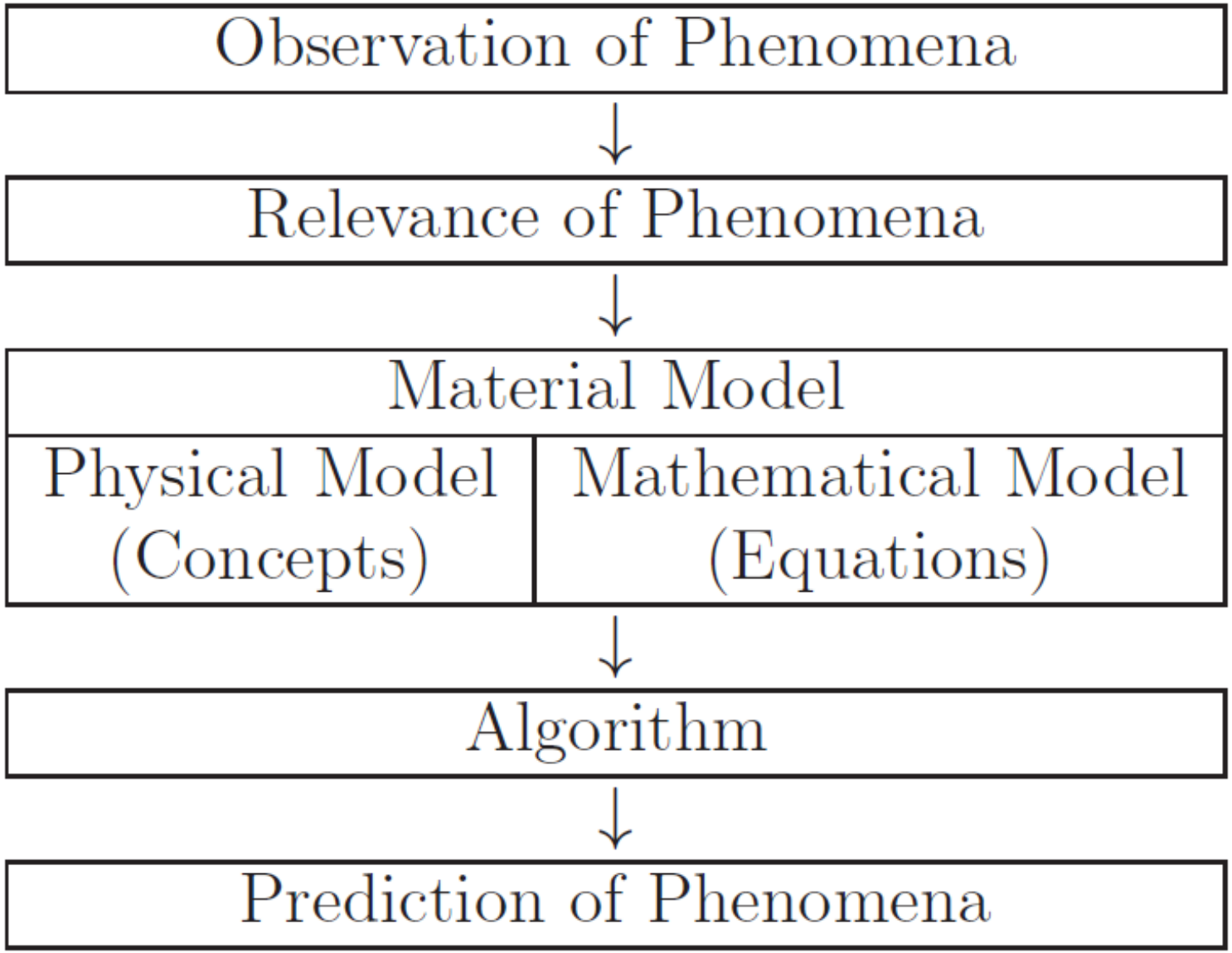
It‘s the Mechanics, Stupid!

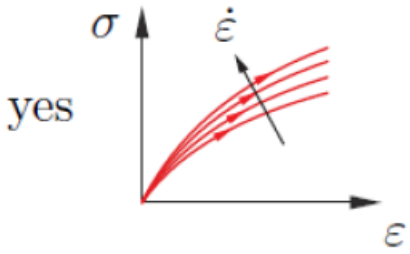
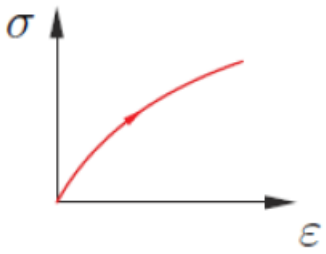
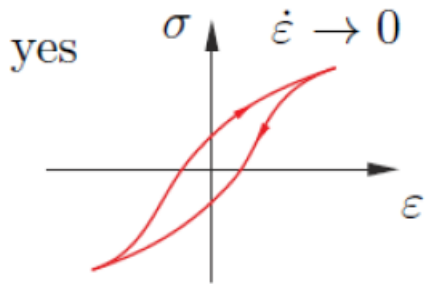
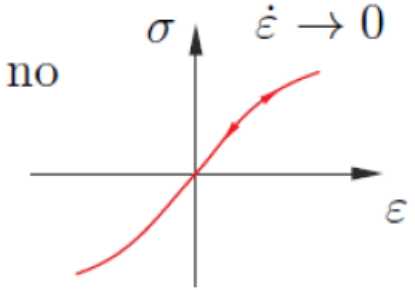
-The Joy of Material Modelling-

*modified from Bill Clinton‘s presidential campaign 1992

Modelling


Observation of Phenomena
Relevance of Phenomena
Material Model
Physical Model (Concepts)
Mathematical Model (Equations)
Algorithm
Prediction of Phenomena

Phenotypes

		rate-dependent behaviour	
		yes 	no 
quasi-static hysteresis	yes 	viscoplasticity	plasticity
	no 	viscoelasticity	elasticity

Phenotypes

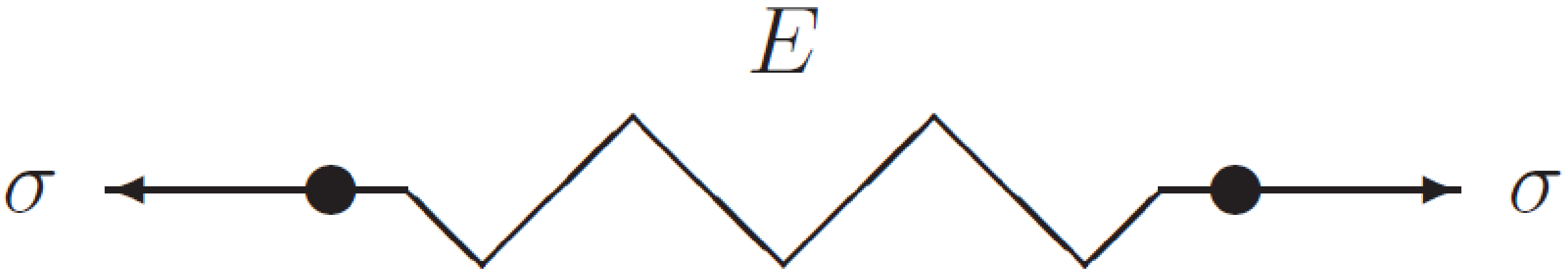
Mechanical Phenomena	Rate-Independent	Rate-Dependent
Quasi-Statically Reversible	Elasticity	Visco-Elasticity
Quasi-Statically Irreversible	Plasticity	Visco-Plasticity

Elasticity

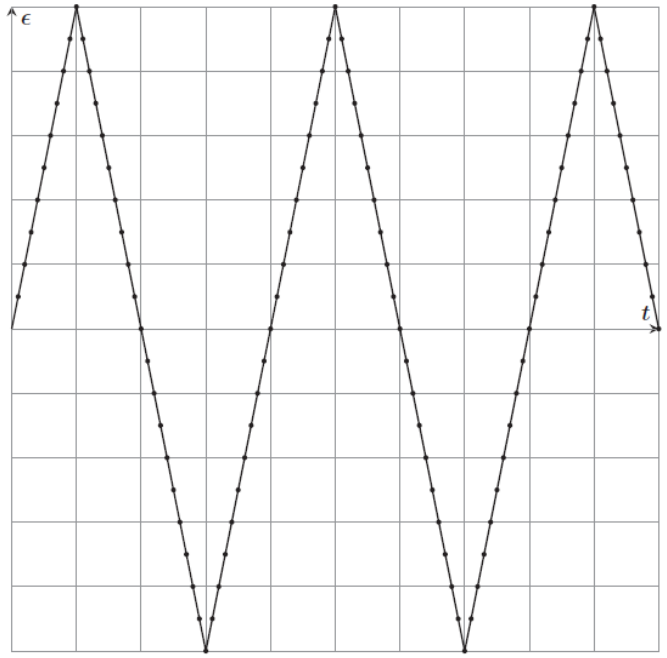
Hooke Model

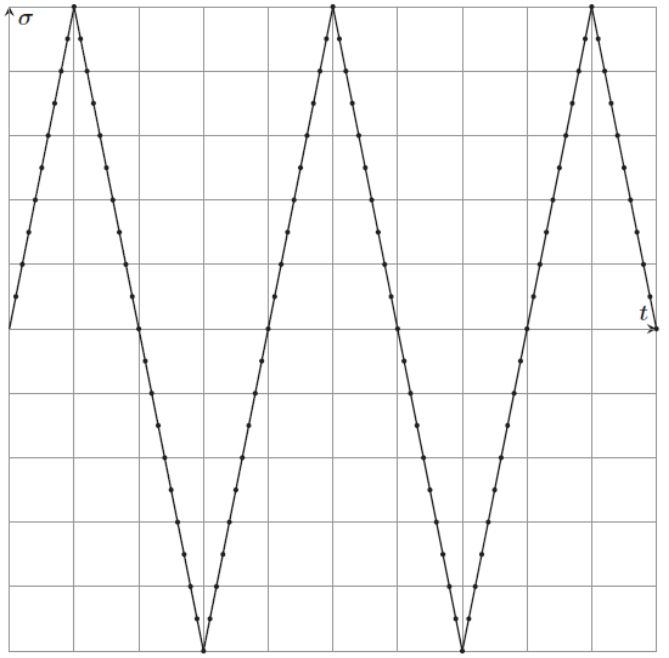
Robert Hooke [b. 18.7.1635, Isle of Wight, England, d. 3.3.1703, London, England] was polymath, Curator of Experiments of the Royal Society, Professor of Geometry at the Gresham College in London, Surveyor of the City of London and architect. He largely contributed to mechanics, microscopy, astronomy, meteorology and geology. Due to his tract "De potentia restitutiva" on the elasticity of springs from 1678, the Hooke model of linear elastic solids is named in his honour.

