

MET 440 Test 3 Problem 2

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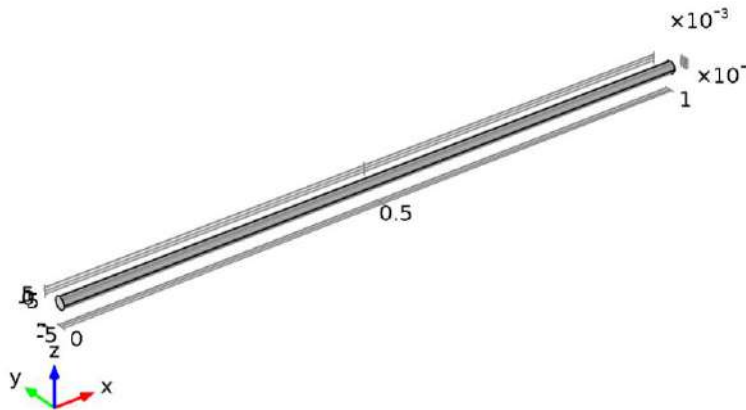
1 Purpose

To determine the diameter of the plastic rod whose center temperature is 30°C after 1338 seconds. To determine the temperature at the surface and at half the radius of the rod. Compare the analytical and the numerical results (diameter and temperatures) by computing the error.

2 Data & Variables

3 Drawing and Diagrams

3.1 Geometry 1



Geometry 1

Units

Length unit	m
Angular unit	deg

3.1.1 Cylinder 1 (cyl1)

Position

Description	Value
Position	{0, 0, 0}

Axis

Description	Value
Axis type	x - axis
Layers	

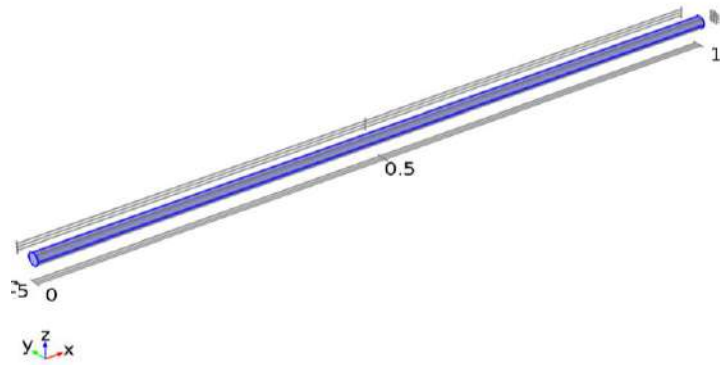
Size and shape

Description	Value
Radius	0.0098
Height	1

4 Materials

4.1 Materials

4.1.1 Material 1



Material 1

Selection

Geometric entity level	Domain
Selection	Domain 1

Material parameters

Name	Value	Unit
Thermal conductivity	0.19	W/(m*K)
Density	1190	kg/m ³
Heat capacity at constant pressure	1465	J/(kg*K)

Basic Settings

Description	Value
Thermal conductivity	{{0.19, 0, 0}, {0, 0.19, 0}, {0, 0, 0.19}}
Density	1190
Heat capacity at constant pressure	1465

5 Sources

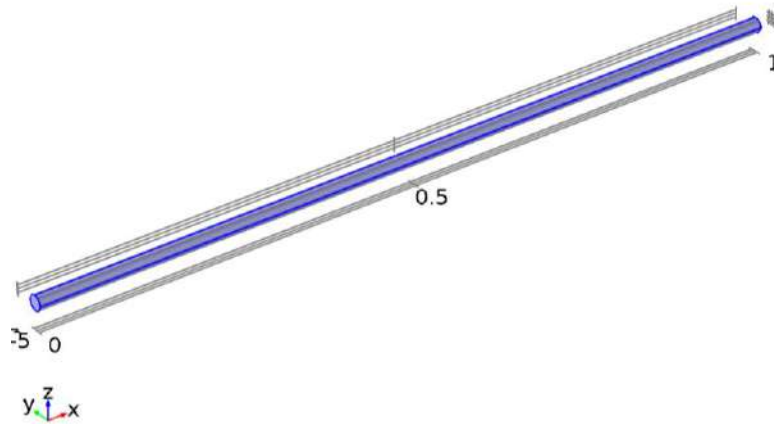
Bayazitoglu, Y., Ozisik, N., "A textbook for Heat Transfer Fundamentals", Begel House Inc

