Lecture Notes on

Engineering Fracture Mechanics

Prepared by

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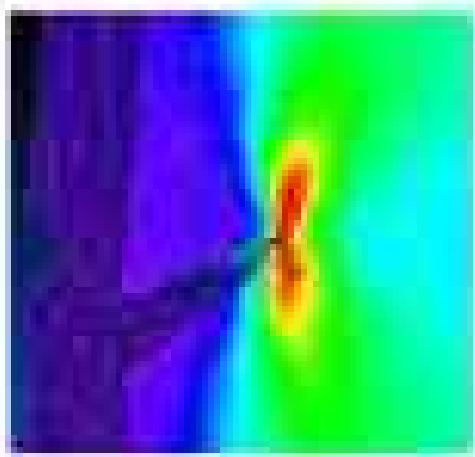

AMRITA VISHWA VIDYAPEETHAM | School of Engineering

Resumen

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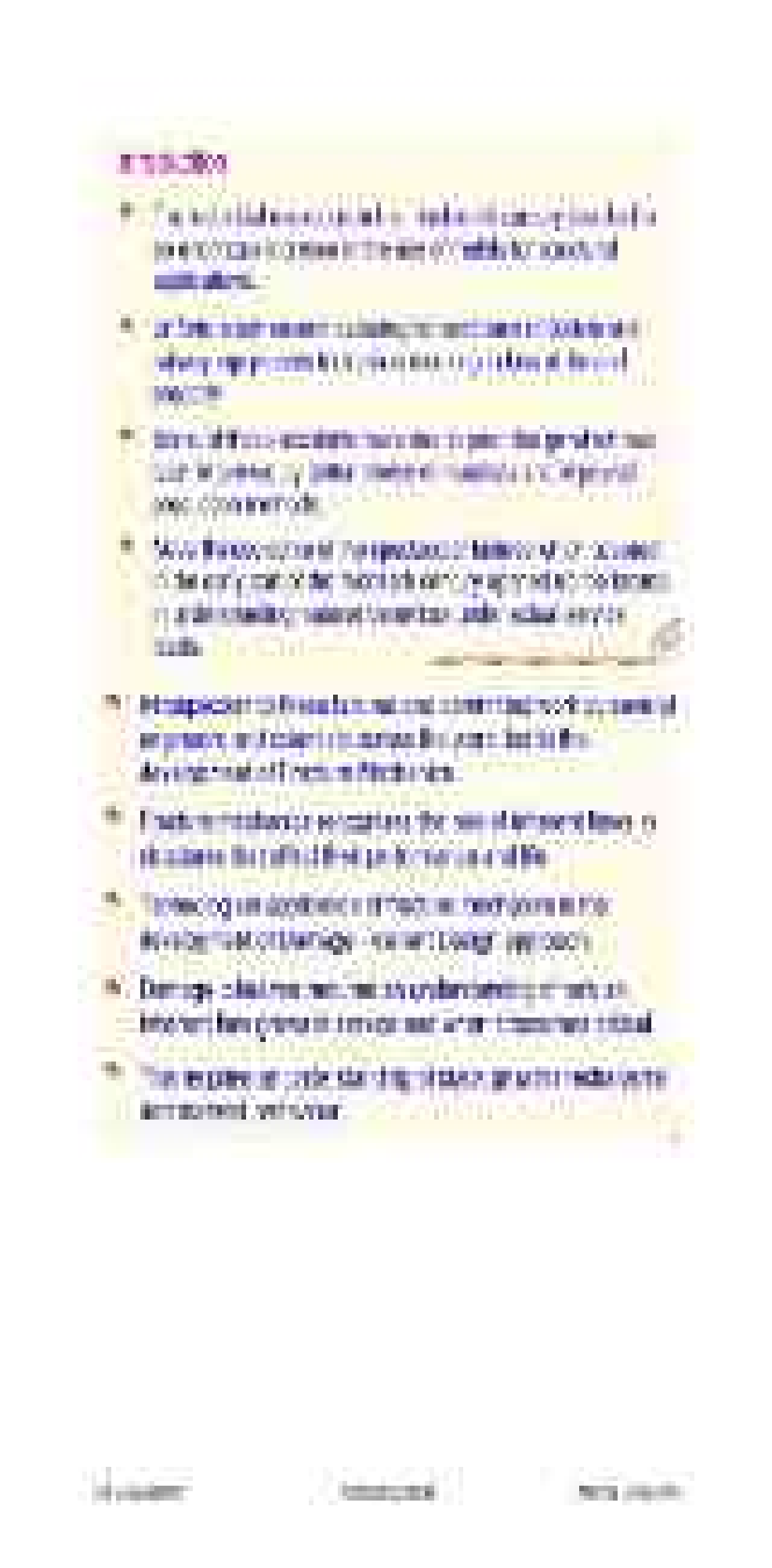
Ils n'ont pas tué Jean Moulin, ils ont tué en lui
l'espérance et la vie de millions d'hommes.

Contents



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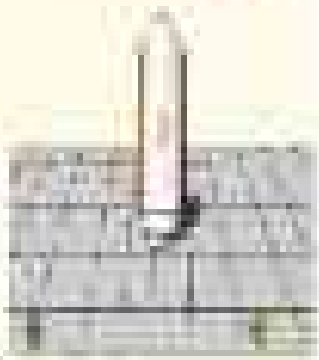

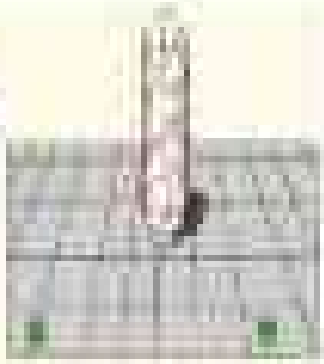

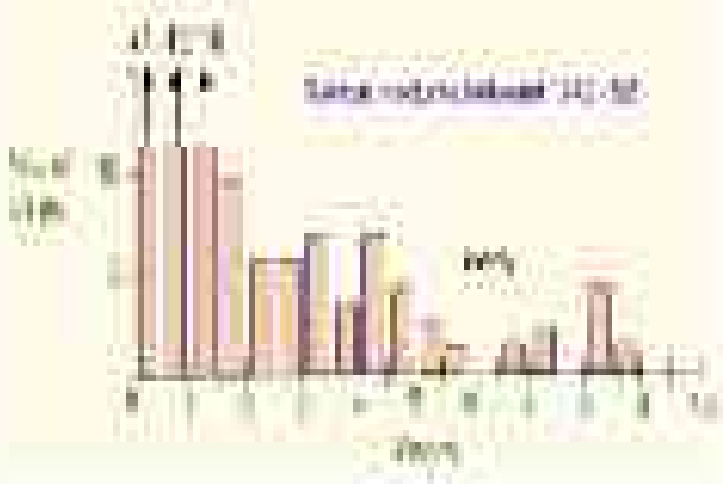

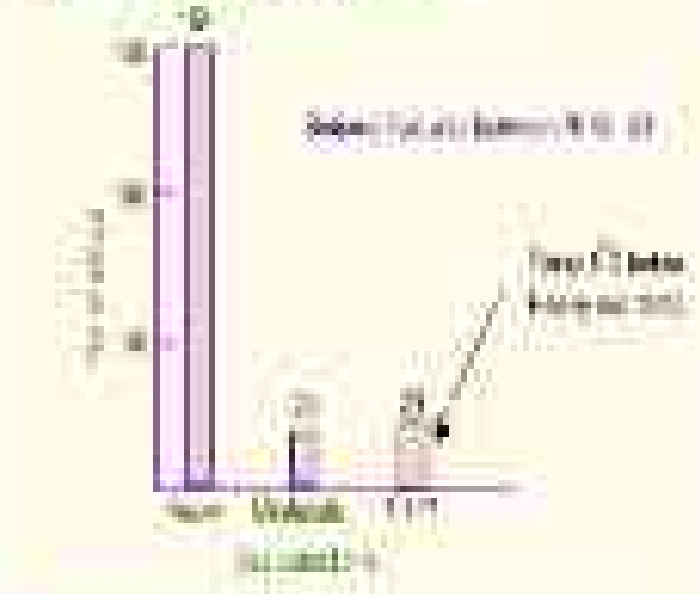

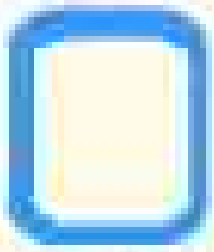

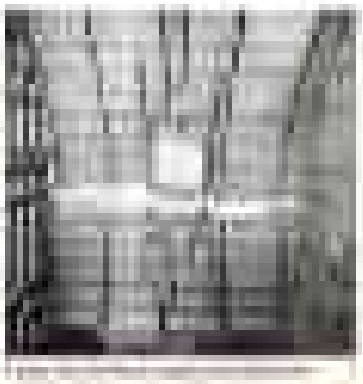

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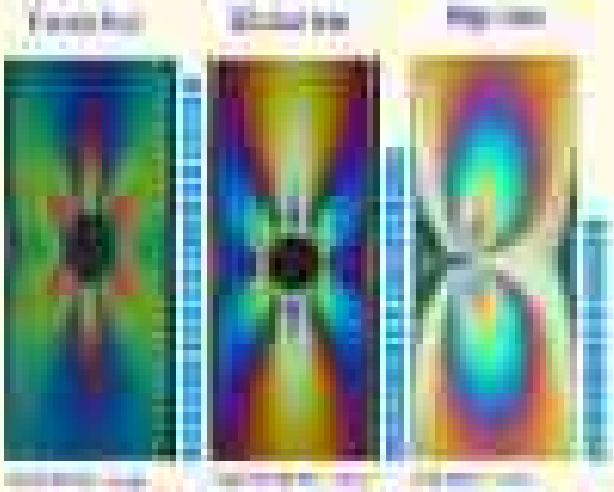
Photovoltaic Appreciation of Energy into Charge

