Introduction to Aerospace Propulsion
A course under NPTEL-II

Prof. Bhaskar Roy ; Prof. A.M.Pradeep,

1. Introduction to Propulsion (Prof B Roy)

Jet Propulsion

1.1. The making of thrust to fly – science and history of propulsion

1.2. How the jet engines make thrust : conceptual basis

1.3. Jet engines : Turbojet, Turbofans, Turboprop, Turboshaft

2. Thermodynamic basis of Propulsion devices (Prof A M Pradeep)

2.1. Basic concepts :Scope and Method of Thermodynamics;

2.2. System-Boundary, Surroundings; State, Stable Equilibrium, State Co-ordinates and parameters, Extensive and Intensive Parameters;

2.3. Energy interactions, Work and Heat transfers, Equilibrium, Quasistatic and Reversible process, Non-equilibrium and Irreversible Processes;

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2. Thermodynamic basis of Propulsion devices (Prof A M Pradeep)

2.4. Zeroeth Law and Temperature, First Law and Internal Energy; Second Law – Entropy and Absolute Temperature; Third Law and Absolute Entropy;

2.5. Thermodynamics of simple compressible systems, State postulate, Fundamental Representations

2.6 Thermodynamic Potentials

2.7. Jacobean and Legender Transformations – Maxwell's Equations

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2. Thermodynamic basis of Propulsion devices (Prof A M Pradeep)

2.8 Derivation of thermodynamic properties.

2.9. Applications: Closed and open systems, Polytropic processes, Cyclic processes

2.10 Carnot's cycle; Gas and vapour power cycles;

2.11. Mixtures of gases and vapours, One-D compressible flow, isentropic flow, flow with friction and heat transfer, normal shock.

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3. Piston –Prop Engines for Aircraft (Prof B Roy)

3.1 The Otto cycles : Ideal, Real & Boosted
3.2 IC engines for aircraft application
3.3 Reciprocating engine performance
3.4 Supercharging and
3.5 Propeller speed control mechanism and Gear Box
3.6 Propeller fundamentals and Blade theory

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4. Ideal Cycles for Jet Propulsion
Prof A M Pradeep

4.1. Joules Cycle
4.2. Brayton Cycle

5. Introduction to Missiles and Rockets (Prof B Roy)

5.1 Ramjets and Pulsejets

5.2 Rockets : fundamental principle of working of rockets and missiles

5.3 Various Space propulsive devices and their operating principles

Text References :

1. Nag, P.K. ***Engineering Thermodynamics***, Tata McGraw Hill, 2008 (4th ed)

2. Emmanuel G., ***Advanced Classical Thermodynamics***, AIAA Ed. Series, 1987.

3. Hill Philip, Peterson Carl, ***Mechanics and Thermodynamics of Propulsion***, 1992, Addison Wesly,.

4. Bhaskar Roy, ***Aircraft Propulsion***, 2008, Elsevier (India),

5. J.D.Mattingly, ***Elements of Propulsion - Gas Turbines and Rockets***, 2006, AIAA Education series

More books shall be referenced during the course of the lecture series.

These will be mentioned during the presentation of various chapters

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Basic Sciences involved in Propulsion

1. Laws of Motion
2. Laws of Thermodynamics
3. Principles and Theories of Aerodynamics
4. Mechanical sciences
5. Material sciences
6. Control Theory

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Basics of Continuous Motion

- Before Newton's laws of motion (July, 1687) were codified various concepts of creating continuous motion were tried.

- Paddling of oars in boats uses the laws of motion – and has been used for thousands of years.

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Basics of Continuous Motion

- Perpetual motion concept has been debunked by the Laws of motion.

- Which means continuous force or power is required for continuous motion

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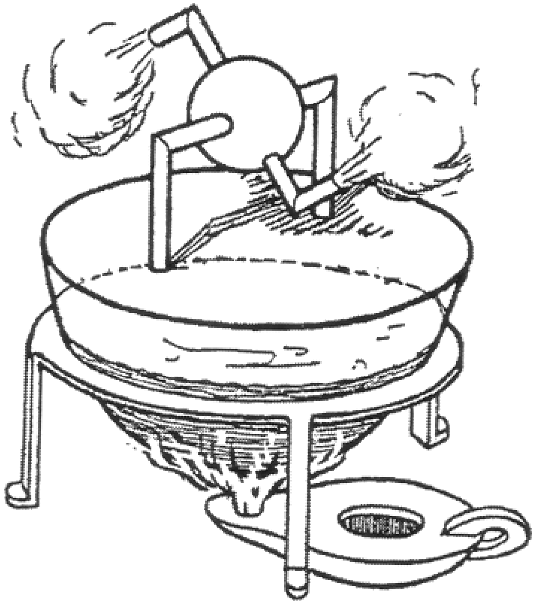
Hero's Aeolepile (2nd BC)