Test 3

6 Design Considerations

6.1 Heat Transfer in Solids

6.1.1 Heat Transfer in Solids 1



Heat Transfer in Solids 1

Selection

Geometric entity level	Domain
Selection	Domain 1

Equations

$$\rho C_p \frac{\partial T}{\partial t} + \rho C_p \mathbf{u} \cdot \nabla T + \nabla \cdot \mathbf{q} = Q + Q_{\text{ted}}$$
$$\mathbf{q} = -k \nabla T$$

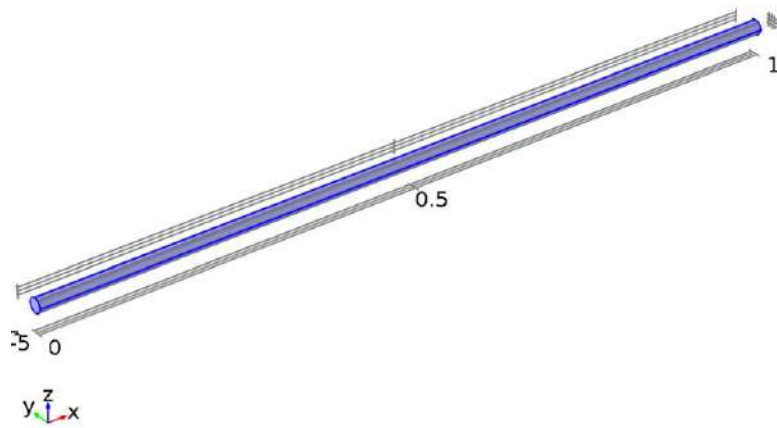
Settings

Description	Value
Thermal conductivity	From material
Density	From material
Heat capacity at constant pressure	From material

Properties from material

Property	Material	Property group
Thermal conductivity	Material 1	Basic
Density	Material 1	Basic
Heat capacity at constant pressure	Material 1	Basic

6.1.2 Plastic Rod Initial Temperature



Initial Values 1

Selection

Geometric entity level	Domain
Selection	Domain 1

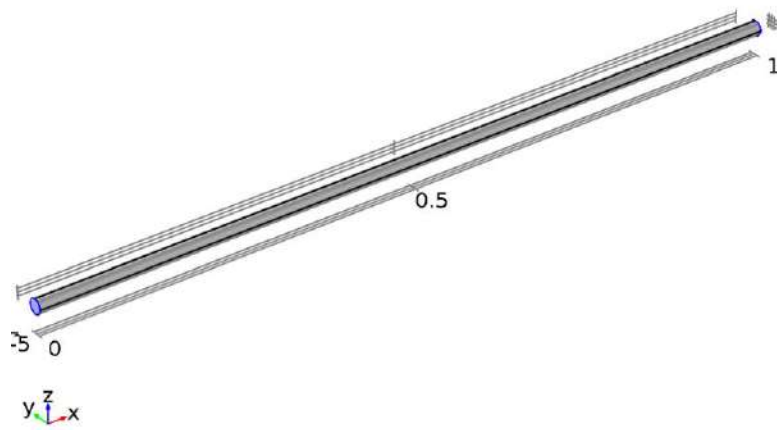
Settings

Description	Value
Temperature	70[degC]

Variables

Name	Expression	Unit	Description	Selection
ht.Tinit	70[degC]	K	Temperature	Domain 1