- Energy density is indicative of the intensity of the electric field



- The [illegible] interaction of light and matter for the [illegible] of energy

Practical Considerations

- [illegible] is a semiconductor [illegible] has brought [illegible] recently [illegible]
- Different [illegible] the recognition of [illegible] and [illegible] the [illegible]
- [illegible] will give [illegible] between [illegible] is [illegible]
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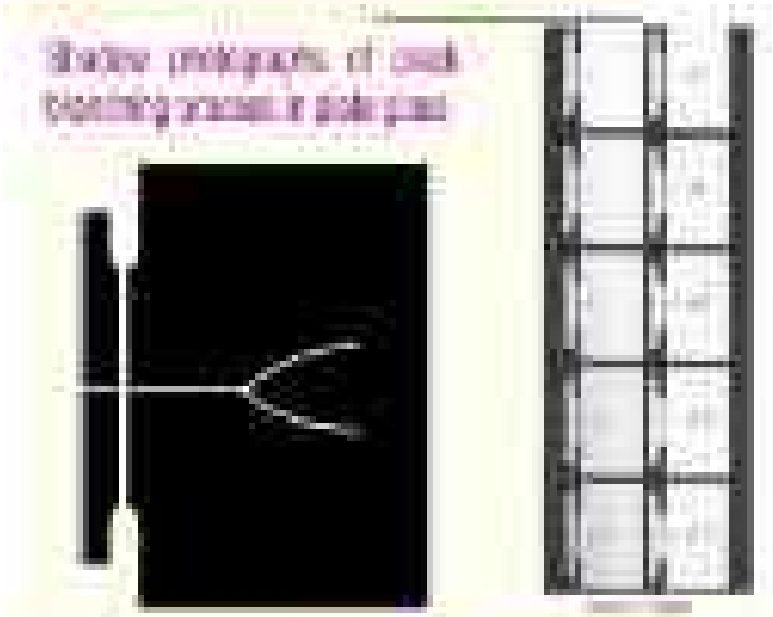
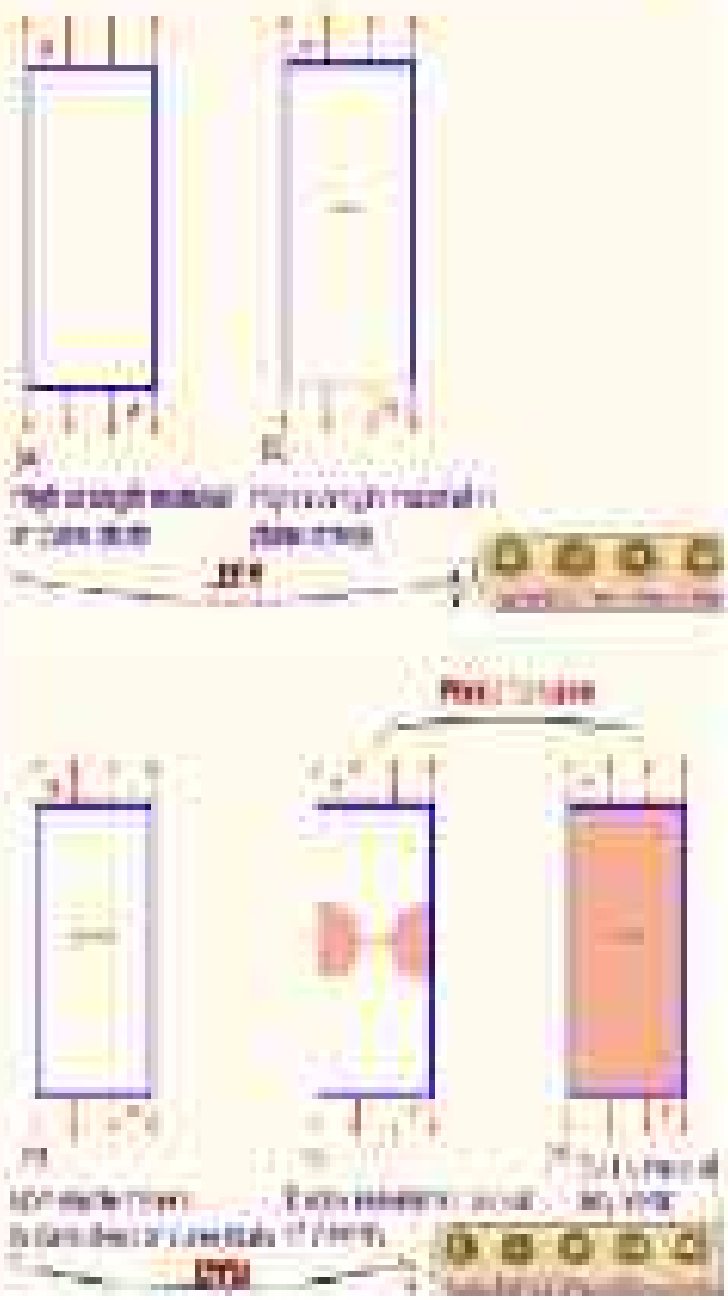
- Different [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible]





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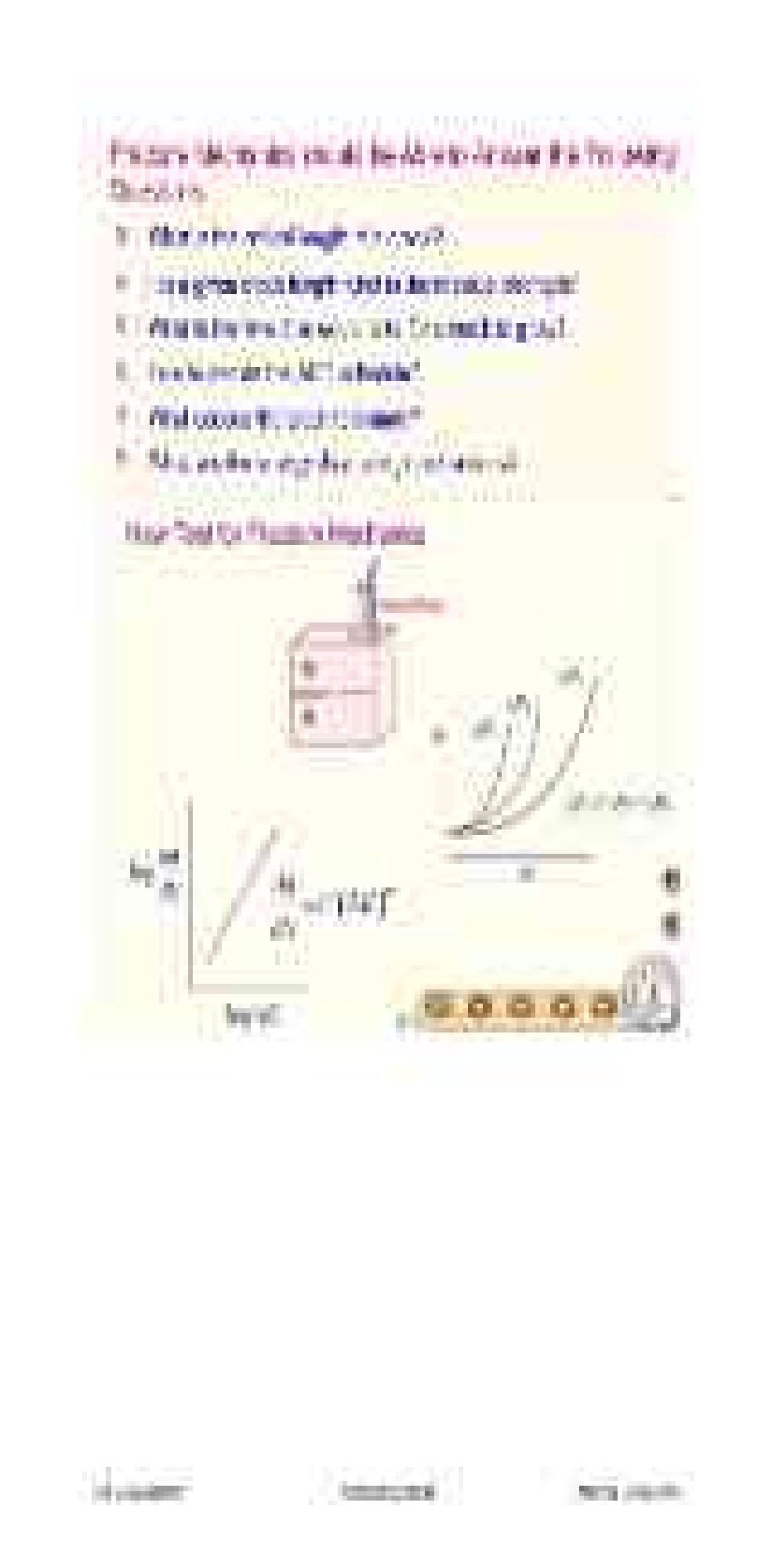