William Avery (1830)

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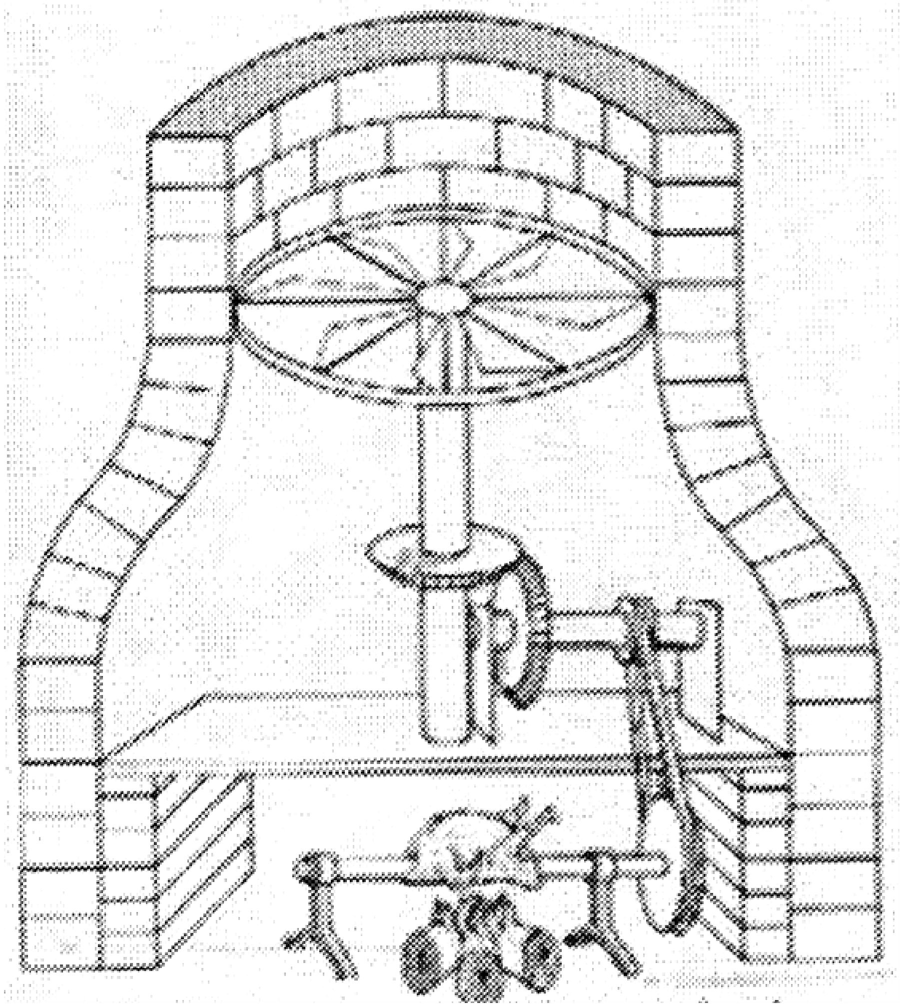
Wan Hu's Rocket (13th AD)