6.1.3 Thermal insulation at ends of rod because rod is infinitely long, so heat conduction only occurs radially



Thermal Insulation 1

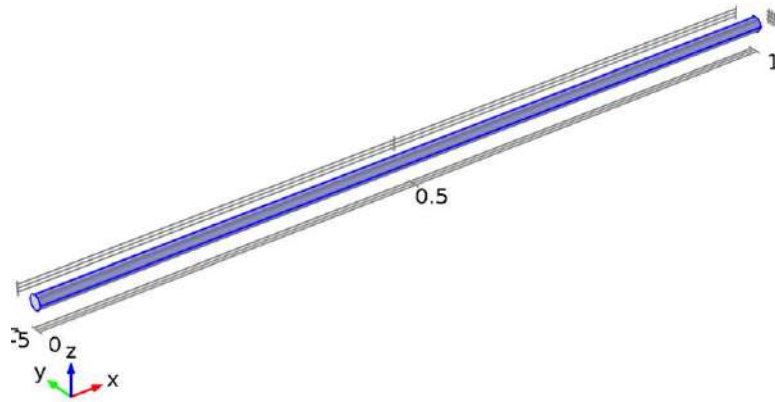
Selection

Geometric entity level	Boundary
Selection	Boundaries 1, 6

Equations

$$-\mathbf{n} \cdot \mathbf{q} = 0$$

6.1.4 Convection on lateral surface of rod



Heat Flux 1

Selection

Geometric entity level	Boundary
Selection	Boundaries 2–5

Equations

$$-\mathbf{n} \cdot \mathbf{q} = q_0$$

Settings

Description	Value
Heat flux	Convective heat flux
Heat transfer coefficient	User defined
Heat transfer coefficient	20.42
External temperature	25[degC]

Variables

Name	Expression	Unit	Description	Selection
ht.hf1.h	20.42	W/(m ² *K)	Heat transfer coefficient	Boundaries 2–5
ht.hf1.Text	25[degC]	K	External temperature	Boundaries 2–5

7 Procedure

7.1 Mesh 1

Mesh statistics

Description	Value
Minimum element quality	0.1903
Average element quality	0.7619
Tetrahedral elements	245273
Triangular elements	37176
Edge elements	2108
Vertex elements	8



Mesh 1

7.1.1 Size (size)

Settings

Description	Value
Maximum element size	0.02
Minimum element size	2.0E-4
Curvature factor	0.2
Maximum element growth rate	1.3
Predefined size	Extremely fine

Computation information

Computation time	8 min 6 s
CPU	Intel(R) Xeon(R) Platinum 8370C CPU @ 2.80GHz, 4 cores
Operating system	Windows Server 2012

7.2 Time Dependent

Study settings

Description	Value
Include geometric nonlinearity	Off

Times	Unit
range(0,1,1338)	s

Physics and variables selection

Physics interface	Discretization
Heat Transfer in Solids (ht)	physics

Mesh selection

Geometry	Mesh
Geometry 1 (geom1)	mesh1

7.3 Solver Configurations

7.3.1 Solution 1

Compile Equations: Time Dependent (st1)

Study and step

Description	Value
Use study	Study 1
Use study step	Time Dependent

Dependent Variables 1 (v1)

General

Description	Value
Defined by study step	Time Dependent

Initial values of variables solved for

Description	Value
-------------	-------

Description	Value
Solution	Zero

Values of variables not solved for

Description	Value
Solution	Zero

Temperature (comp1.T) (comp1_T)

General

Description	Value
Field components	comp1.T

Time-Dependent Solver 1 (t1)