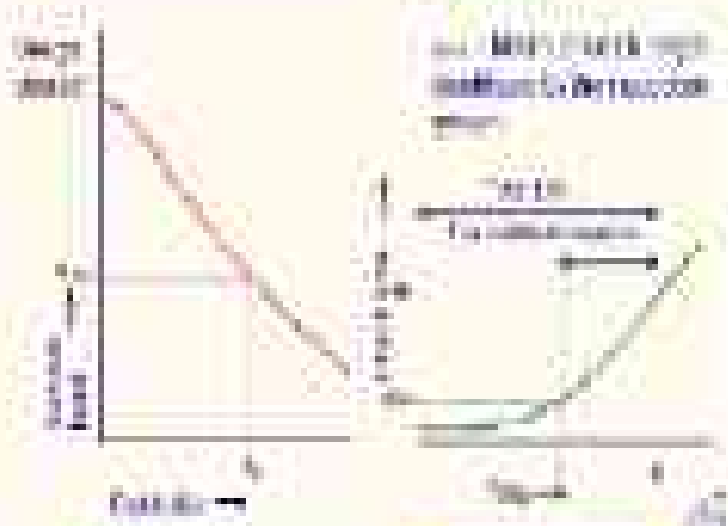

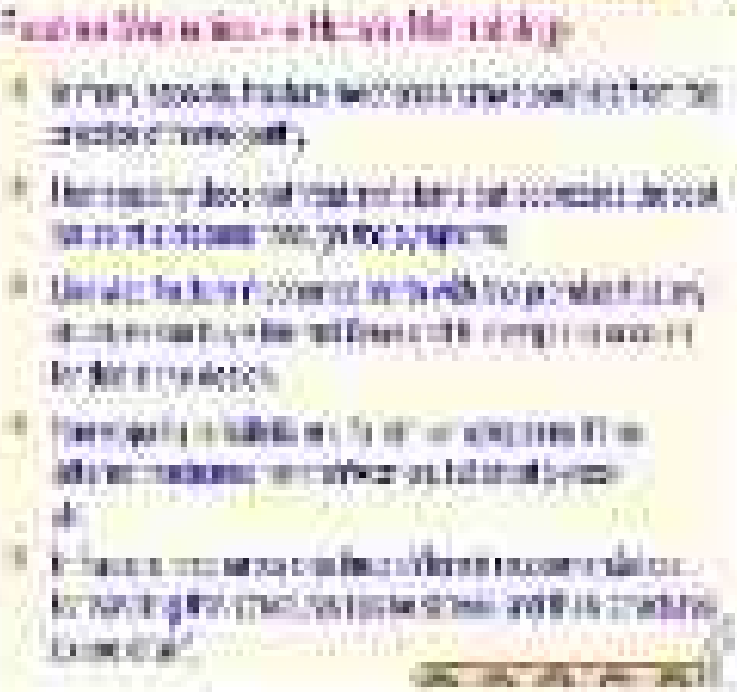

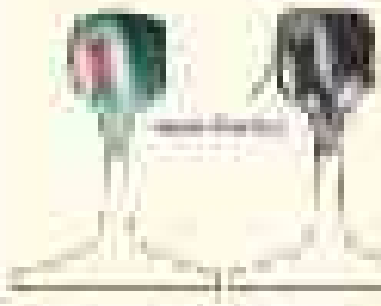

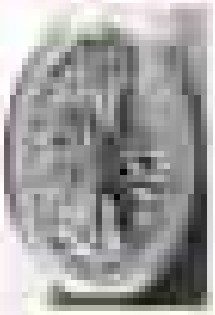

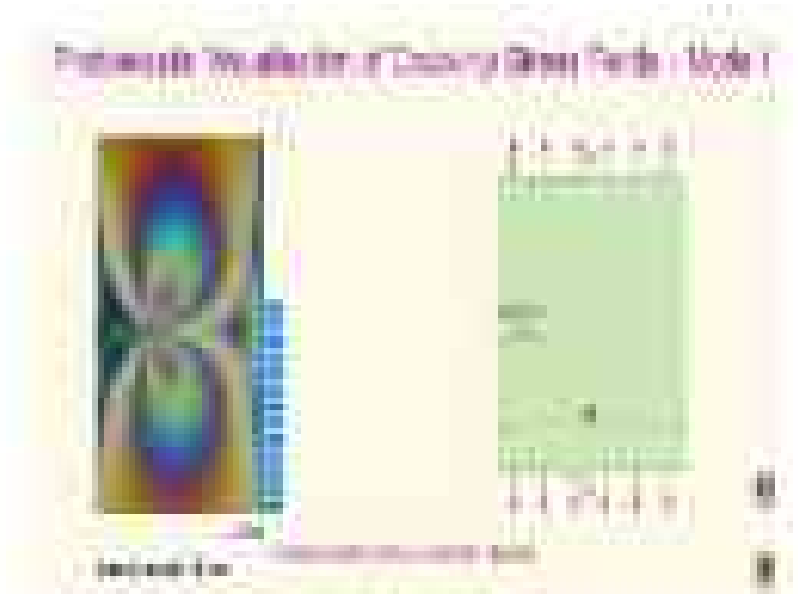

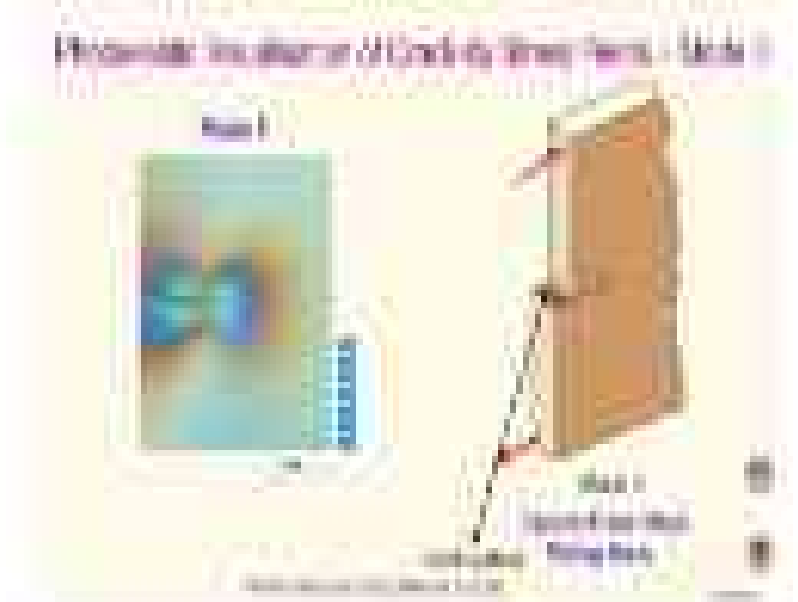

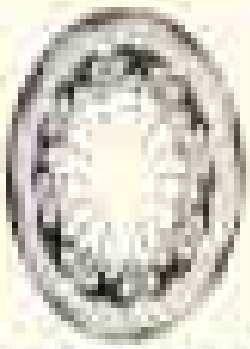

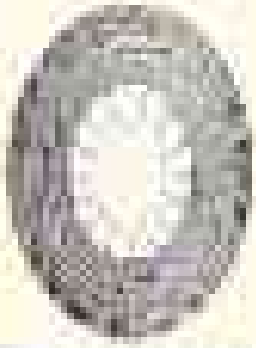

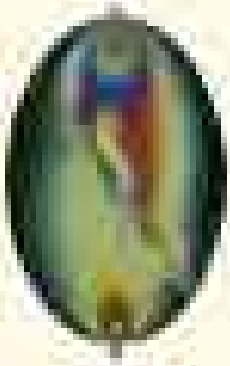

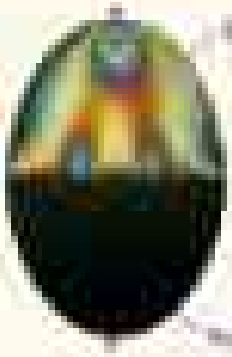

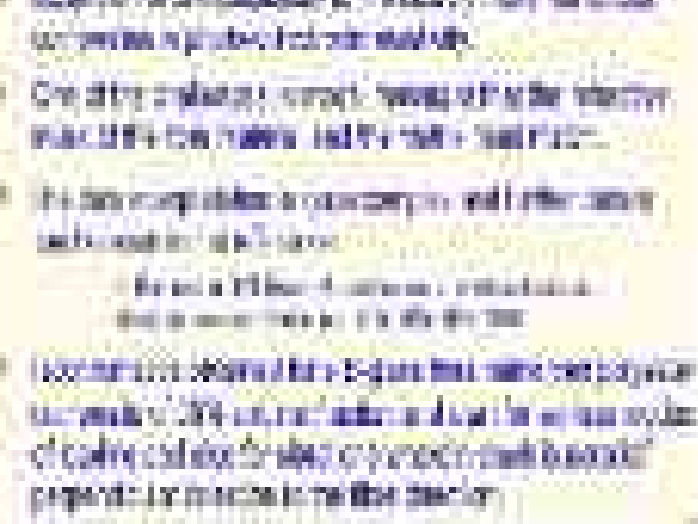

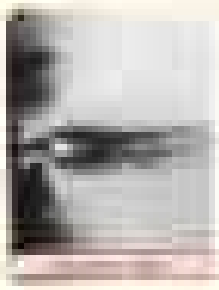

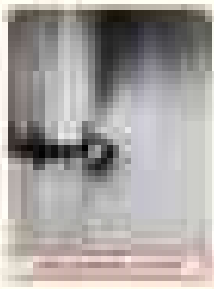

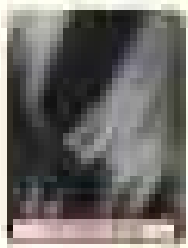

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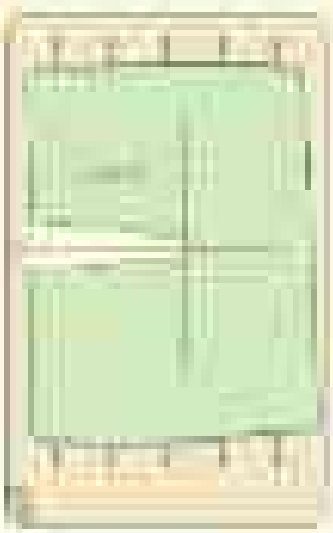