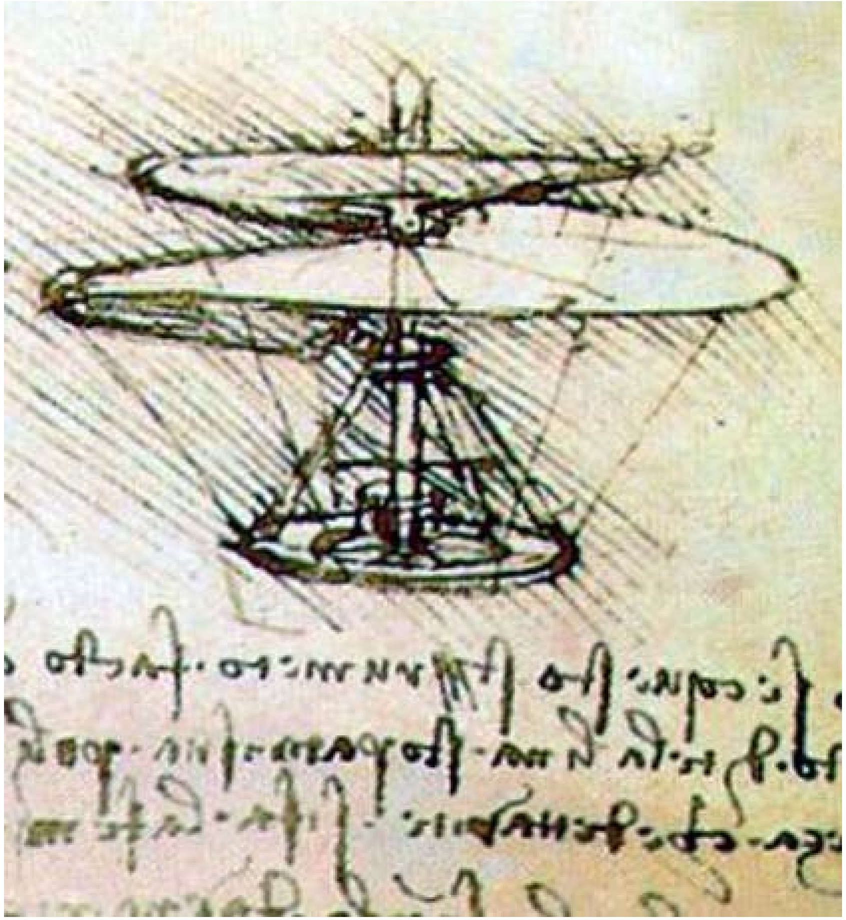
Multiple Rockets

Rocket Jets

Da Vinci's Chimney Jack (1500 AD)



Da Vinci' Ornithopter



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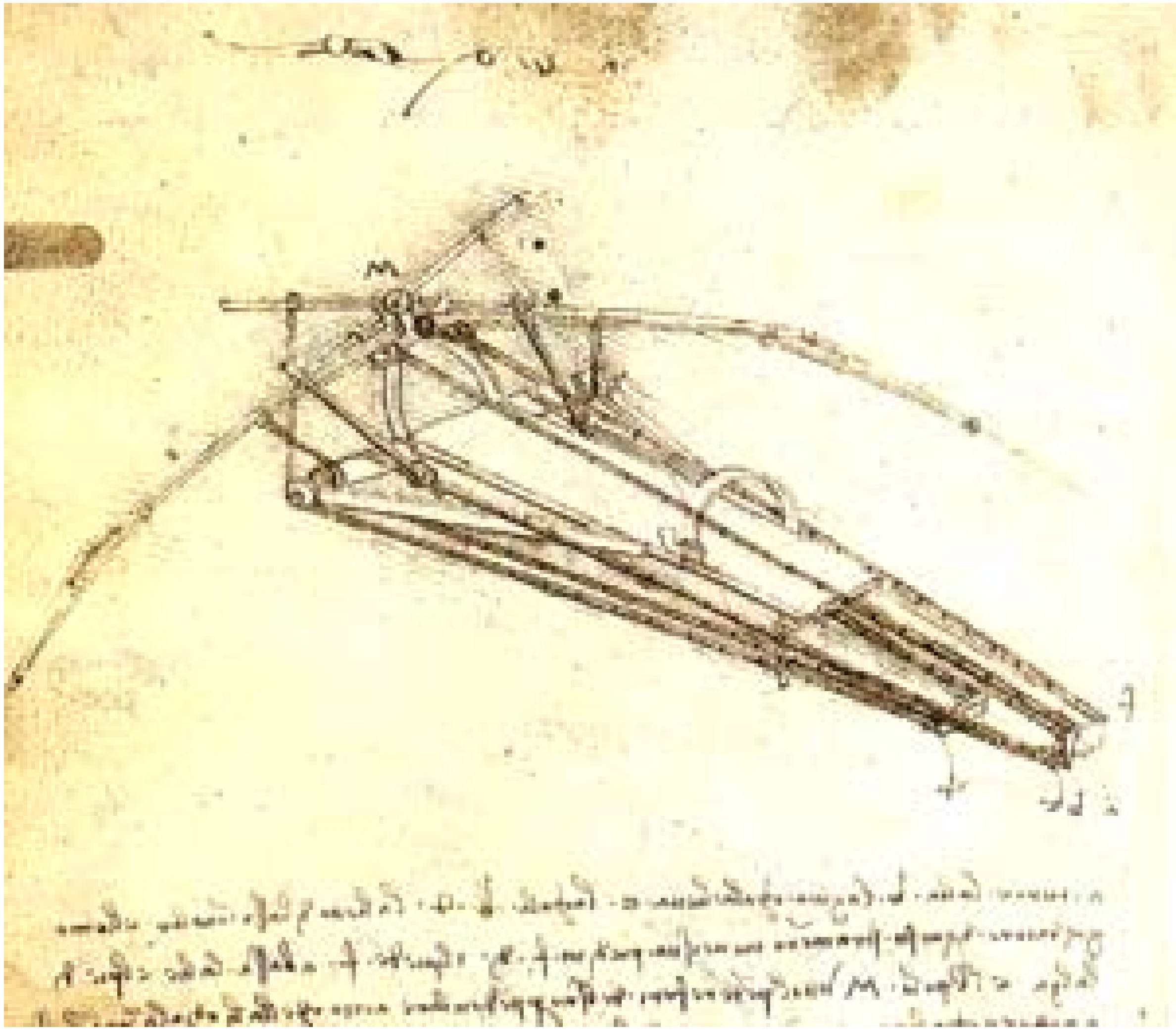
Da Vinci's Flapping Wing Concept