General

Description	Value
Defined by study step	Time Dependent
Time	{0, 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31, 32, 33, 34, 35, 36, 37, 38, 39, 40, 41, 42, 43, 44, 45, 46, 47, 48, 49, 50, 51, 52, 53, 54, 55, 56, 57, 58, 59, 60, 61, 62, 63, 64, 65, 66, 67, 68, 69, 70, 71, 72, 73, 74, 75, 76, 77, 78, 79, 80, 81, 82, 83, 84, 85, 86, 87, 88, 89, 90, 91, 92, 93, 94, 95, 96, 97, 98, 99, 100, 101, 102, 103, 104, 105, 106, 107, 108, 109, 110, 111, 112, 113, 114, 115, 116, 117, 118, 119, 120, 121, 122, 123, 124, 125, 126, 127, 128, 129, 130, 131, 132, 133, 134, 135, 136, 137, 138, 139, 140, 141, 142, 143, 144, 145, 146, 147, 148, 149, 150, 151, 152, 153, 154, 155, 156, 157, 158, 159, 160, 161, 162, 163, 164, 165, 166, 167, 168, 169, 170, 171, 172, 173, 174, 175, 176, 177, 178, 179, 180, 181, 182, 183, 184, 185, 186, 187, 188, 189, 190, 191, 192, 193, 194, 195, 196, 197, 198, 199, 200, 201, 202, 203, 204, 205, 206, 207, 208, 209, 210, 211, 212, 213, 214, 215, 216, 217, 218, 219, 220, 221, 222, 223, 224, 225, 226, 227, 228, 229, 230, 231, 232, 233, 234, 235, 236, 237, 238, 239, 240, 241, 242, 243, 244, 245, 246, 247, 248, 249, 250, 251, 252, 253, 254, 255, 256, 257, 258, 259, 260, 261, 262, 263, 264, 265, 266, 267, 268, 269, 270, 271, 272, 273, 274, 275, 276, 277, 278, 279, 280, 281, 282, 283, 284, 285, 286, 287, 288, 289, 290, 291, 292, 293, 294, 295, 296, 297, 298, 299, 300, 301, 302, 303, 304, 305, 306, 307, 308, 309, 310, 311, 312, 313, 314, 315, 316, 317, 318, 319, 320, 321, 322, 323, 324, 325, 326, 327, 328, 329, 330, 331, 332, 333, 334, 335, 336, 337, 338, 339, 340, 341, 342, 343, 344, 345, 346, 347, 348, 349, 350, 351, 352, 353, 354, 355, 356, 357, 358, 359, 360, 361, 362, 363, 364, 365, 366, 367, 368, 369, 370, 371, 372, 373, 374, 375, 376, 377, 378, 379, 380, 381, 382, 383, 384, 385, 386, 387, 388, 389, 390, 391, 392, 393, 394, 395, 396, 397, 398, 399, 400, 401, 402, 403, 404, 405, 406, 407, 408, 409, 410, 411, 412, 413, 414, 415, 416, 417, 418, 419, 420, 421, 422, 423, 424, 425, 426, 427, 428, 429, 430, 431, 432, 433, 434, 435, 436, 437, 438, 439, 440, 441, 442, 443, 444, 445, 446,

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Time stepping

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Time-stepping completed.

Time-Dependent Solver 1 in Solution 1: Solution time: 482 s (8 minutes, 2 seconds)

Physical memory: 2.46 GB

Virtual memory: 2.54 GB

Fully Coupled 1 (fc1)

General

Description	Value
Linear solver	Iterative 1

Method and termination

Description	Value
Damping factor	0.9
Jacobian update	Once per time step
Maximum number of iterations	5

Iterative 1 (i1)

General

Description	Value
Factor in error estimate	20

Multigrid 1 (mg1)

General

Description	Value
Use hierarchy in geometries	Geometry 1

Presmoothing (pr)

SOR Line 1 (sl1)

Main

Description	Value
Relaxation factor	0.2

Secondary

Description	Value
Number of secondary iterations	2
Relaxation factor	0.5

Postsmoother (po)

SOR Line 1 (sl1)

Main

Description	Value
Relaxation factor	0.2

Secondary

Description	Value
Number of secondary iterations	2
Relaxation factor	0.5

Coarse Solver (cs)

Direct 1 (d1)