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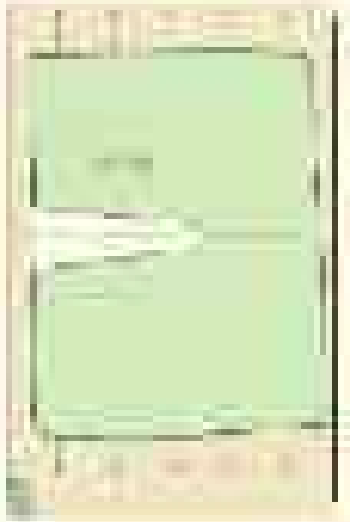
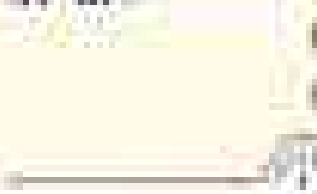
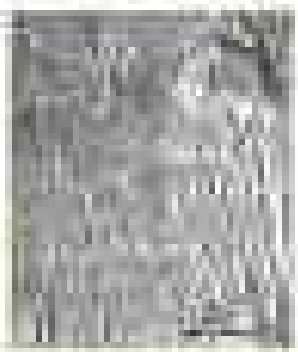






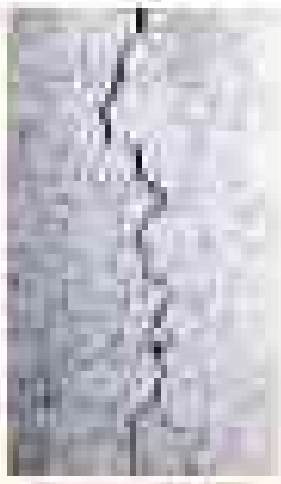
Bunsen burner

Bunsen burner safety (SQA)

- SQA is the awarding body that sets the exams and marks your practical investigation.
- You must learn how to use equipment safely and follow safety rules when carrying out practical investigations.
- You must be competent in using equipment and techniques safely and know what to do if an accident occurs.

Delayed hydrogen cracking

- It is also known as
- The time is needed for it to commence
- There are two processes identified to cause HIC
  - Acid or salt corrosion
  - Hydrogen embrittlement
  - Can be seen on image



Advantages and disadvantages

- Safe, quick, reliable and inexpensive method of non-destructive
- Has some limitations including the requirement for skilled operators to interpret the results and the need for
- Human factor dependent and requires skilled operators to interpret the results

Hydrogen embrittlement

- Hydrogen embrittlement is a phenomenon in which certain metals can become brittle and fracture after being exposed to hydrogen. The hydrogen can be introduced during manufacturing processes such as welding, electroplating, or pickling, or it can be absorbed from the environment during service.
- Hydrogen atoms are very small and can easily diffuse into the metal lattice, causing it to become brittle.
- Hydrogen embrittlement can occur in a wide range of metals, including steel, aluminum, and titanium.
- The severity of hydrogen embrittlement depends on several factors, including the amount of hydrogen present, the temperature, and the stress level in the material.
- Hydrogen embrittlement can be prevented or minimized by using proper manufacturing techniques, such as avoiding excessive hydrogen exposure during welding or using low-hydrogen electrodes.
- Some metals are more susceptible to hydrogen embrittlement than others, and it is important to select the appropriate material for the intended application.

1. [illegible]
2. [illegible]
3. [illegible]

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1. [illegible]
2. [illegible]
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4. [illegible]

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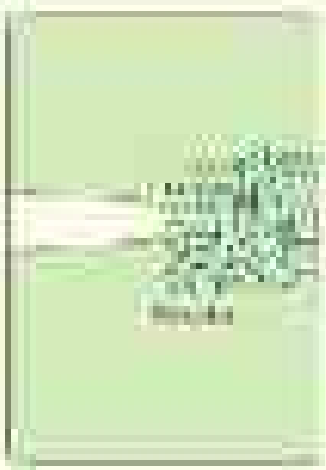

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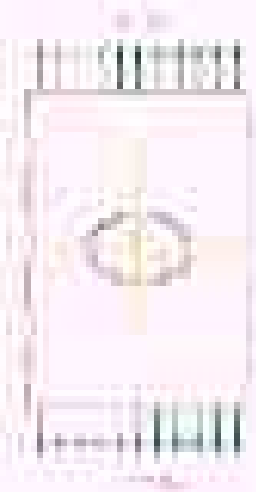
Coated particles in fuel

Irradiation of fuel pebbles



Effective Elements

Scientific

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b. [illegible]

c. [illegible]

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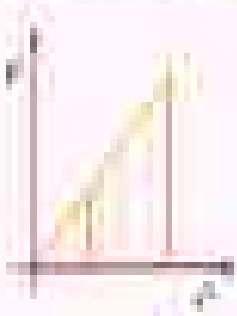


$$\varepsilon_x = \frac{\partial u}{\partial x} \qquad \varepsilon_y = \frac{\partial v}{\partial y} \qquad \varepsilon_z = \frac{\partial w}{\partial z}$$

$$\gamma_{xy} = \frac{\partial u}{\partial y} + \frac{\partial v}{\partial x} \qquad \gamma_{yz} = \frac{\partial v}{\partial z} + \frac{\partial w}{\partial y} \qquad \gamma_{zx} = \frac{\partial w}{\partial x} + \frac{\partial u}{\partial z}$$

$$U = \frac{1}{2}\int_V \left[\sigma_x \varepsilon_x + \sigma_y \varepsilon_y + \sigma_z \varepsilon_z + \tau_{xy}\gamma_{xy} + \tau_{yz}\gamma_{yz} + \tau_{zx}\gamma_{zx}\right] dV$$

$$= \frac{1}{2}\int_V \left[\sigma_x \frac{\partial u}{\partial x} + \sigma_y \frac{\partial v}{\partial y} + \sigma_z \frac{\partial w}{\partial z} + \tau_{xy}\left(\frac{\partial u}{\partial y} + \frac{\partial v}{\partial x}\right) + \tau_{yz}\left(\frac{\partial v}{\partial z} + \frac{\partial w}{\partial y}\right) + \tau_{zx}\left(\frac{\partial w}{\partial x} + \frac{\partial u}{\partial z}\right)\right] dV$$

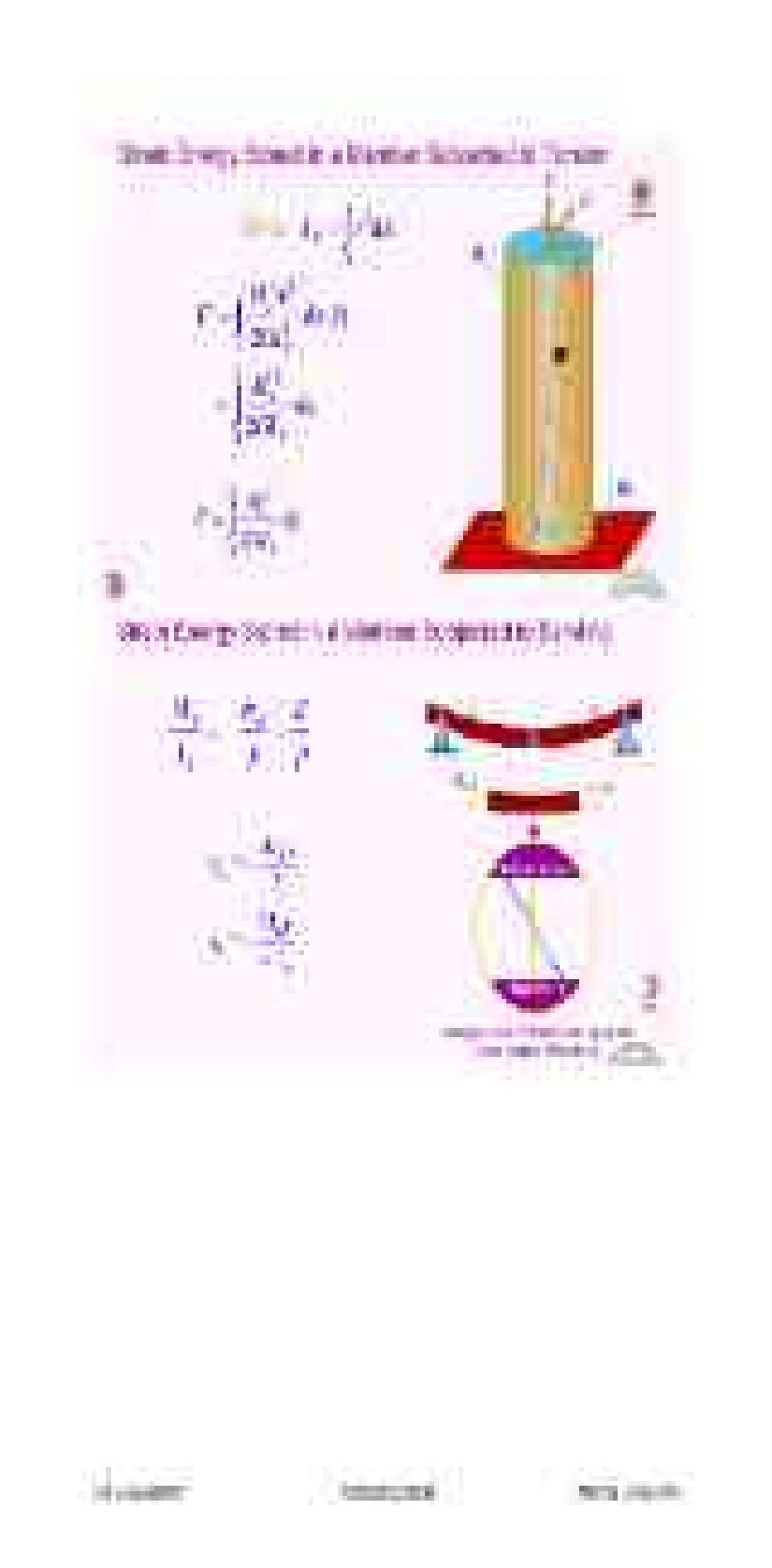
Strain Energy in Terms of Applied Load / for Axially Loaded Member