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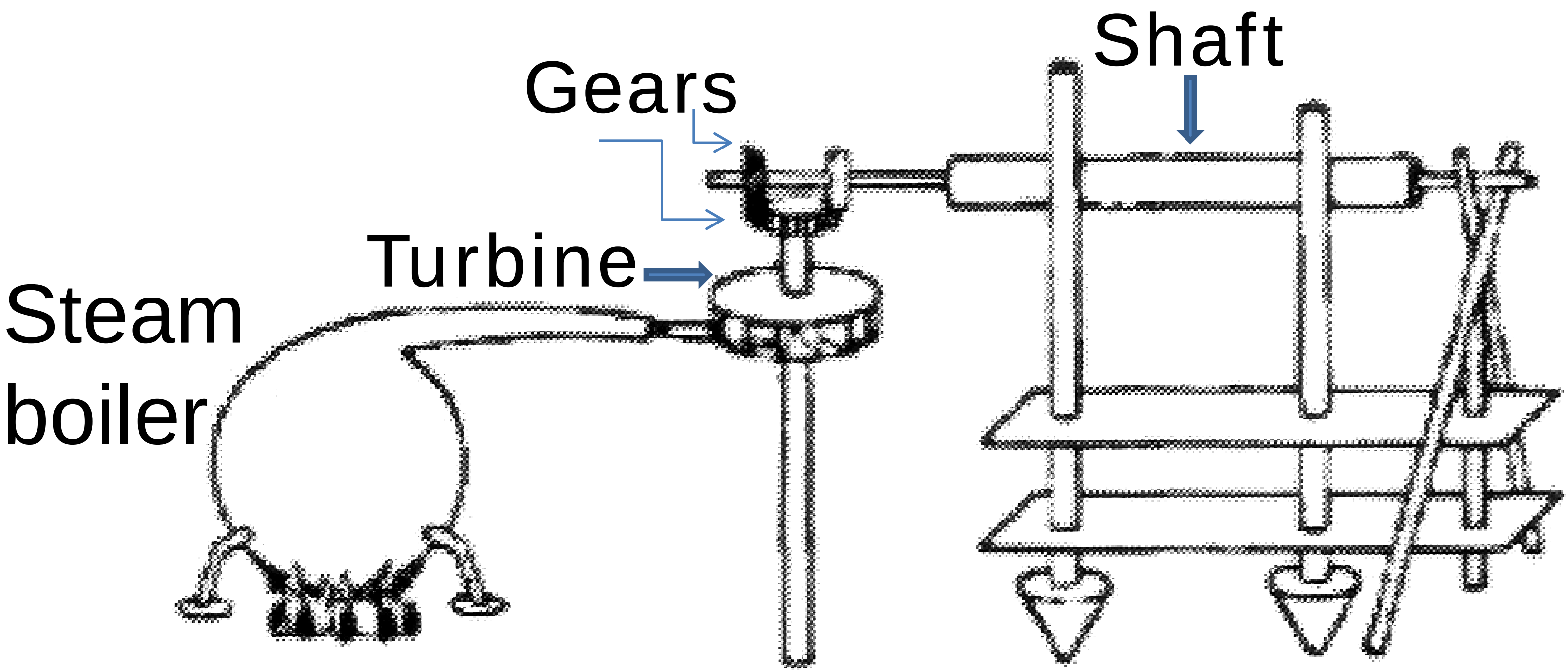
Giovanni Branca's Jet Turbine (1629)