Hooke Model



Hooke Model

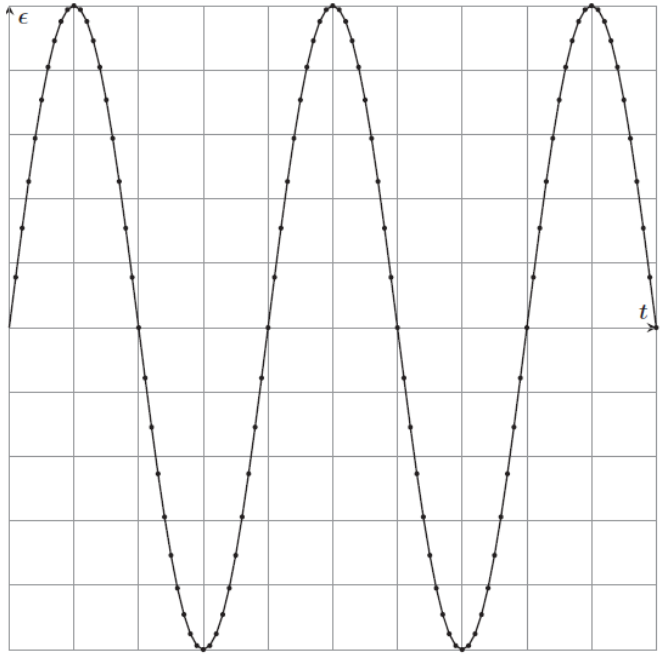


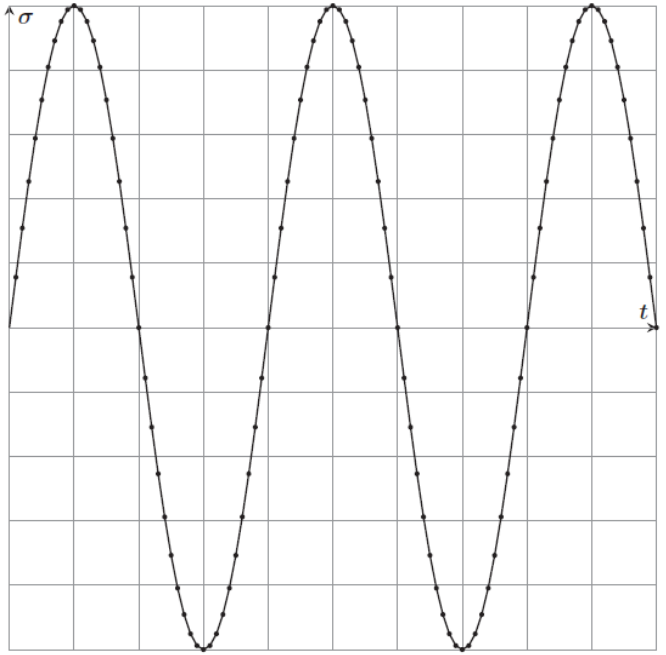


no phase shift

zig-zag strain & stress histories

Hooke Model

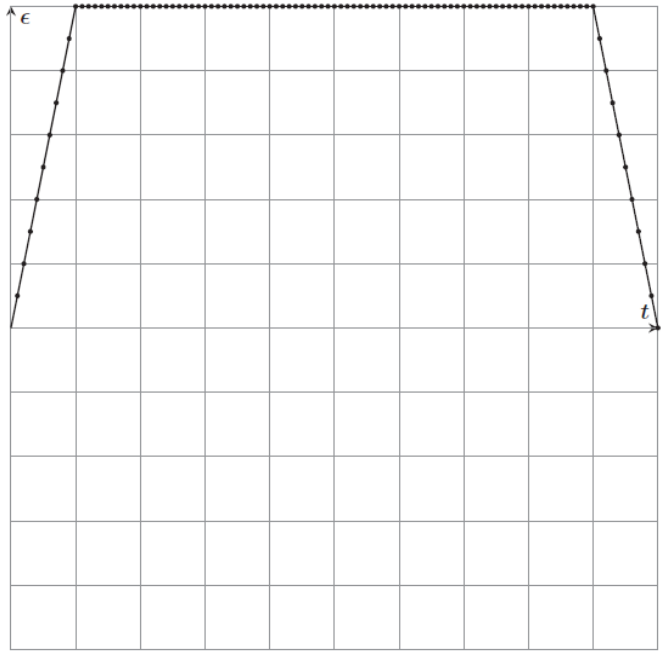


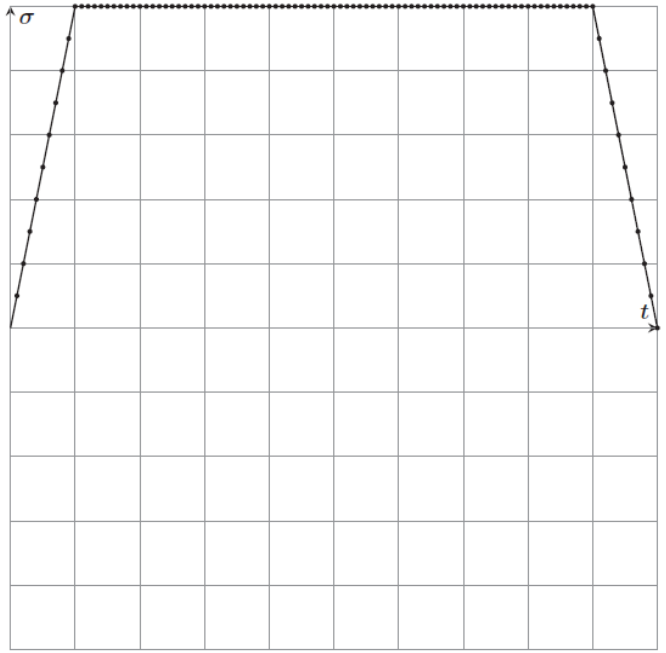


no phase shift

sine strain & stress histories

Hooke Model





no creep
no relaxation
solid-like

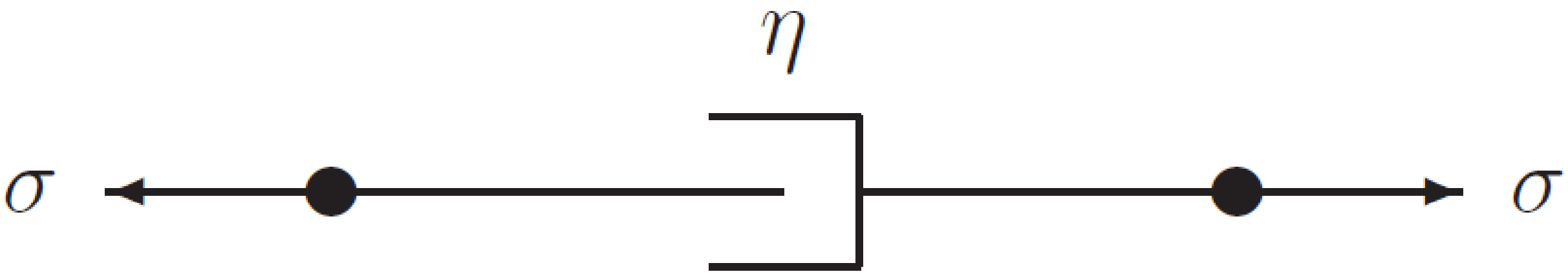
ramp strain & stress histories

Visco-Elasticity

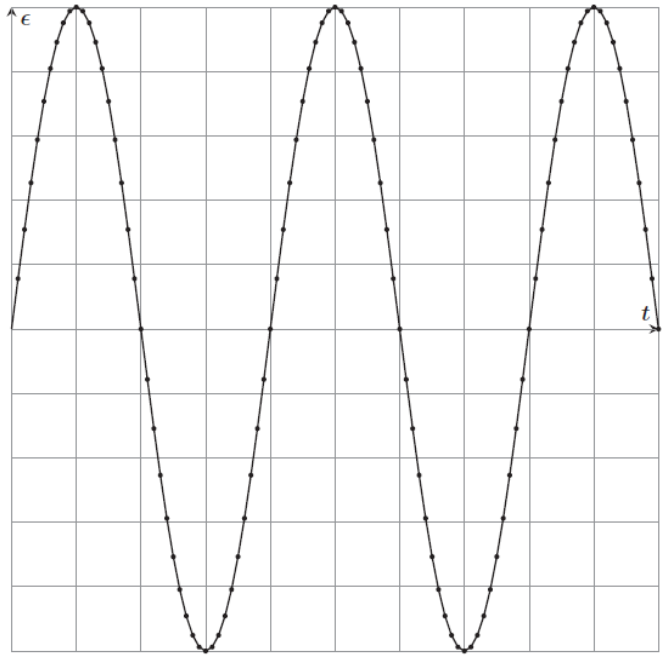
Newton Model

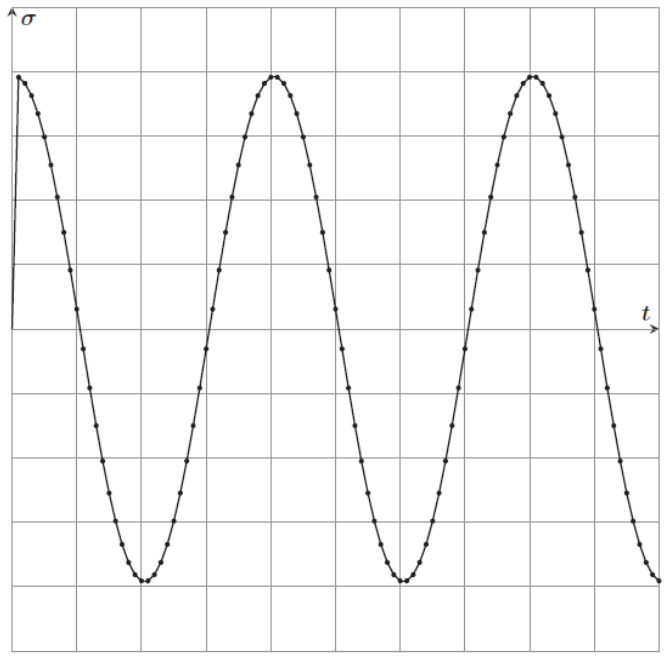
Sir Isaac Newton [b. 4.1.1643, Woolsthorpe, England, d. 31.3.1727, London, England] was Lucasian Professor of Mathematics at the Trinity College in Cambridge. He laid the foundations of classical mechanics in his landmark treatise "Philosophiae Naturalis Principia Mathematica" from 1687. Likewise he is the co-founder of differential and integral calculus (as the opponent to Leibniz) and greatly contributed to optics. The Newton model of viscous fluids is named after him.