$$\Delta U = \frac{1}{2}\int_0^{\Delta} \left(\frac{P}{AE}x\right) d\left(\frac{P}{AE}x\right)$$

$$= \frac{1}{2}\frac{P^2}{AE}\int_0^{\Delta} x\,dx$$

$$U = \frac{1}{2}\int_0^{\Delta} \frac{P^2}{AE}\,dx$$

$$U = \frac{1}{2}\frac{P^2}{AE}\int_0^{L} dx$$



Changes in the Components When Gas Is Adsorbed

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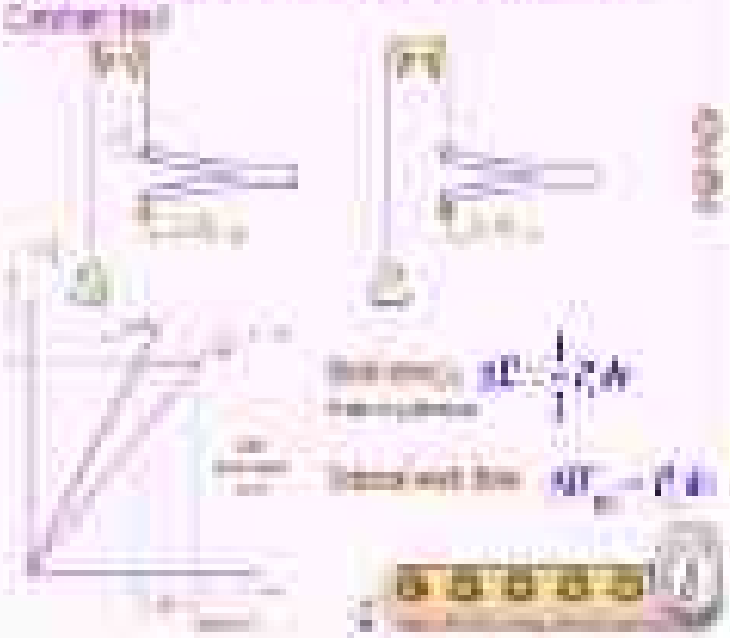

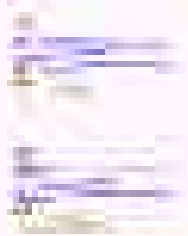

Quantum Energy Confinement Potential Energy Wells

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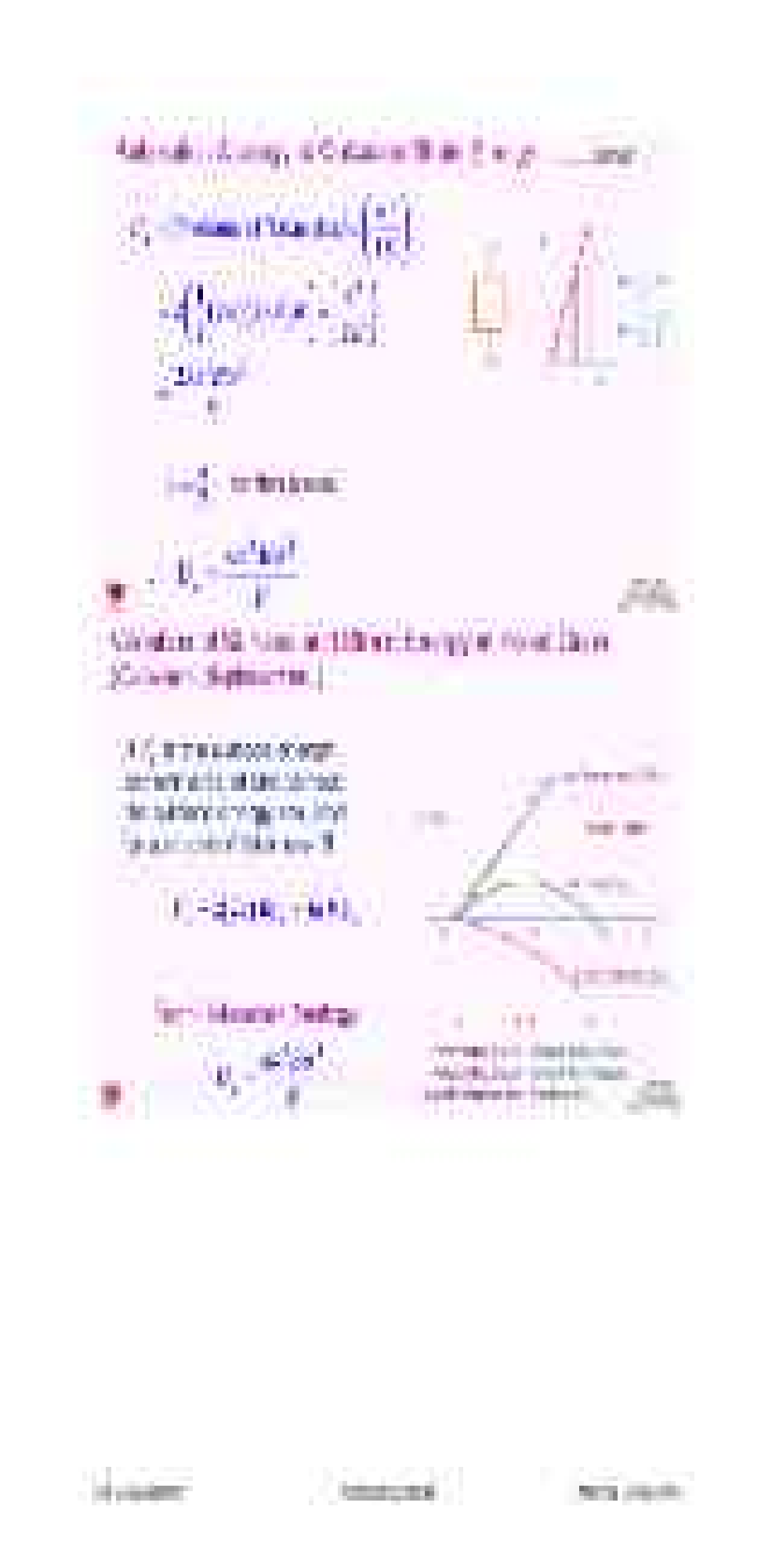
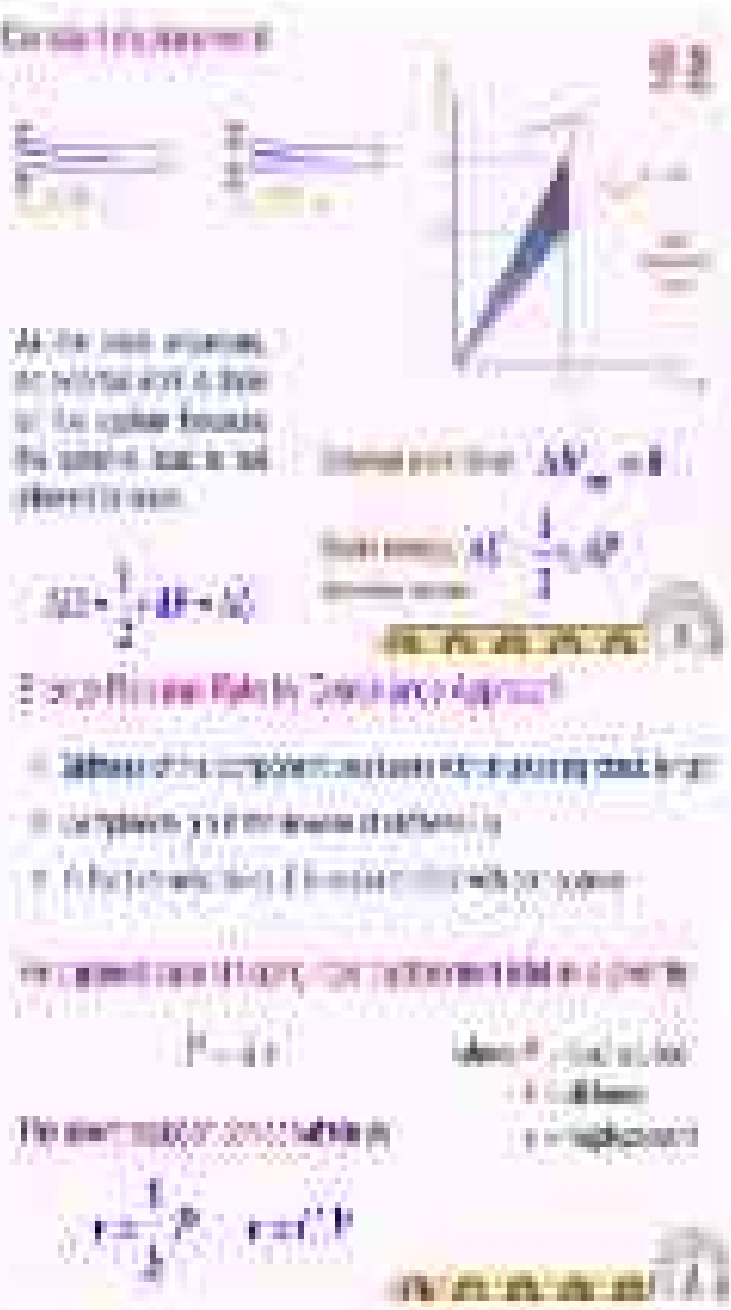
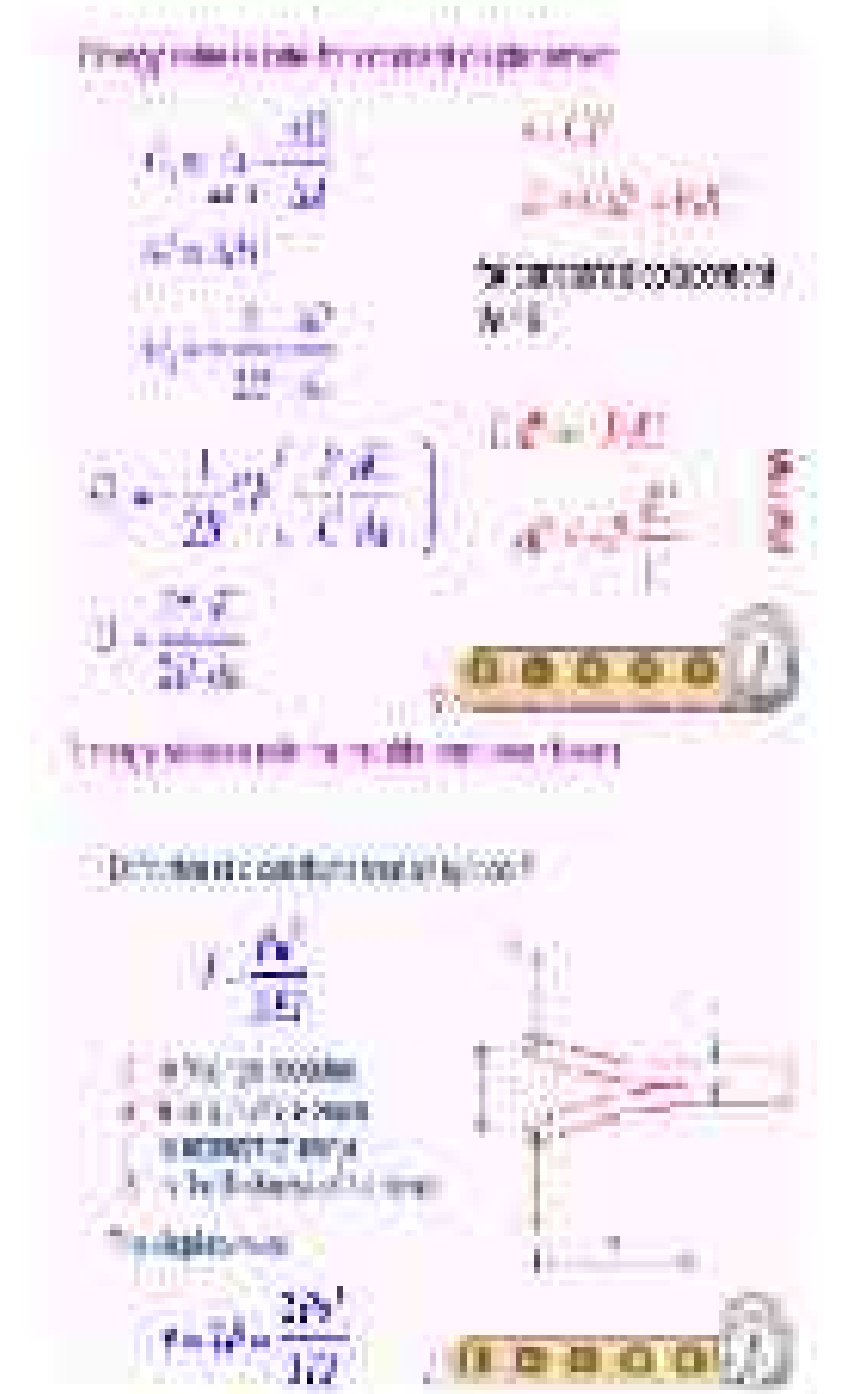
$$E_n = \frac{n^2 h^2}{8mL^2}$$