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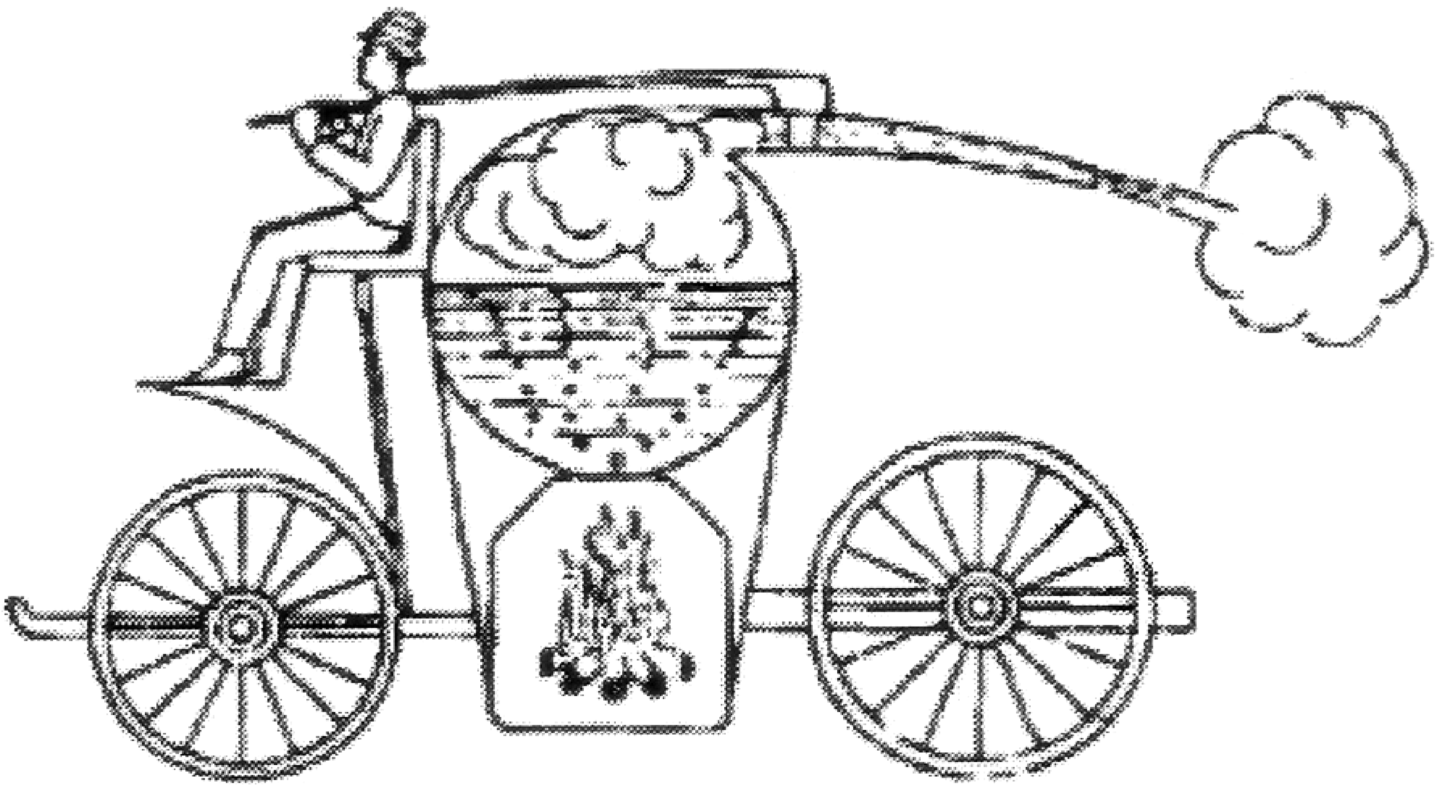