Newton Model



Newton Model

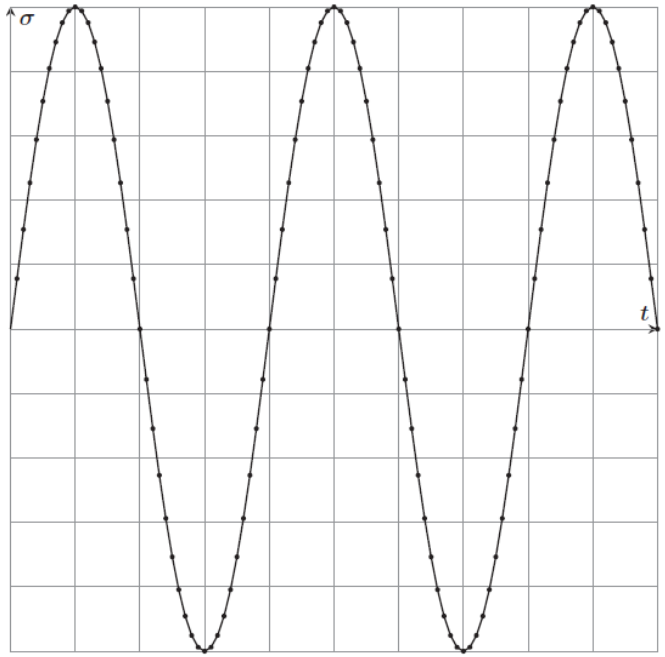


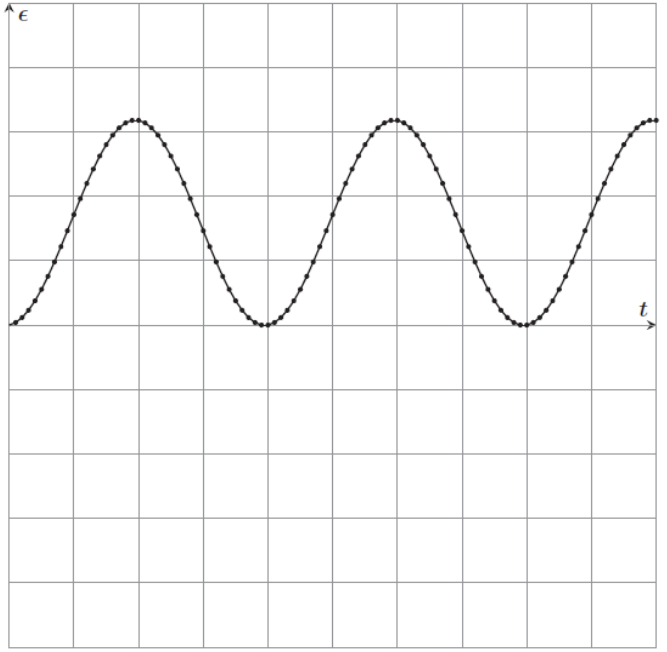


phase shift
fluid-like

sine strain history

Newton Model



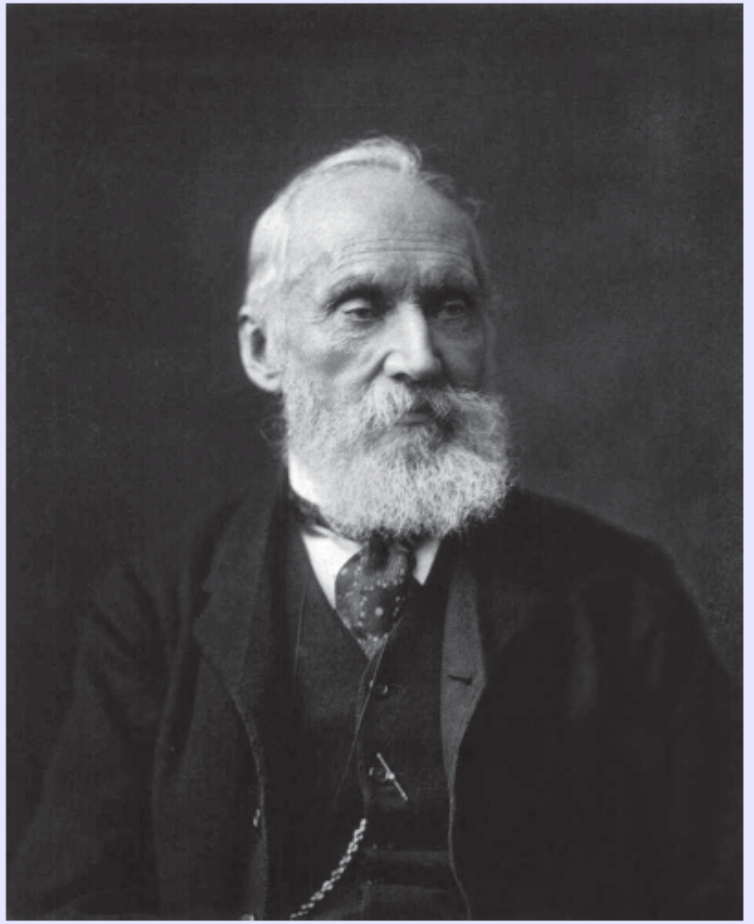


phase shift
fluid-like

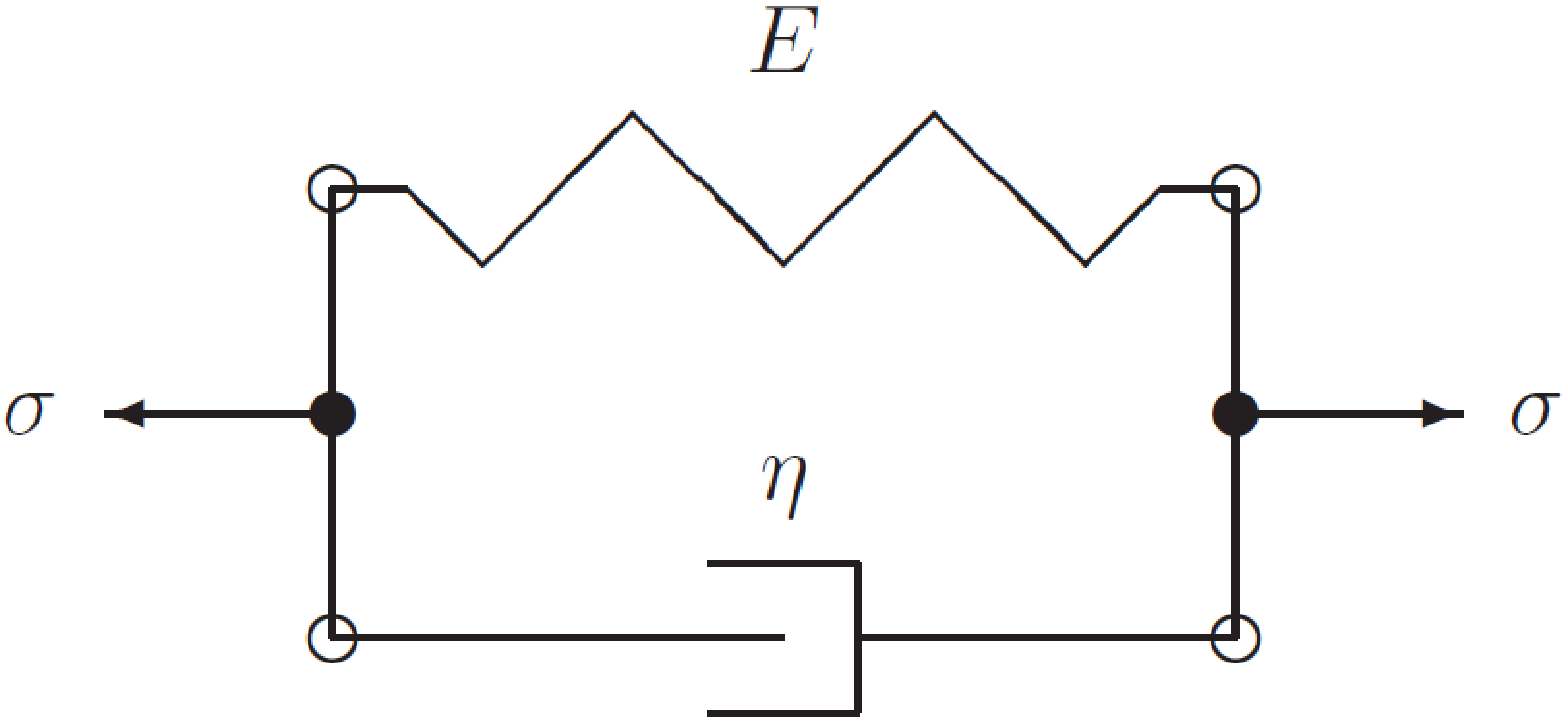
sine stress history

Kelvin Model

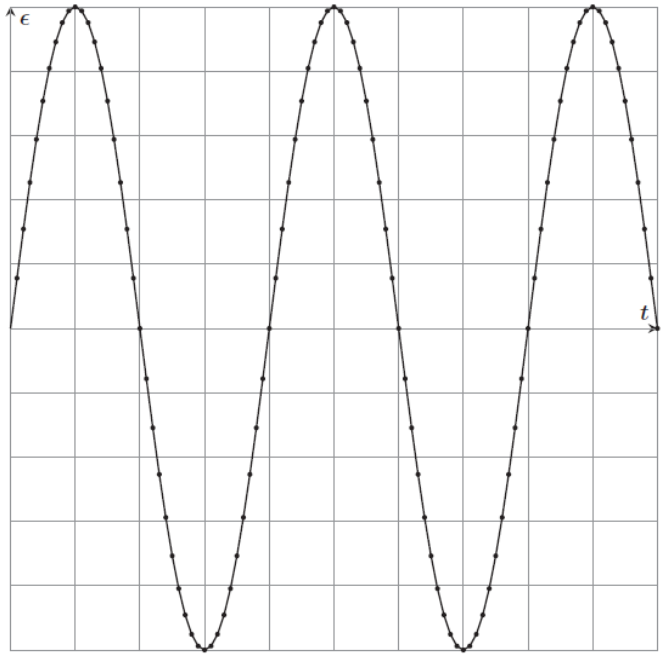
Sir William Thomson (Lord Kelvin) [b. 26.6.1824, Belfast, Ireland, d. 17.12.1907, Netherhall, Scotland] was Professor of Theoretical Physics at the University of Glasgow. He worked mainly on thermo- and electrodynamics for which he developed ingenious (measuring) devices. The so-called Kelvin scale is based on his correct determination of the absolute zero temperature. 1892 he became Baron Kelvin in recognition of his achievements in thermodynamics. The Kelvin model for visco-elastic solids is named after him.

