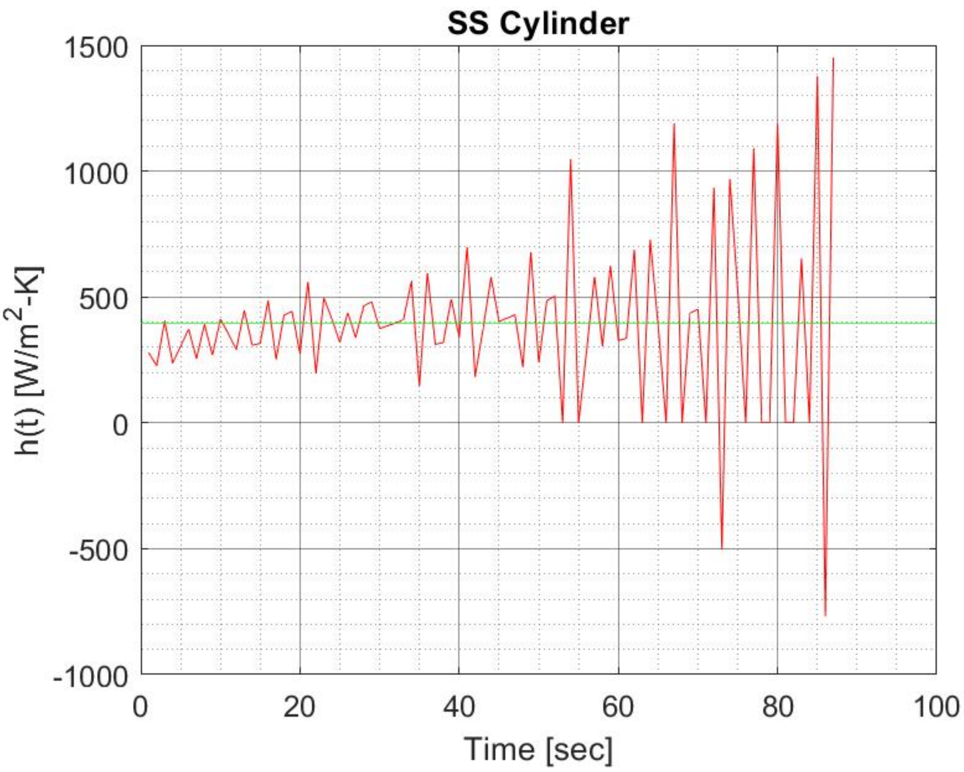
Also compute the average heat transfer coefficient $\bar{h}$.

Instantaneous Heat Transfer Coefficient can be written as,

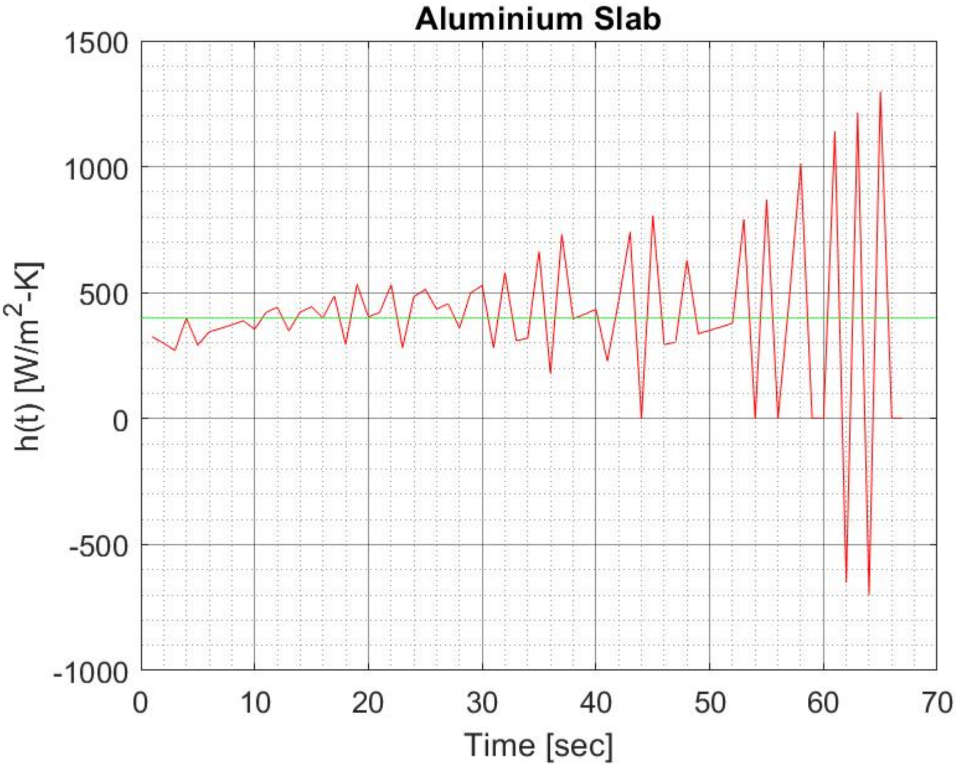
$$h(t) = \frac{\rho V c_p}{A} \cdot \frac{\frac{dT(t)}{dt}}{T_\infty - T(t)}$$



