Freezing Time by Plank's Equation

Freezing time of a slab, cylinder or sphere of food from density, latent heat, freezing point, medium temperature, size, h and frozen conductivity (Plank).

Method: Plank's equation: t = ρλ/(T_f − T_a) · (P a/h + R a²/k); P; R = 1/2; ...

Input parameters

Unit system: SI

Parameter	Value	Unit
Shape	Infinite slab (a = thickness)	
Thickness or diameter	50.000	mm
Density	1,000.0	kg/m³
Latent heat of the food (per kg)	250.00	kJ/kg
Initial freezing point	-2.0000	°C
Freezing medium temperature	-30.000	°C
Surface heat transfer coefficient	25.000	W/(m²·K)
Conductivity of the frozen food	1.5000	W/(m·K)

Calculated results

Parameter	Value	Unit
Shape factor P	0.50000	
Shape factor R	0.12500	
Freezing time	2.9969	h

Notes for this case

- Plank gives the phase-change time only; pre-cooling and sub-cooling add to it.

Formula and method

$$t_f = \frac{\rho\lambda}{T_f - T_a}\left(\frac{Pa}{h} + \frac{Ra^2}{k}\right)$$

Variables

shape	Shape	-
a	Thickness or diameter	m
ρ	Density	kg/m³
λ	Latent heat of the food (per kg)	J/kg
T_f	Initial freezing point	K
T_a	Freezing medium temperature	K
h	Surface heat transfer coefficient	W/(m²·K)
k	Conductivity of the frozen food	W/(m·K)
P	Shape factor P	-
R	Shape factor R	-
t_f	Freezing time	s

Method and standards

Plank's equation.

Assumptions and limits

- Uniform freezing point; no sensible heat. Plank is known to underestimate practical freezing times because it leaves out pre-cooling to the freezing point and tempering below it; methods that add these (for example Pham or Cleland and Earle) are not offered here, so allow a margin.

References

- Plank's equation: $t = \rho\lambda/(T_f - T_a) \cdot (P\,a/h + R\,a^2/k)$; P
- R = 1/2
- 1/8 (slab)
- 1/4
- 1/16 (cylinder)
- 1/6
- 1/24 (sphere)

Report details

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Release checks	2 reference cases of this calculator, computed independently, are checked on every release

Results are for engineering estimation. Verify critical designs against the referenced standards and your own data.

This calculator online

https://calc.firecad.com/chemical/food-dairy/food-freezing-time-plank

Open this case on calc.firecad.com →

Reopens the calculator with the inputs of this report.