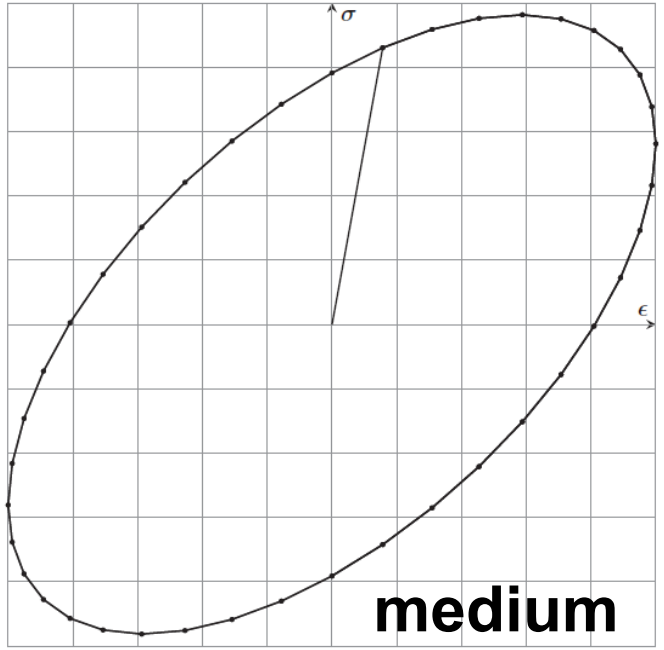


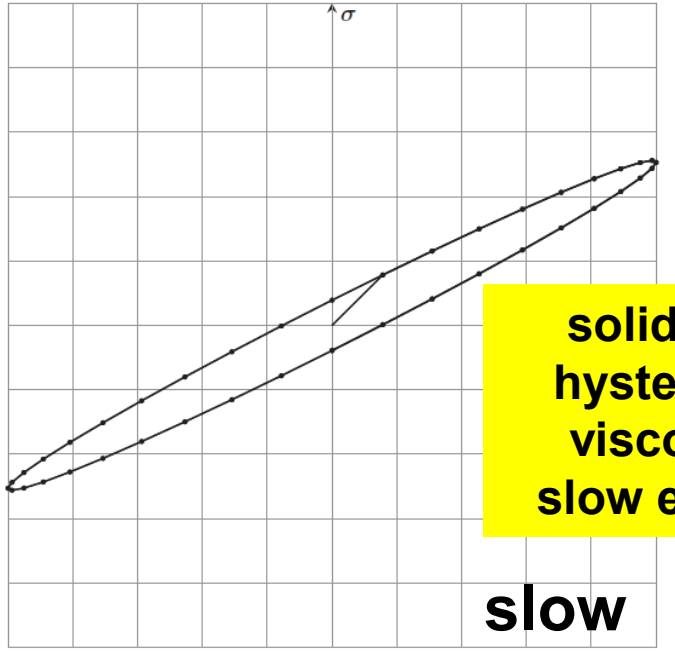
Kelvin Model



Kelvin Model



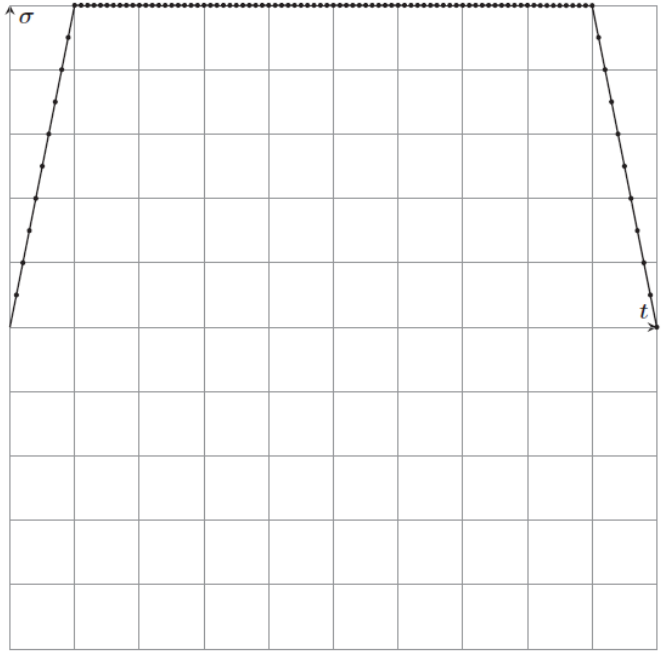


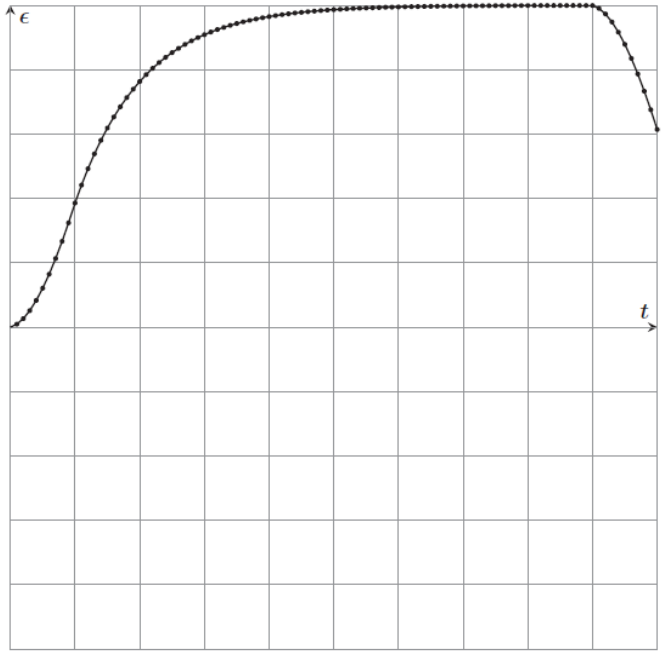


solid-like
hysteresis
viscosity
slow elastic

sine strain history

Kelvin Model



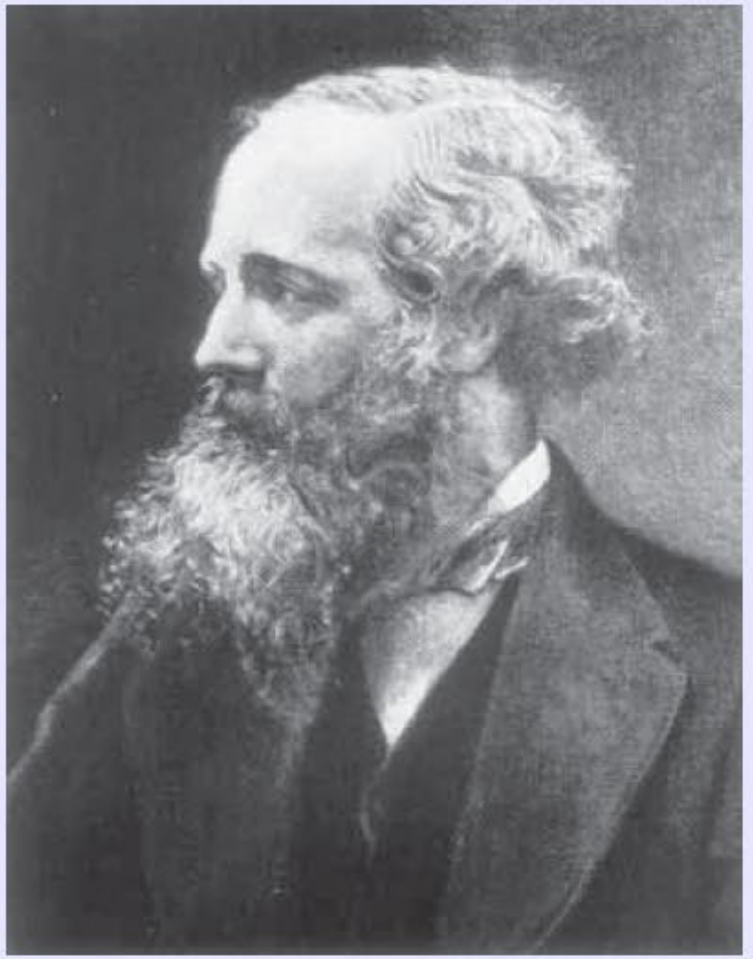


solid-like creep

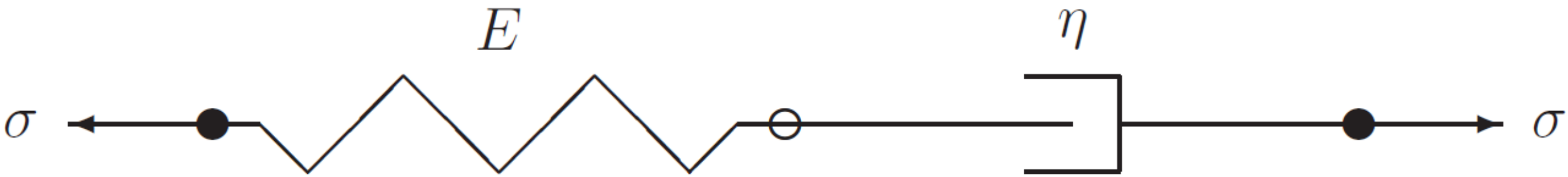
ramp stress history

Maxwell Model

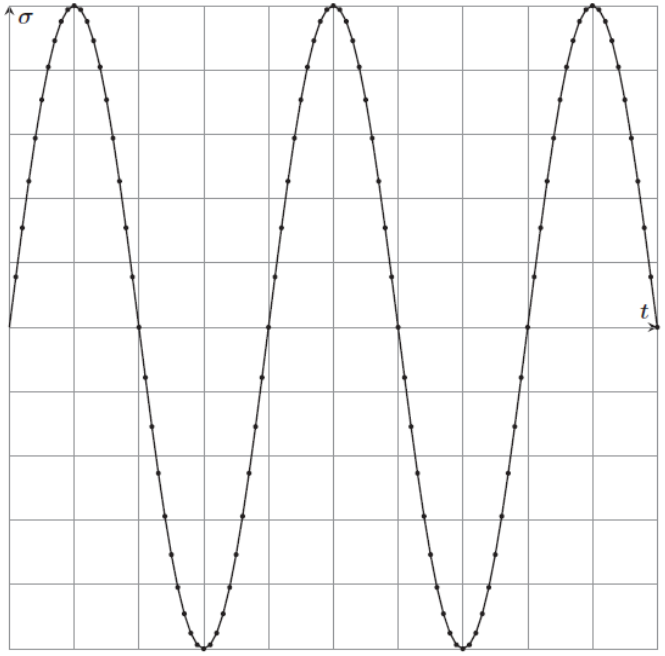
James Clerk Maxwell [b. 13.6.1831 Edinburgh, Scotland, d. 5.11.1879 Cambridge, England] was Professor of Physics at various British Universities. He is best known for his unification of electricity, magnetism and light in the so-called Maxwell equations of electromagnetism that imply i.a. the finite speed of light, see his "A Treatise on Electricity and Magnetism" from 1873. As part of his occupation with the dynamical theory of gases he proposed in 1867 what is now called the Maxwell model for visco-elastic fluids.