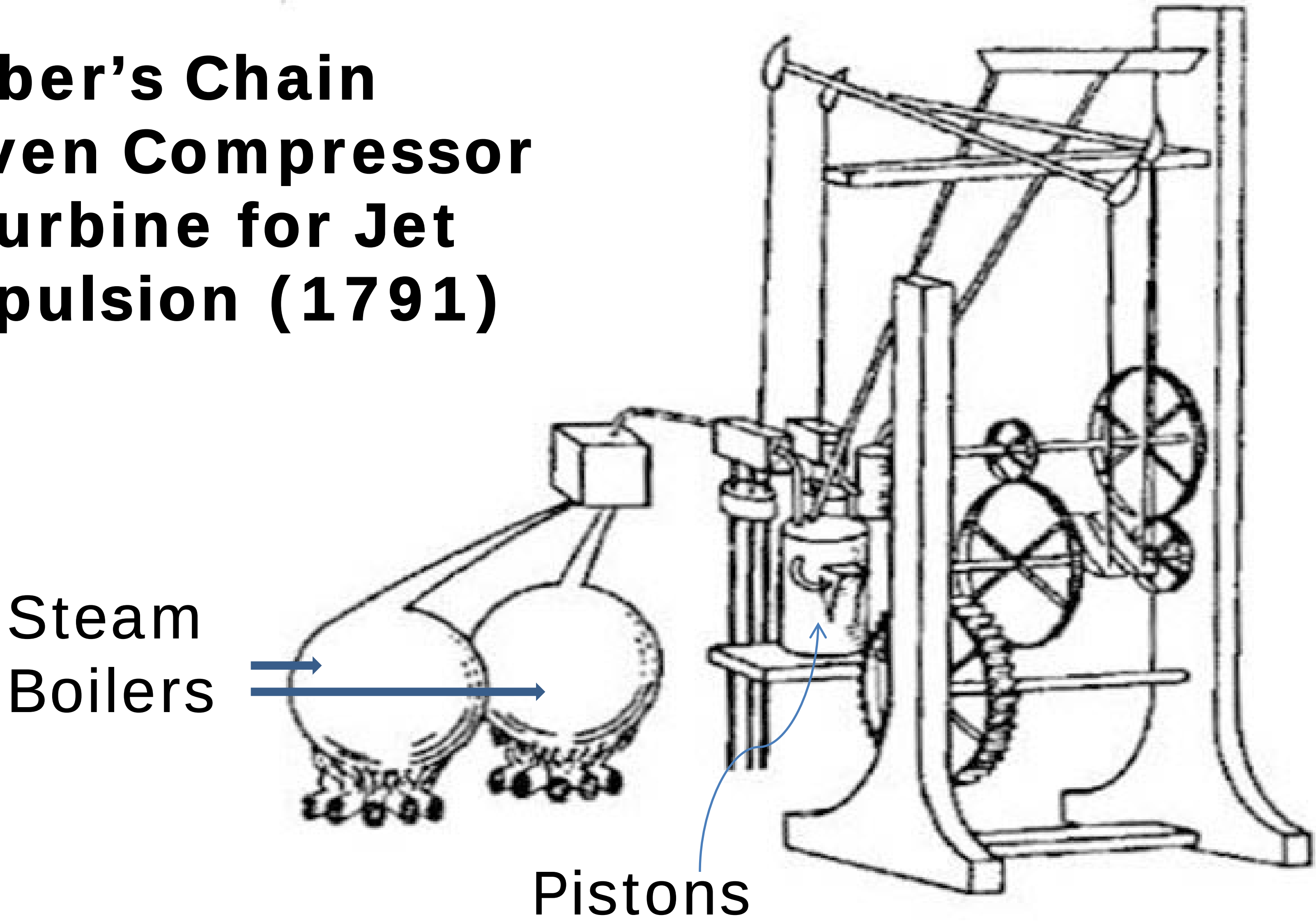
Newton's Steam Wagon