General

Description	Value
Solver	PARDISO

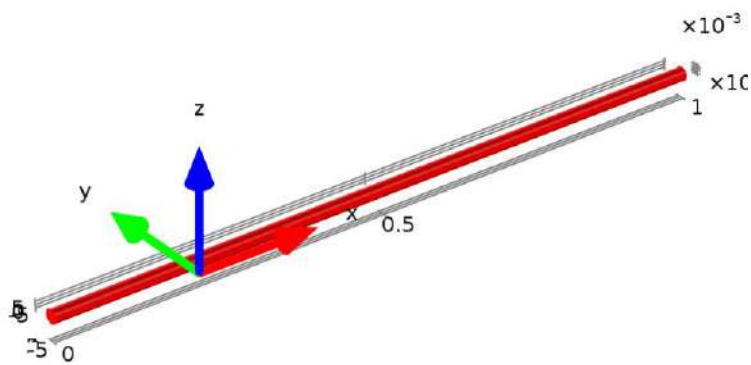
8 Calculations

8.1 Data Sets

8.1.1 Study 1/Solution 1

Solution

Description	Value
Solution	Solution 1
Component	Save Point Geometry 1



Data set: Study 1/Solution 1

8.1.2 Cut Point 3D 1

Data

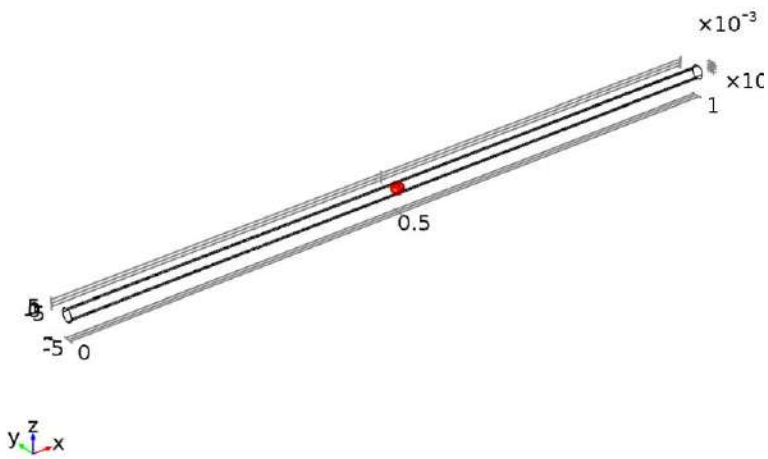
Description	Value
Data set	Study 1/Solution 1

Point data

Description	Value
Entry method	Coordinates

Settings

Description	Value
x	0.5
y	0
z	0



Data set: Cut Point 3D 1

8.1.3 Cut Point 3D 2

Data

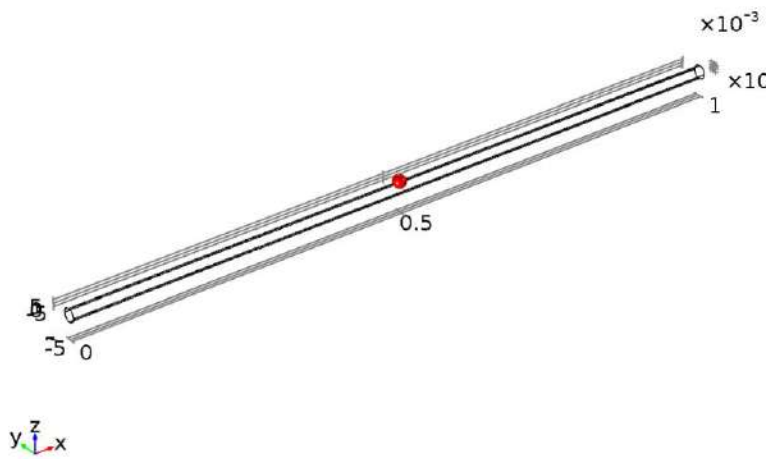
Description	Value
Data set	Study 1/Solution 1

Point data

Description	Value
Entry method	Coordinates

Settings

Description	Value
x	0.5
y	0
z	0.0098



Data set: Cut Point 3D 2

8.1.4 Cut Point 3D 3

Data

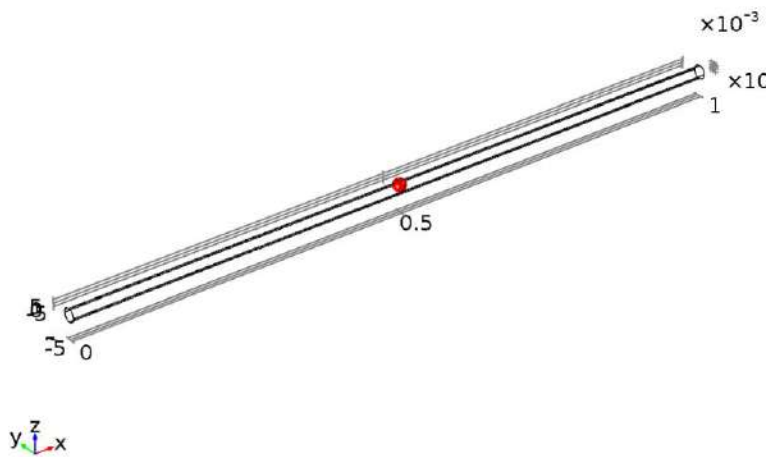
Description	Value
Data set	Study 1/Solution 1