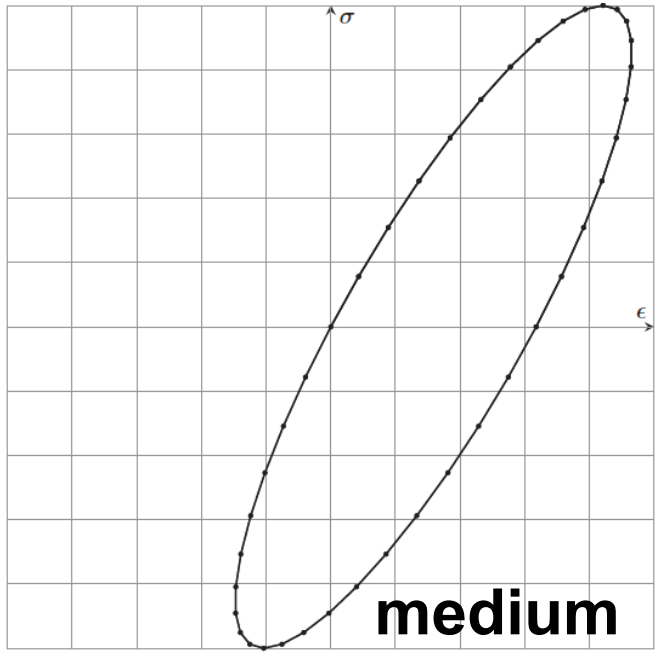


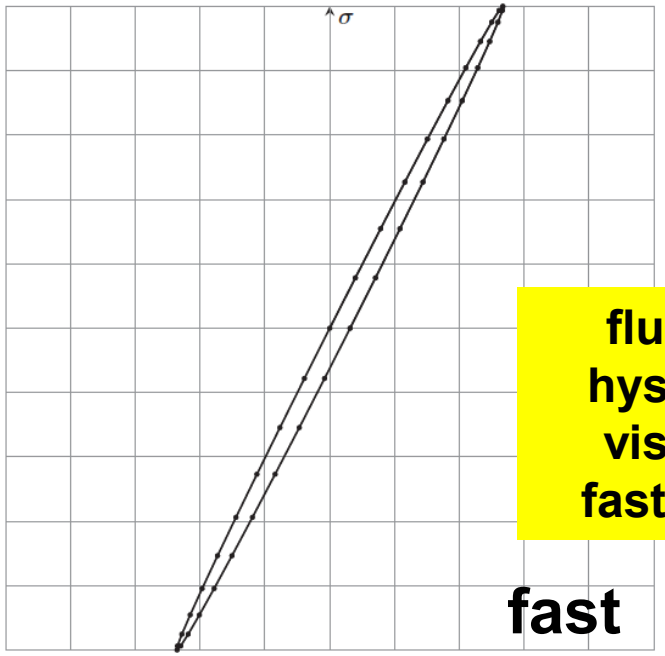
Maxwell Model



Maxwell Model



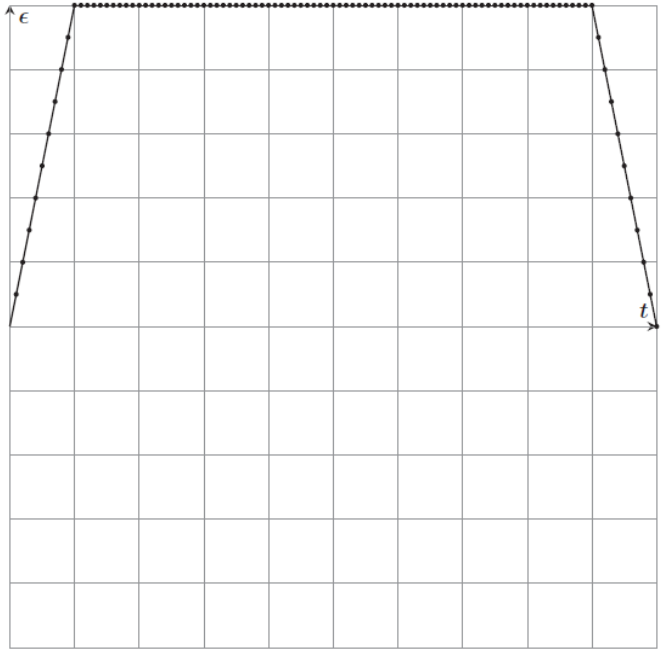


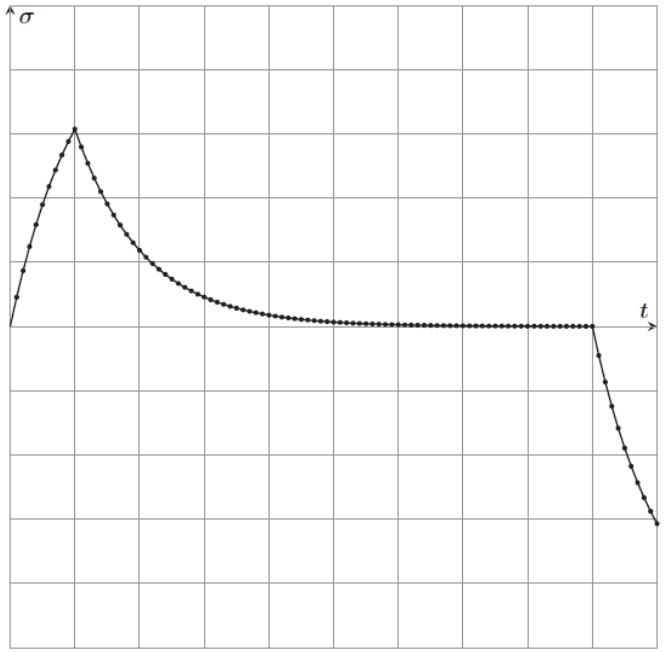


fluid-like
hysteresis
viscosity
fast elastic

sine stress history

Maxwell Model





fluid-like relaxation

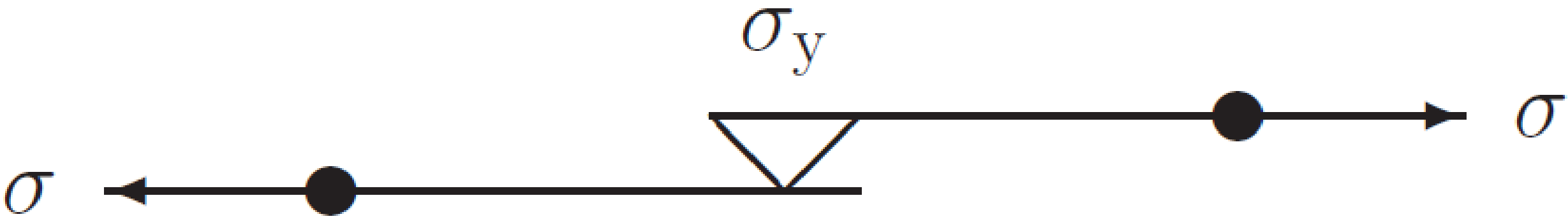
ramp strain history

Plasticity

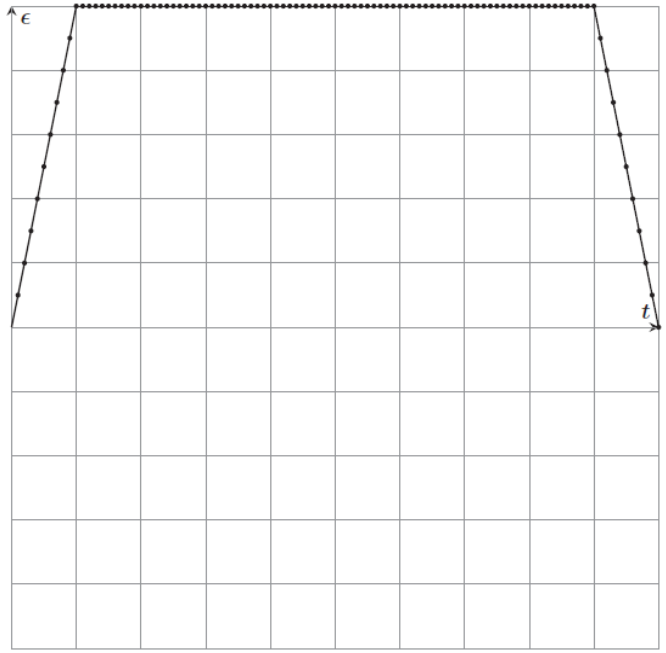
Saint Venant Model

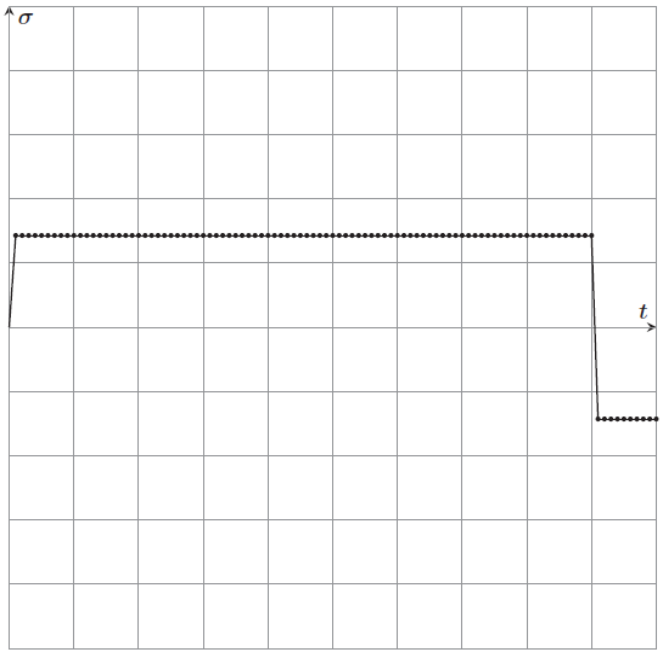
Adhémar Jean Claude Barré de Saint-Venant [b. 23.8.1797, Villiers-en-Biére, Seine-et-Marne, France, d. 6.1.1886, Saint-Ouen, Loir-et-Cher, France] worked initially as Engineer and later became Professor of Mathematics at the École des Ponts et Chaussées in Paris. He contributed largely to mechanics, elasticity, plasticity, hydrostatics and hydrodynamics. He was first to present a correct derivation of the Navier-Stokes equations in 1843. The St. Venant model for rigid-plastic solids is named after him.