Barber's Chain Driven Compressor + Turbine for Jet propulsion (1791)



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Newton's Laws of Motion

<u>Newton's first law</u>.

An object at rest will remain at rest unless acted on by an external force. An object in motion continues in motion with the same speed and in the same direction unless acted upon by an external force.

This law is often called "the law of inertia“ as it establishes the Newtonian frame of reference.

Newton’s Laws of Motion

Newton's second law

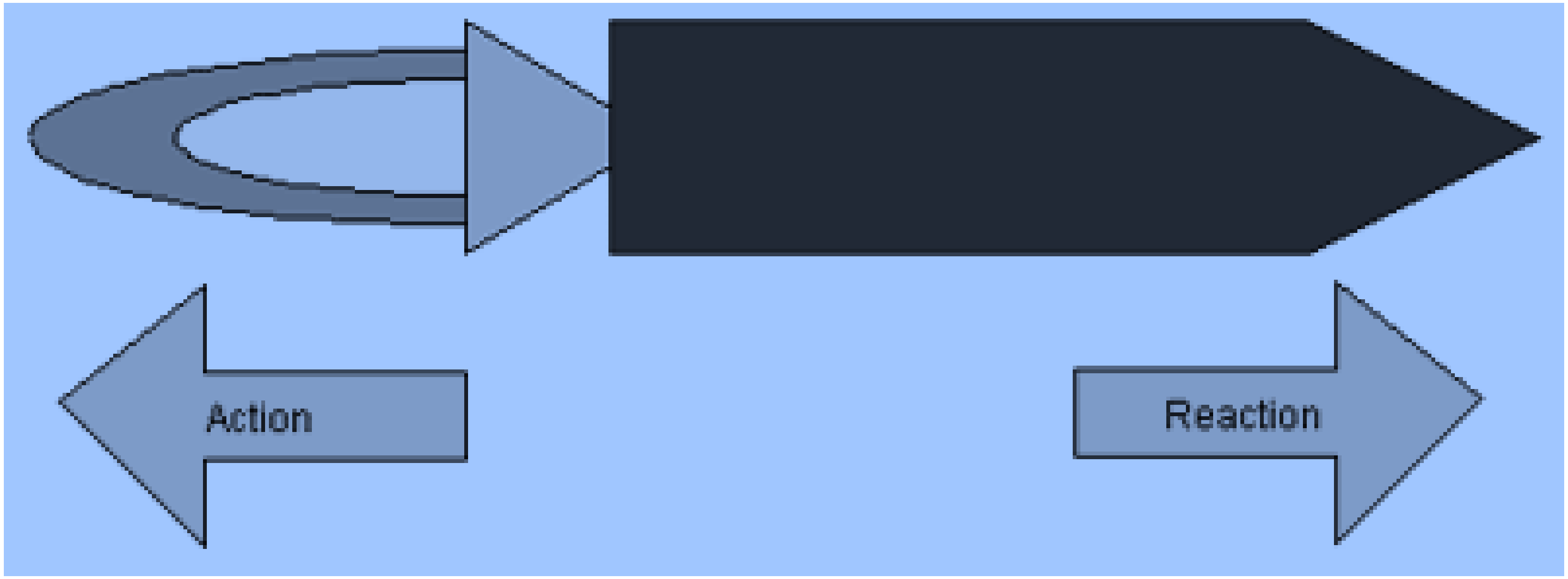
Acceleration is produced when a force acts on a mass. The greater the mass (of the object) being accelerated the greater the amount of force needed to accelerate the object.

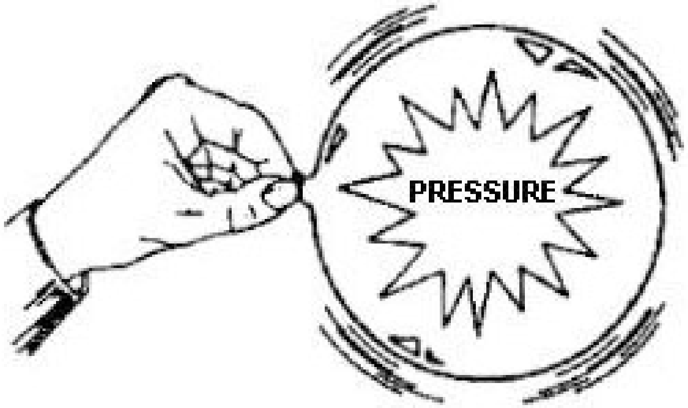
$$F = MA$$

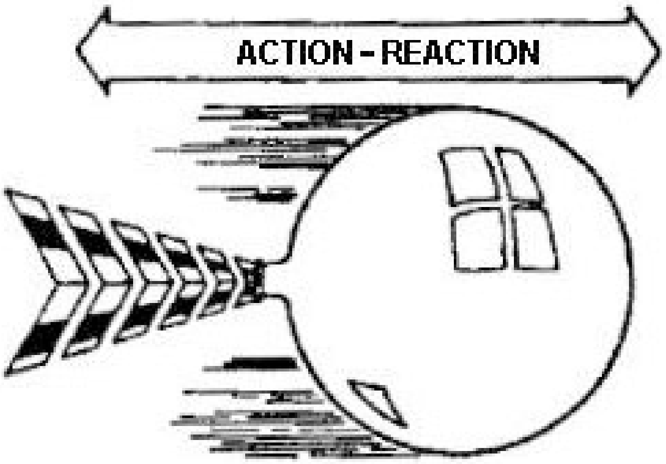
Newton’s Laws of Motion

Newton's third law

For every action there is an equal and opposite re-action.