h(t) → Red and $\bar{h}$ → Green. $\bar{h} = 750.66 W/m^2 K$



$\bar{h} = 394.11 W/m^2 K$



$\bar{h} = 399.28W/m^2K$

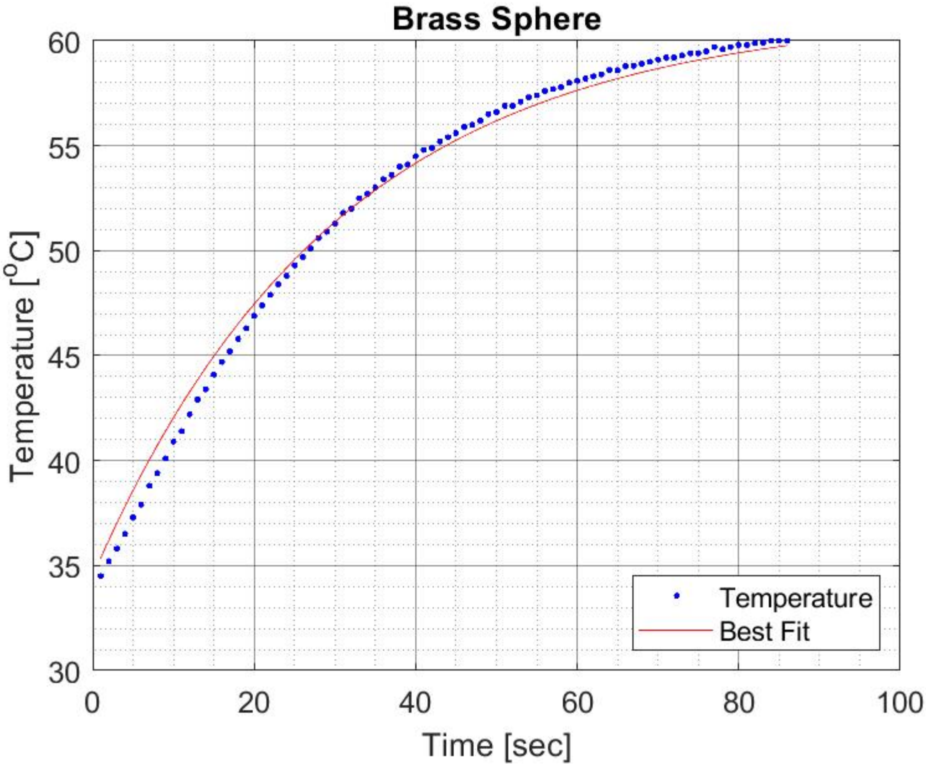
Q. Based on a best fit curve of the temperature variation with time, estimate the average heat transfer coefficient $\bar{h}_{overall}$.

Ans. Integrating the previous equation with time and then setting limits between t=0 to t=t, we get,

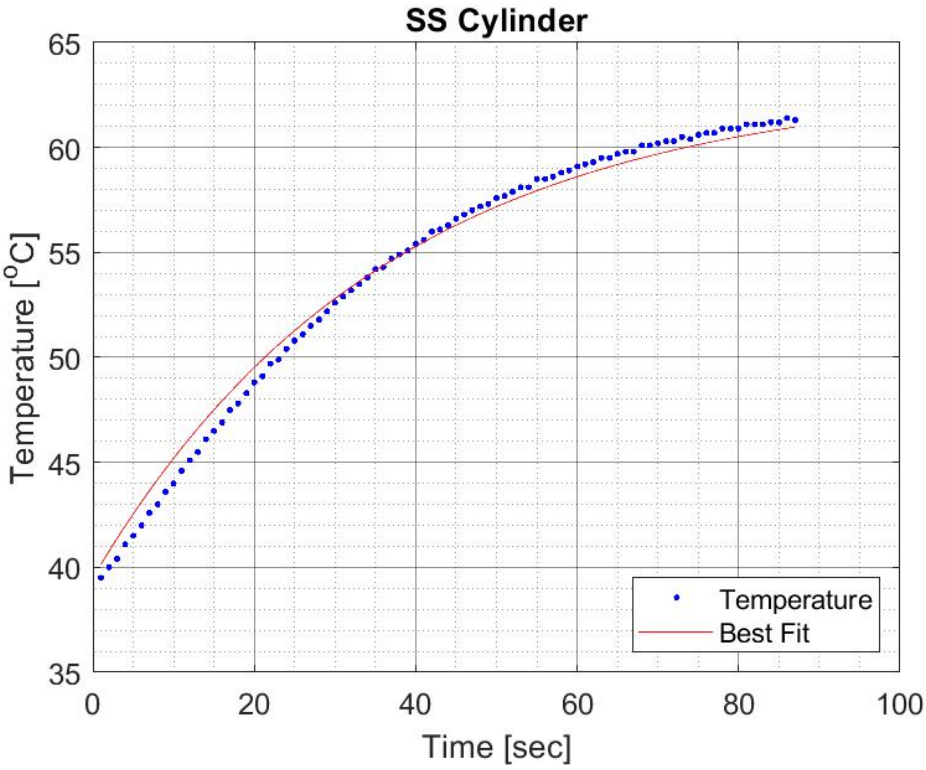
$$log\left(\frac{T_\infty - T(0)}{T_\infty - T(t)}\right) = \frac{A}{\rho V c_p}\int_0^t h(t)dt$$