Saint Venant Model



Saint Venant Model

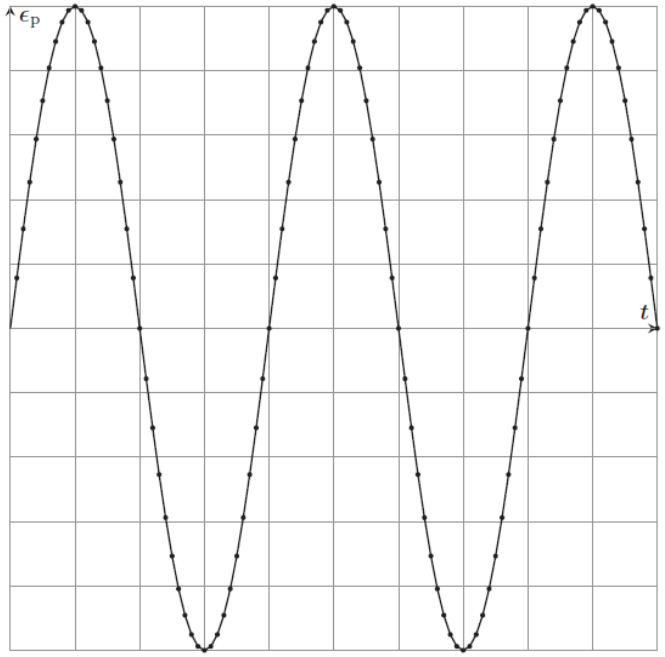


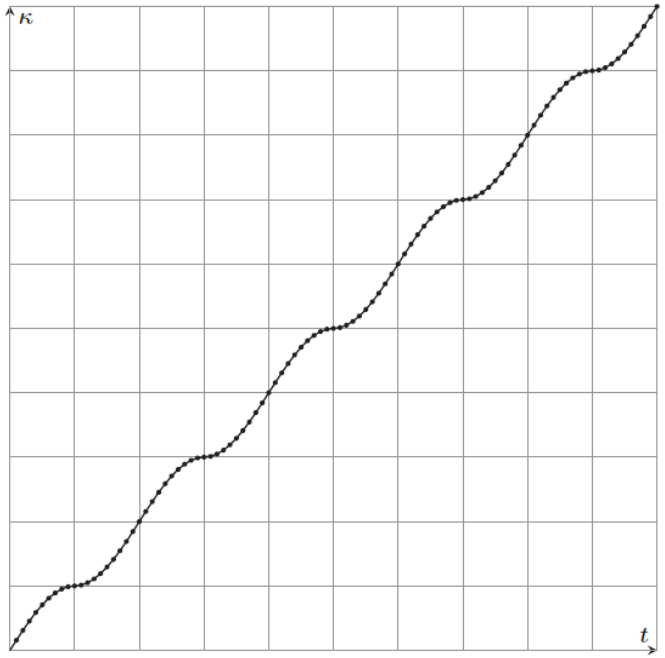


yield stress
rigid solid
irreversibility
no viscosity

ramp strain history

Saint Venant Model





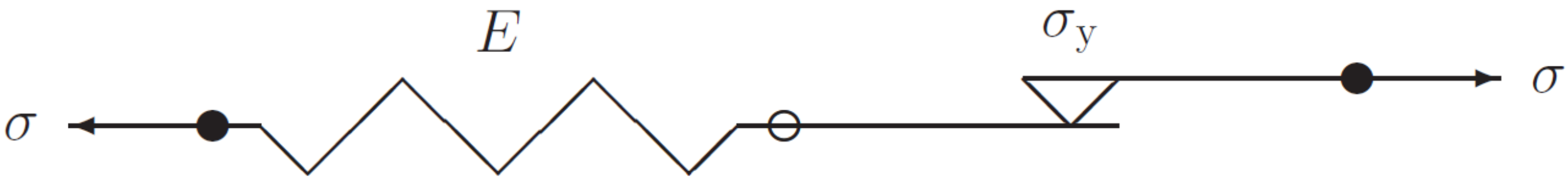
yield stress
irreversibility
internal var.
no viscosity

sine strain history

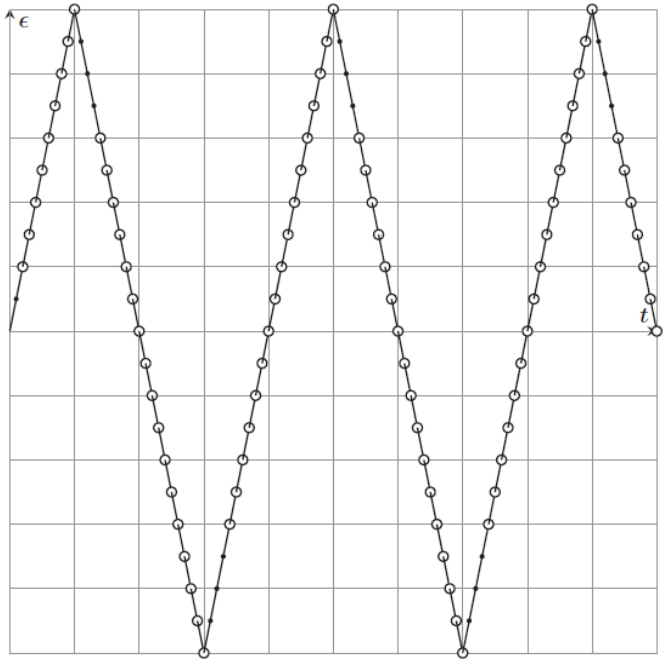
Prandtl Model

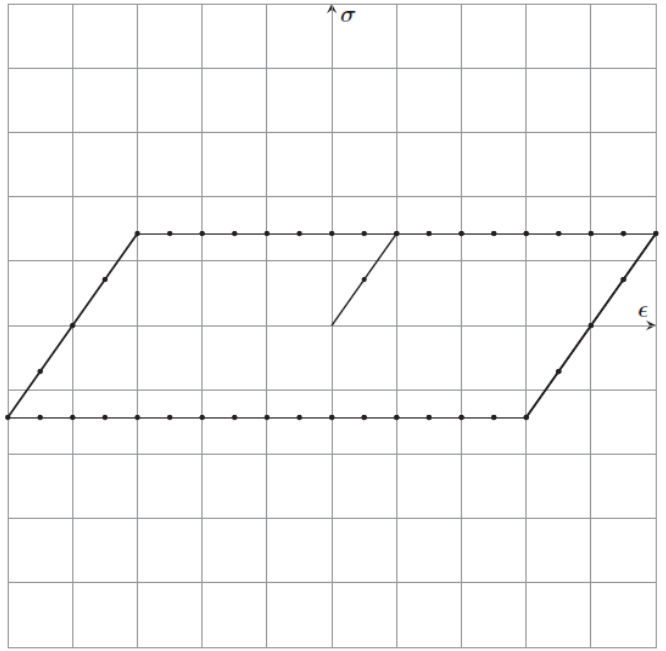
Ludwig Prandtl [b. 4.2.1875, Freising, Germany, d. 15.8.1953, Göttingen, Germany] was Professor of Fluid Mechanics at the University Göttingen and the attached Kaiser Wilhelm Institute for Flow Research. He is the founding father of the boundary layer theory in fluid dynamics. Although mainly known for his research in aerodynamics, he also worked on problems of plasticity. His contribution to dry friction from 1928 gave an atomistic explanation of the static friction force. The Prandtl model thus describes solids displaying a yield stress after an initial elastic phase.

Prandtl Model



Prandtl Model

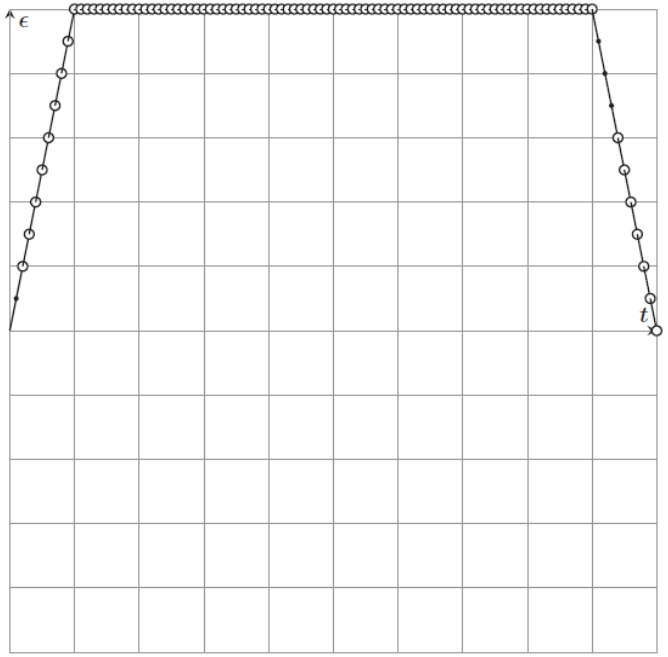


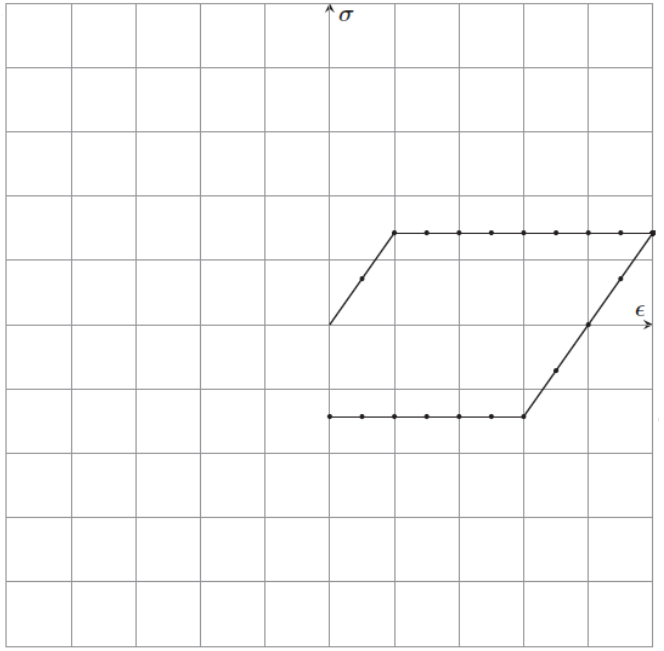


yield stress
irreversibility
no viscosity

zig-zag strain history

Prandtl Model





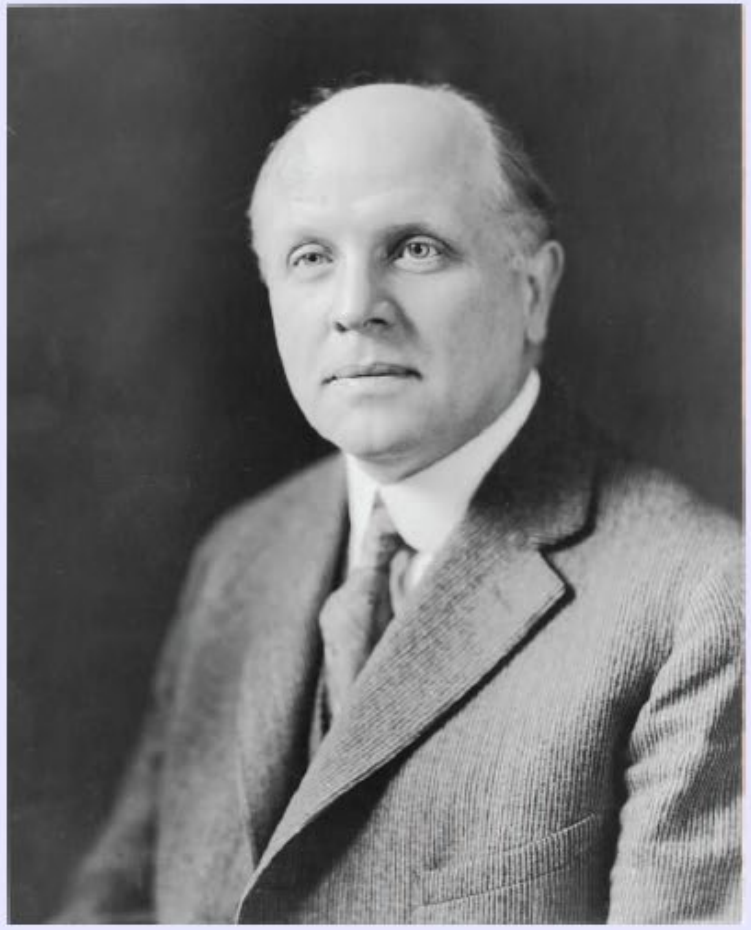
yield stress
irreversibility
no viscosity