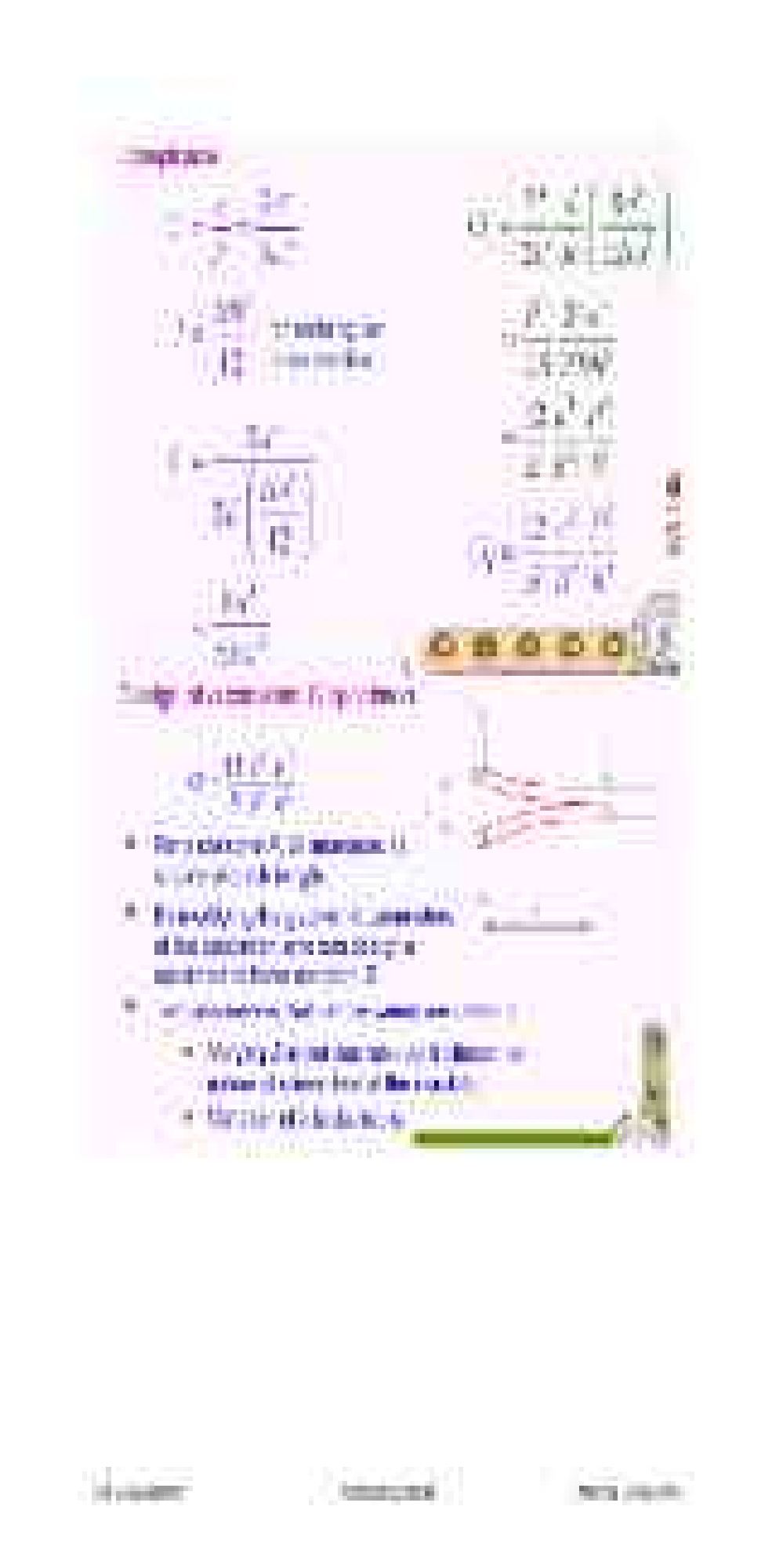
[illegible]

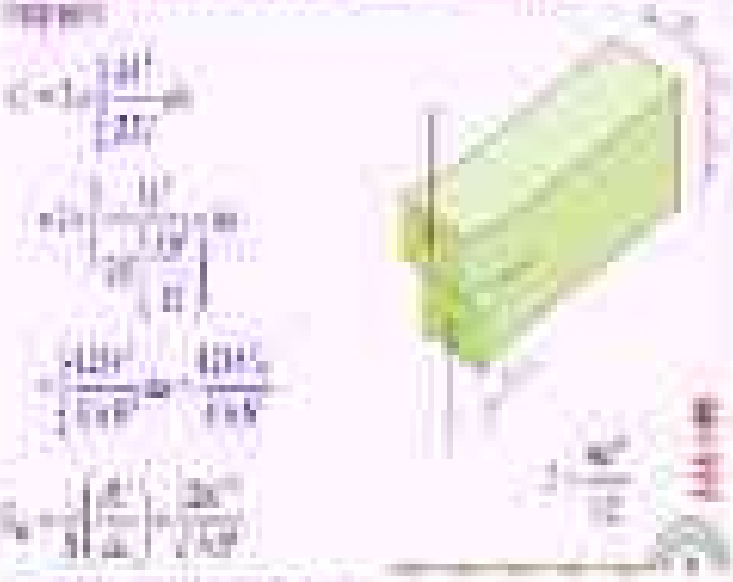
Resonant Tunneling Quantum Well Energy











$$I_y = \frac{2\pi\rho}{3}\int_0^{R} x^3\sqrt{R^2-x^2}\,dx$$

$$\int_0^{R} x^3\sqrt{R^2-x^2}\,dx = \left[\frac{x^2}{3}\cdot\frac{(R^2-x^2)^{3/2}}{3/2} - \frac{2}{3}\cdot\frac{(R^2-x^2)^{5/2}}{5/2}\right]_0^{R}$$