Point data

Description	Value
Entry method	Coordinates

Settings

Description	Value
x	0.5
y	0
z	0.0049



Data set: Cut Point 3D 3

8.2 Derived Values

8.2.1 Point Evaluation 1

Data

Description	Value
Data set	Cut Point 3D 1

Expression

Description	Value
Expression	T
Unit	degC
Description	Temperature

8.2.2 Point Evaluation 2

Data

Description	Value
Data set	Cut Point 3D 2

Expression

Description	Value
Expression	T
Unit	degC
Description	Temperature

8.2.3 Point Evaluation 3

Data

Description	Value
Data set	Cut Point 3D 3

Expression

Description	Value
Expression	T
Unit	degC
Description	Temperature

8.3 Tables

8.3.1 Table 1

Point Evaluation 1 (T)

Table 2

Time (s)	Temperature (degC), Point: (0.5, 0, 0)	Temperature (degC), Point: (0.5, 0, 0)	Temperature (degC), Point: (0.5, 0, 0)	Temperature (degC), Point: (0.5, 0, 0)
1338.0	30.690	30.338	29.558	30.020

8.3.2 Table 2

Point Evaluation 2 (T)

Table 3

Time (s)	Temperature (degC), Point: (0.5, 0, 0.0098)
1338.0	28.162

8.3.3 Table 3

Point Evaluation 3 (T)

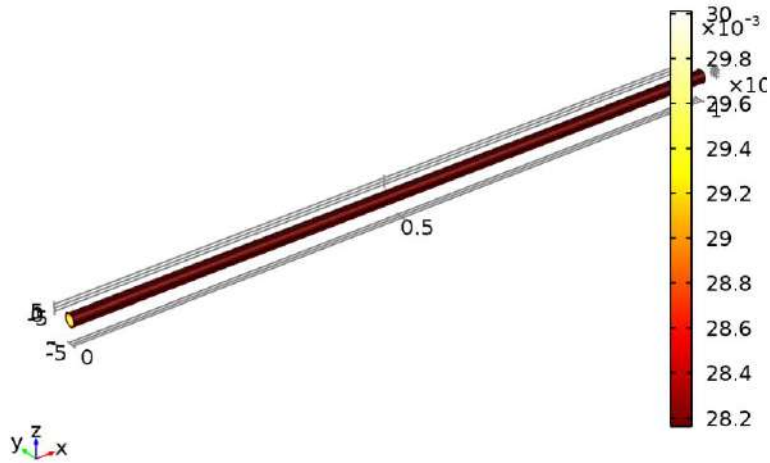
Table 4

Time (s)	Temperature (degC), Point: (0.5, 0, 0.0049)
1338.0	29.518

8.4 Plot Groups

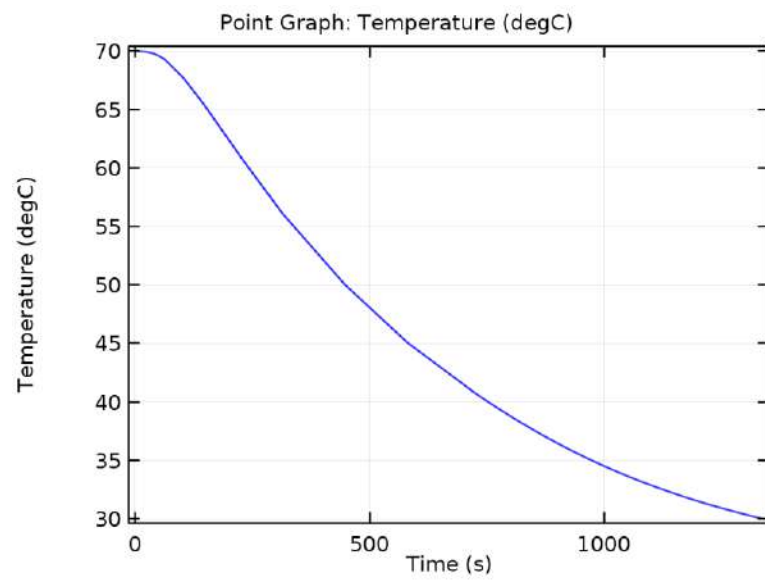
8.4.1 Temperature (ht)

Time=1338 s Surface: Temperature (degC)



Time=1338 s Surface: Temperature (degC)

8.4.2 1D Plot Group 3



Point Graph: Temperature (degC)