ramp strain history

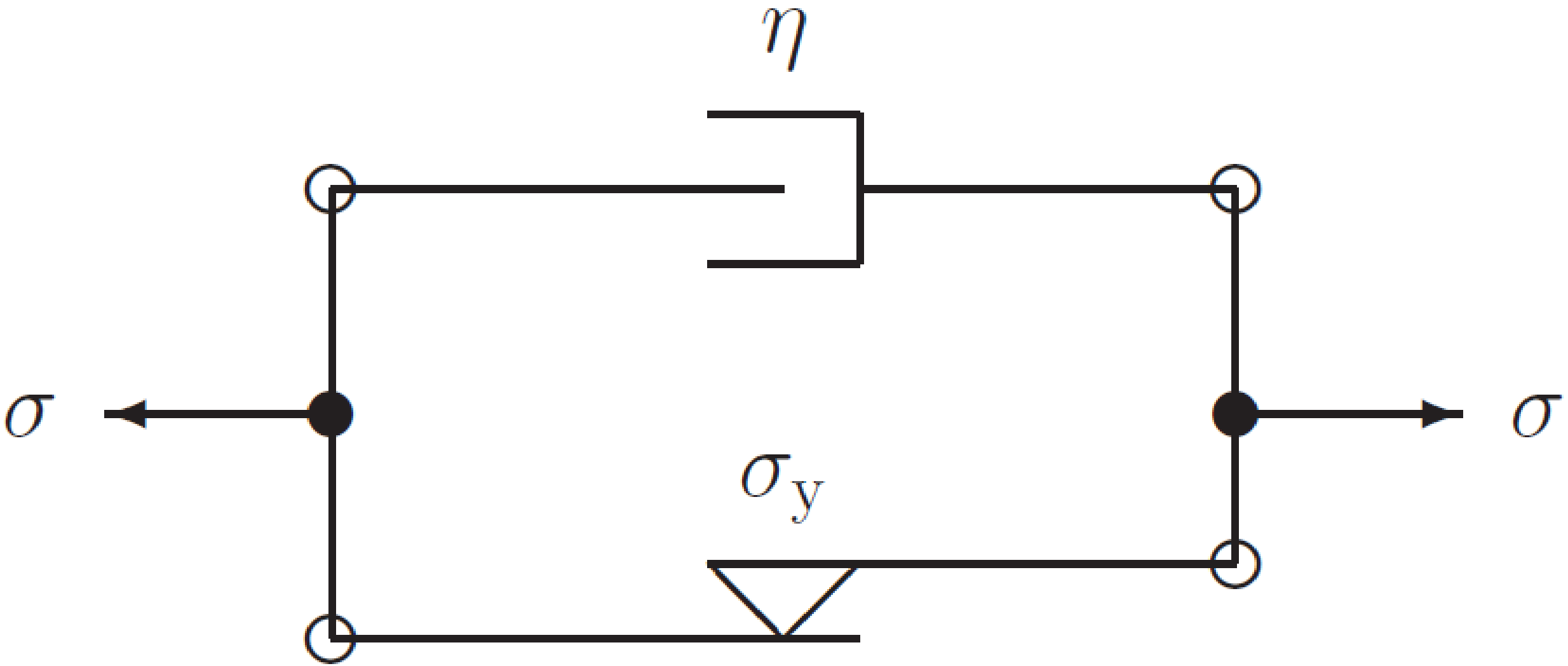
Visco-Plasticity

Bingham Model

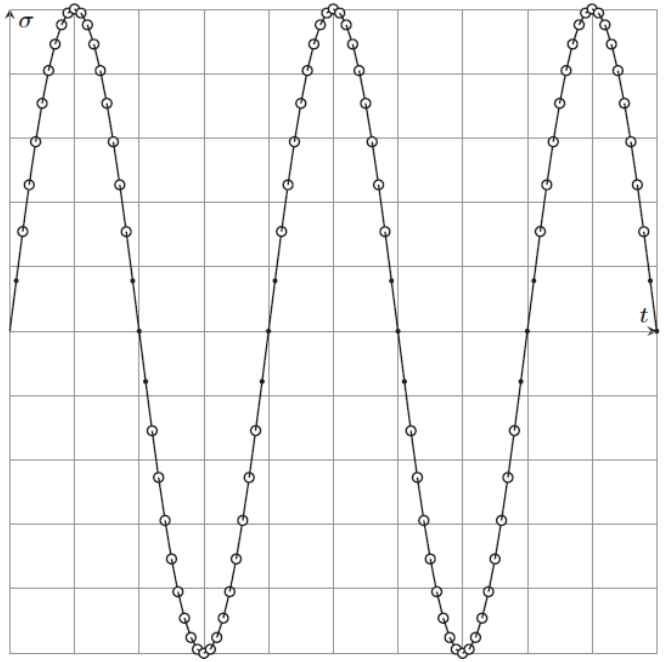
Eugen Cook Bingham [b. 8.12.1878, Cornwall, Vermont, USA, d. 6.11.1945, Easton, Pennsylvania, USA] was Professor of Chemistry at Lafayette College in Easton. He is the founding father (together with Markus Reiner) of the notion and science of rheology. Following a number of publications dealing with viscosity and plastic flow, he published his most popular treatise "Fluidity and Plasticity" in 1922. Fluids displaying a yield stress are named after him as Bingham fluids.