$$= \left(0+\frac{R^5}{15}\right) - \left(-\frac{2}{15}R^5 - 0\right)$$

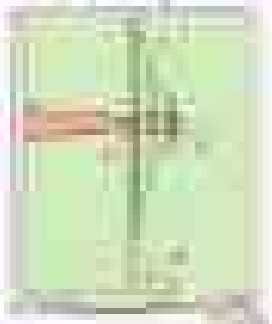
$$= \frac{R^5}{15} + \frac{2R^5}{15}$$

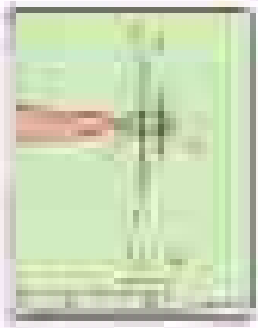
$$= \frac{R^5}{5}$$

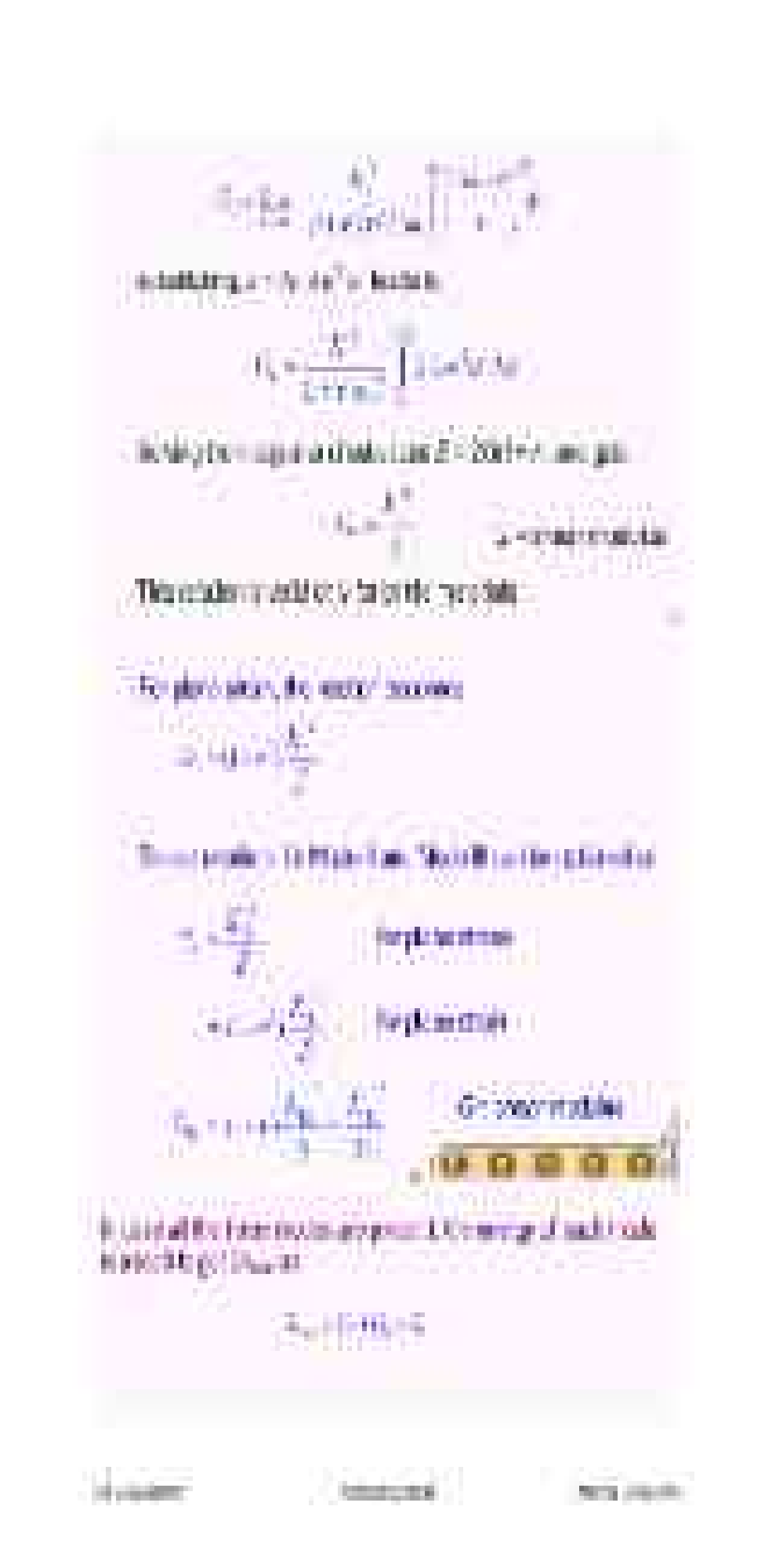
$$I_y = \frac{2\pi\rho}{3}\cdot\frac{R^5}{5}$$

$$I_y = \frac{2\pi\rho R^5}{15}$$

Energy released at O:







Necessary and Sufficient Conditions for Pareto Optimality

(Necessity Condition)

(Sufficiency Condition)

Graphical Representation of Condition of Tension in a Belt in Motion

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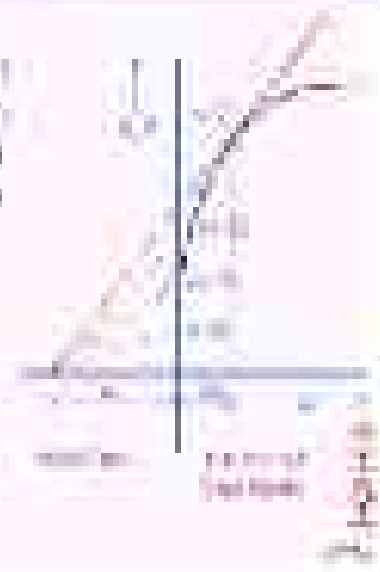

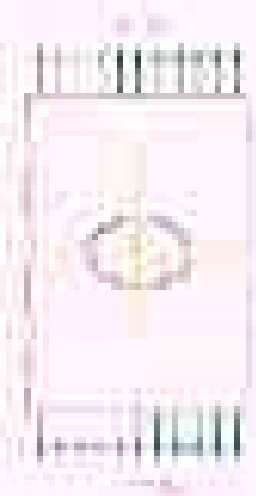

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$$[illegible]$$

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1. [illegible]
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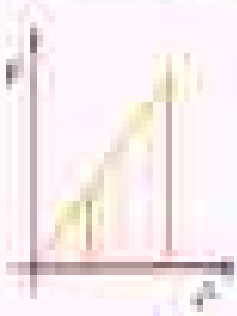


$$\sigma_x = \frac{P_x}{A} \qquad k_x = \frac{P_x}{\delta} \qquad \tau_{xy} = \frac{P_{xy}}{A}$$

$$U = \frac{1}{2E}\int_V \left[\sigma_x^2 + \sigma_y^2 + \sigma_z^2 - 2\nu(\sigma_x\sigma_y + \sigma_y\sigma_z + \sigma_z\sigma_x)\right] dV + \frac{1}{2G}\int_V \left[\tau_{xy}^2 + \tau_{yz}^2 + \tau_{zx}^2\right] dV$$

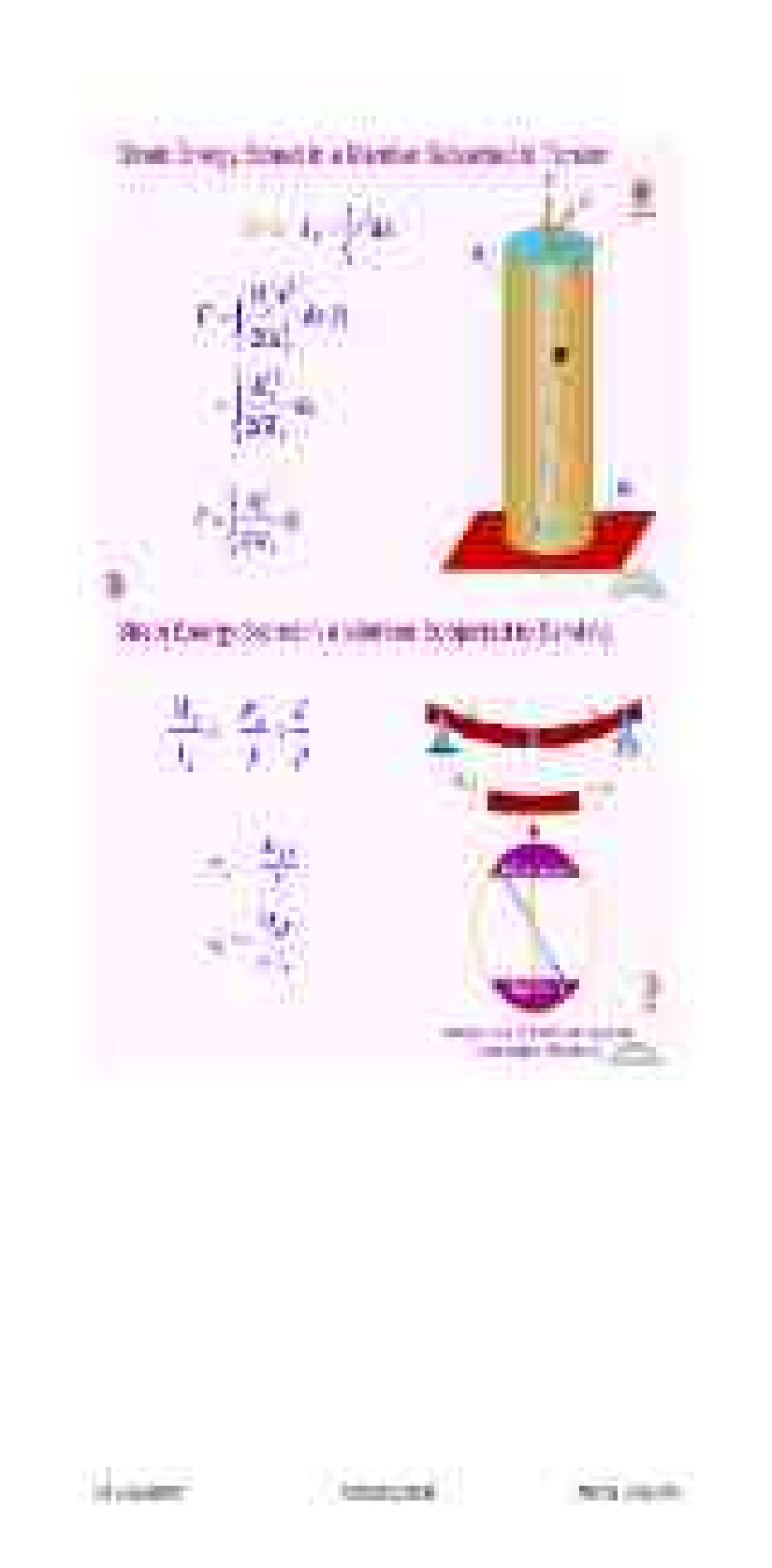
Strain Energy in Terms of Applied Loads (Castigliano's Theorem)