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Newton's law I

This law states that if the vector sum of all the forces acting on an object is zero, then the velocity of the object is constant. Consequently:

- An object that is at rest will stay at rest unless an unbalancing force acts upon it.
- An object that is in motion will not change its velocity (magnitude and/or direction) unless an unbalancing force acts upon it.

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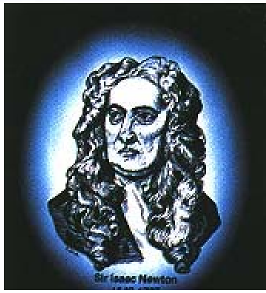

From Newton's 2nd law of motion

The second law states that the net force on a body is equal to the time rate of change of its linear momentum **M_t** in a specified reference frame for the inertial motion under interest:

$$F = \frac{dM_t}{dt} = \frac{d(mV)}{dt} = m\frac{dv}{dt}$$

For a constant mass system

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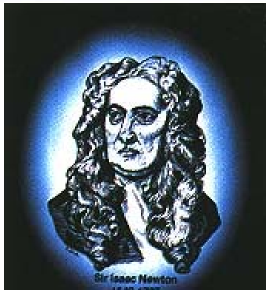

Any mass that is gained or lost by the system will cause a change in momentum that is not the result of an external force. A different equation is necessary for a variable-mass systems

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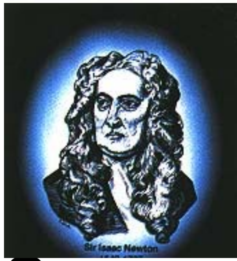
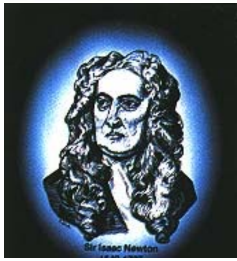


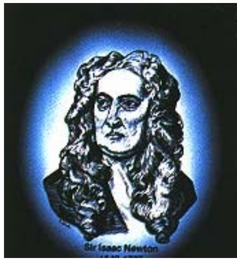
Consistent with the Law I, the time derivative of the momentum is non-zero when the momentum changes direction, even if there is no change in magnitude; such is the case with circular motion.

The relationship implies conservation of momentum: when the net force on the body is zero, the momentum of the body is constant (zero or non-zero). Net force is equal to the rate of change of the momentum.



The Newton's Law II is the conceptual basis of Propulsive Force of all flying vehicles

Newton's law II requires modification if the effects of relativity are to be taken into account, because at very high speeds the approximation that momentum is the product of rest mass and velocity is not accurate. For all propulsive purposes Newtonian bodies, fluids and motion are used.



An impulse **I** occurs when a force **F** acts over an interval of a small time Δt, and it is, thus, given by

$$I = \int F.dt$$

This concept is useful when Rockets/ Space vehicles / Missile propulsion are considered.

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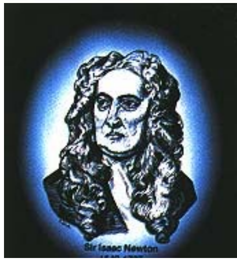

Newton's law III

The 3rd Law means that all forces are interactions between different bodies and thus that there is no such thing as a unidirectional force or a force that acts on only one body. If body *A* exerts a force on body *B*, body *B* simultaneously exerts a force of the same magnitude on body *A*— both forces acting along the same line.

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While the Newton's 3rd law allows us to comprehend the mechanics of action of the propulsive force (Thrust) acting on a flying body, the production of thrust is actually facilitated by the Newton's 2nd law, active on the engine body. Hence it is not only the jet coming out at the exhaust that creates thrust, but the entire body of the engine participates in creation of thrust.

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Additional References:

1. Cengel, Y.A, and Boles, M.A., (2006), Thermodynamics – An Engineering Approach, Tata McGraw Hill.
2. Sutton, G.P. and Biblarz, O, (2001), Rocket Propulsion Elements, John Wiley & Sons.
3. Gill, P. W., Smith, J. H., and Ziurys, E. J., (1967), Fundamentals of Internal Combustion Engines, Oxford & IBH Publishing Co.
4. Saravanamuttoo, H.I.H, Rogers, G.F.C, and. Cohen, H., (2001), Gas Turbine Theory*, Pearson Education.*
5. Treager, I.E., (1997), Aircraft Gas Turbine Engine Technology, Tata McGraw Hill.