$$\implies T(t) = T_\infty - (T_\infty - T_0)e^{-c\int_0^t h(t)dt}$$

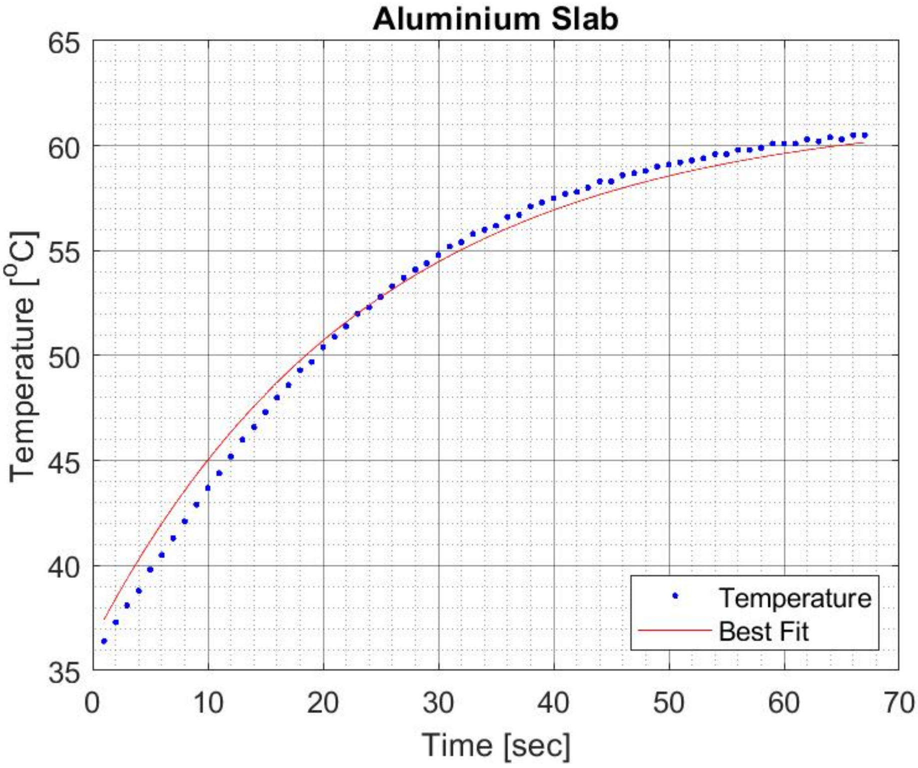
$$\text{where, } c = \frac{A}{\rho V c_p}$$



$h_{overall} = 717.20 W/m^2 K$



$h_{overall} = 363.40 W/m^2 K$



$h_{overall} = 379.00 W/m^2 K$

Q. Compare the values of average heat transfer coefficient found through the above two methods.

	$\bar{h}(W/m^2K)$	$h_{overall}(W/m^2K)$
Brass Sphere	750.66	717.20
SS Cylinder	394.11	363.40
Aluminium Slab	399.28	379.00

Q. Check and comment on the validity of the lumped capacitance approximation.

	h_bar	h_overall	h	Volume	Area	k	Bi
Brass Sphere	750.66	717.2	733.9	3.35E-05	0.005	111	0.04408
Aluminium Slab	399.28	379	389.1	6.00E-05	0.0158	190	0.007778
SS Cylinder	394.11	363.4	378.8	2.31E-05	0.0069	14	0.090421

Lumped Capacitance approximation seems to be perfectly valid in this case.