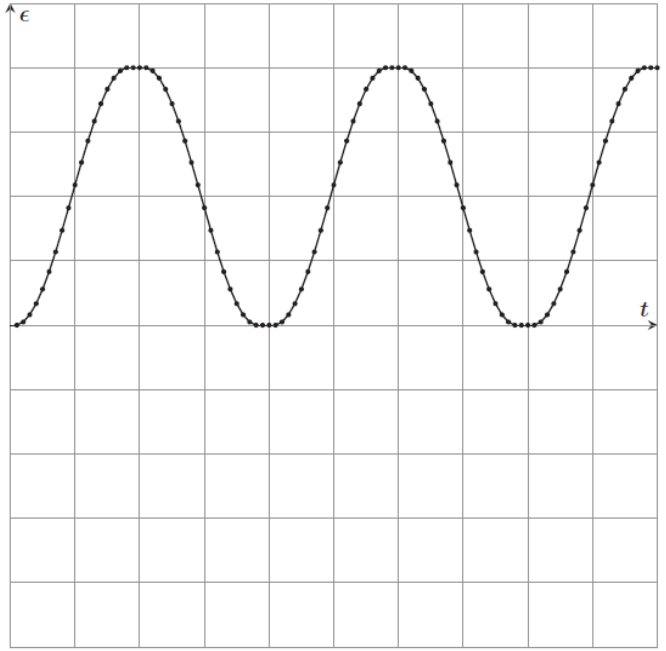


Bingham Model



Bingham Model

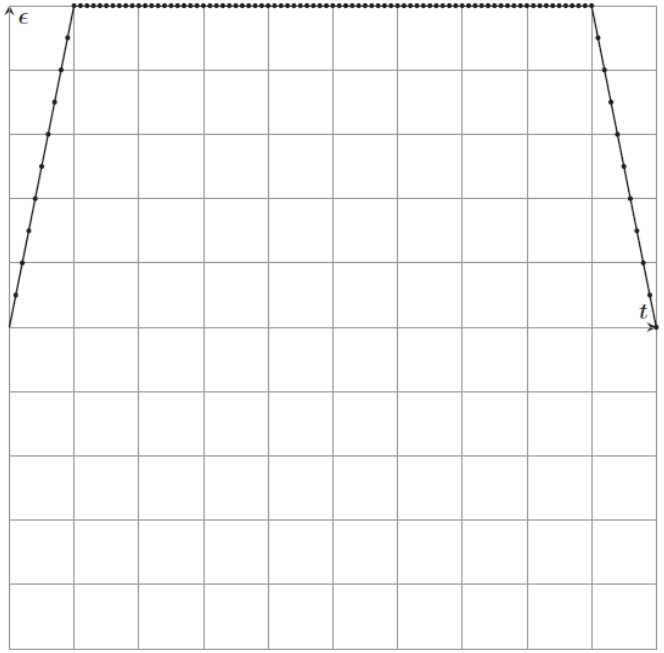


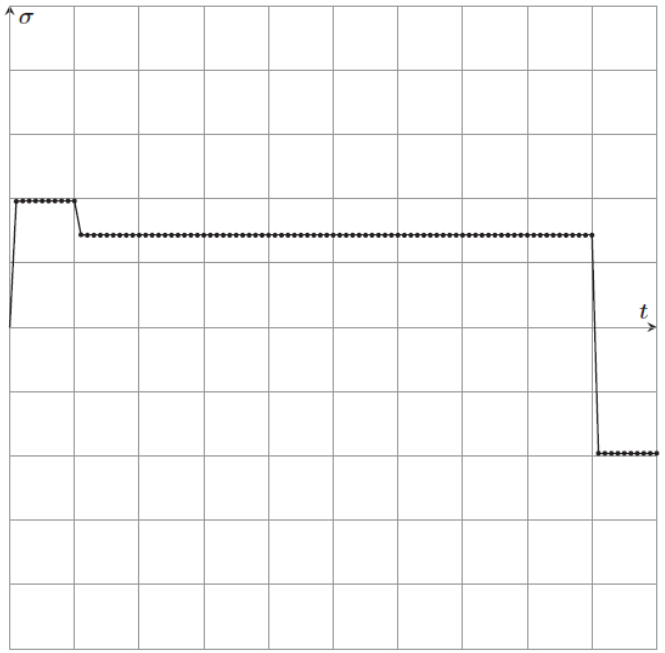


rigid fluid
phase shift
viscosity

sine stress history

Bingham Model





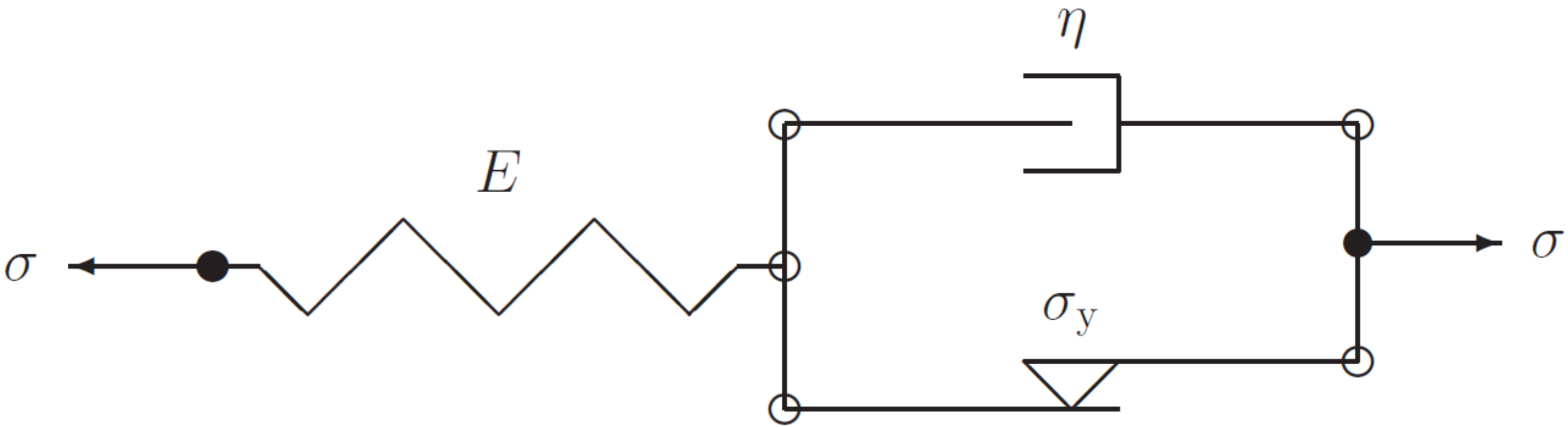
overstress
irreversibility
viscosity

ramp strain history

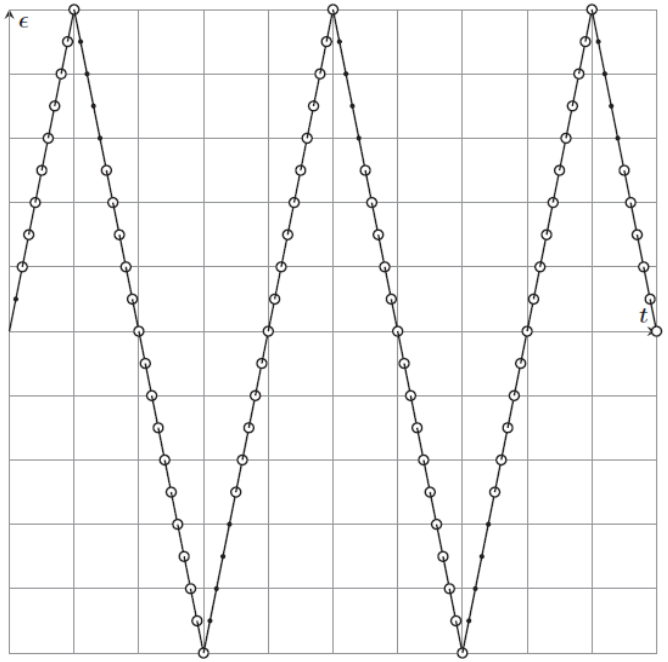
Perzyna Model

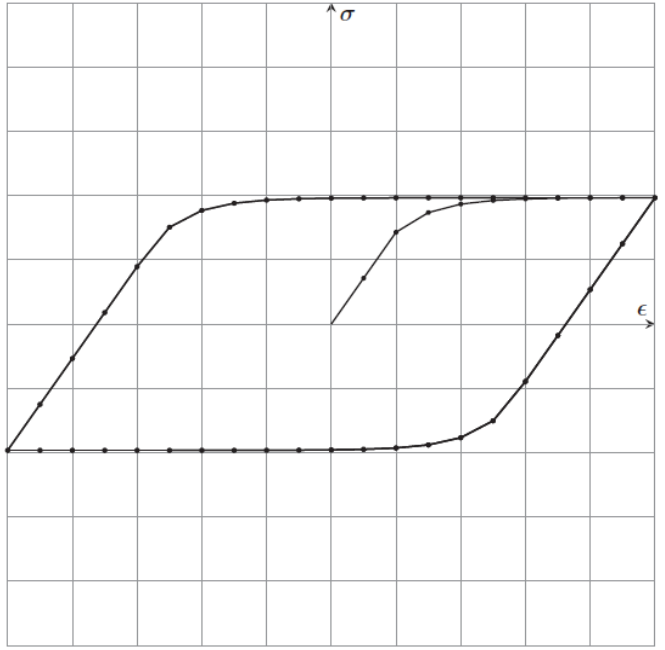
Piotr Perzyna [b. 1.8.1931, Niedźwiada, Poland, d. 22.6.2013, Warsaw, Poland] was Professor of Solid Mechanics at the Institute of Fundamental Technological Research, Polish Academy of Sciences (IPPT PAN) in Warsaw. He is the founding father of overstress-type visco-plasticity that is oftentimes named after him as Perzyna visco-plasticity. Since the foundation for Perzyna visco-plasticity was laid in his milestone publication from 1966, he continued to work on inelastic material models with internal variables.

Perzyna Model



Perzyna Model

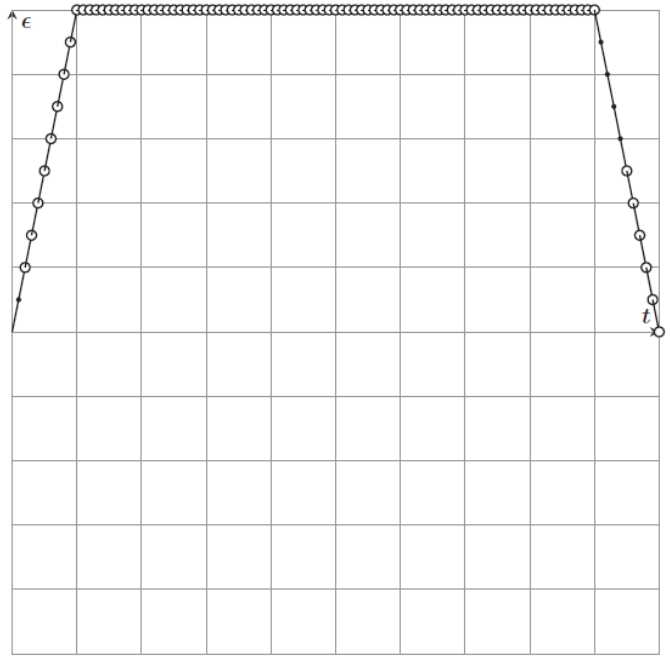


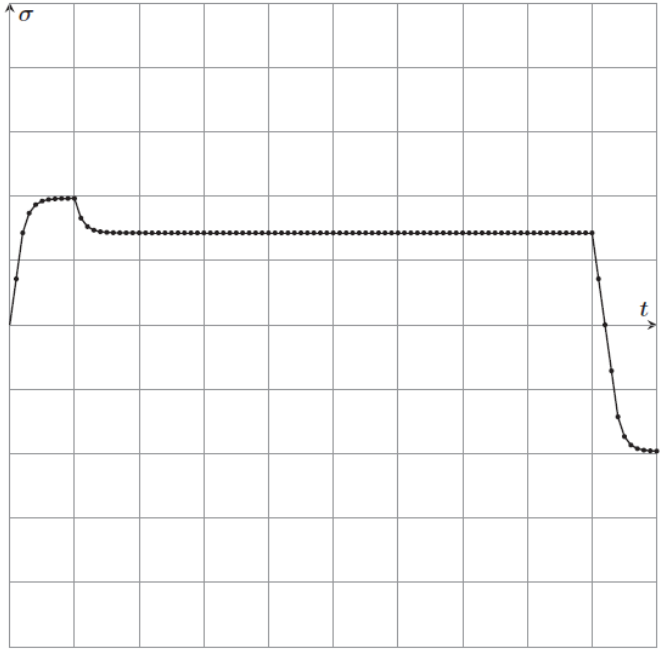


overstress
irreversibility
viscosity

zig-zag strain history

Perzyna Model

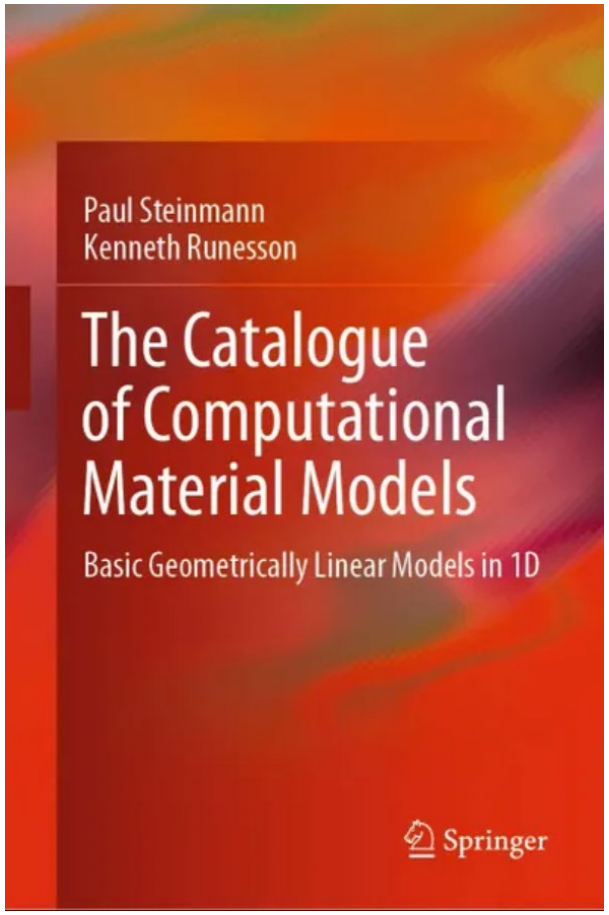




overstress
irreversibility
viscosity

ramp strain history

Everything You Always Wanted to Know about Modelling:



…but were Afraid to Ask

*modified from Woody Allen's film 1972