$$\Delta U = \frac{1}{2E}\left[\frac{\partial}{\partial P_i}\int_V (\sigma_x^2 + \sigma_y^2 + \sigma_z^2 - 2\nu(\sigma_x\sigma_y + \sigma_y\sigma_z + \sigma_z\sigma_x))\, dV\right] \Delta P_i$$

$$= \frac{1}{2E}\frac{\partial}{\partial P_i}\int_V \sigma^2 \, dV \, \Delta P_i$$

$$U = \frac{1}{2E}\int_V \sigma^2 \, dV$$

$$U = \frac{1}{2E}\int_V \frac{P^2}{A^2} dV$$



Energy balance in a Watermill (gravitational energy)

$$\dot{m} = \frac{1}{2}\rho A v_1 \left(v_1^2 - v_2^2\right)$$

$$P_{\text{mech}} = \int_0^{\dots} \dots \, dA$$

$$\dots = \int \frac{\dots}{2\pi r} \, dA$$

$$= \int \frac{\dots}{2\pi r} \, dA$$

Energy balance in a Watermill (gravitational energy)

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Changes in the Ecosystem When Grain Is Added

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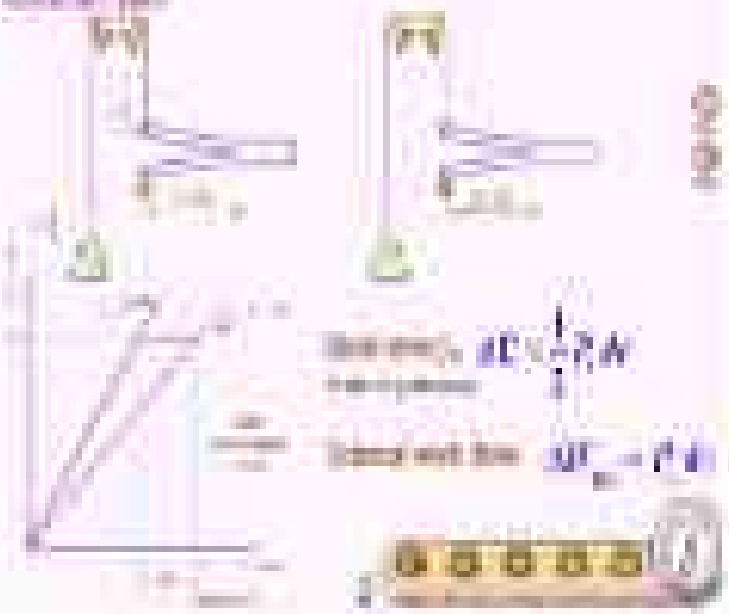

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$$E_n = \frac{n^2 h^2}{8mL^2}$$

[illegible]

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$$[illegible]$$

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$$[illegible]$$

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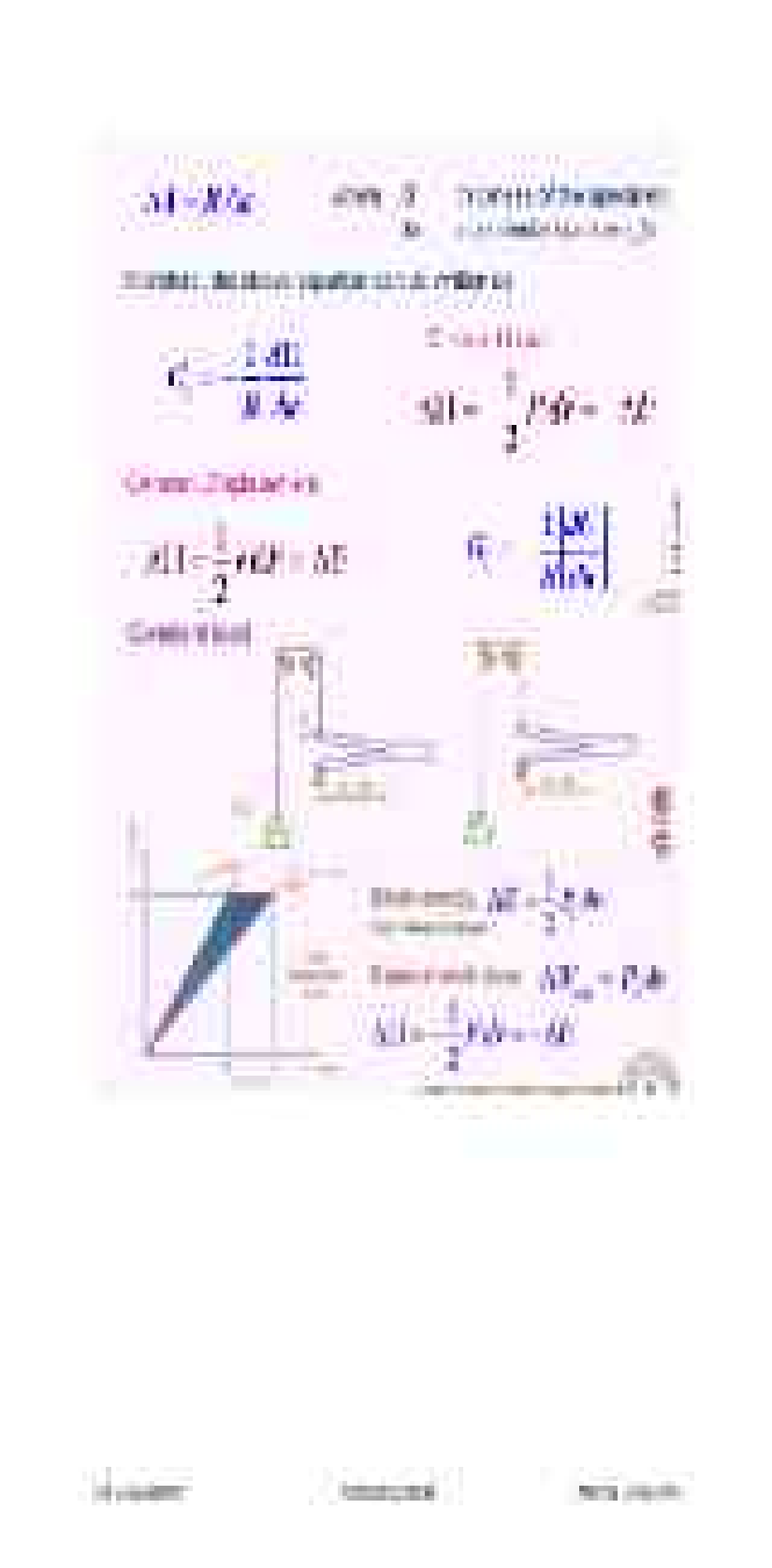

[illegible] Values Help by Contributing Aspect

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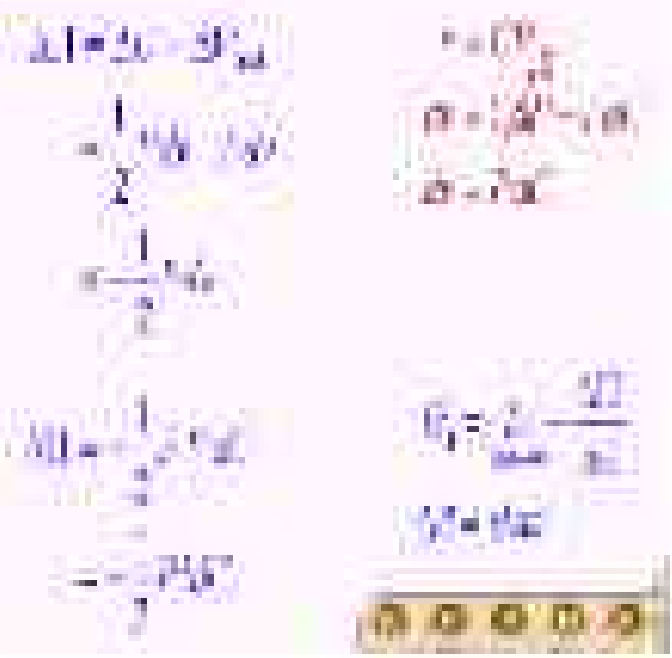
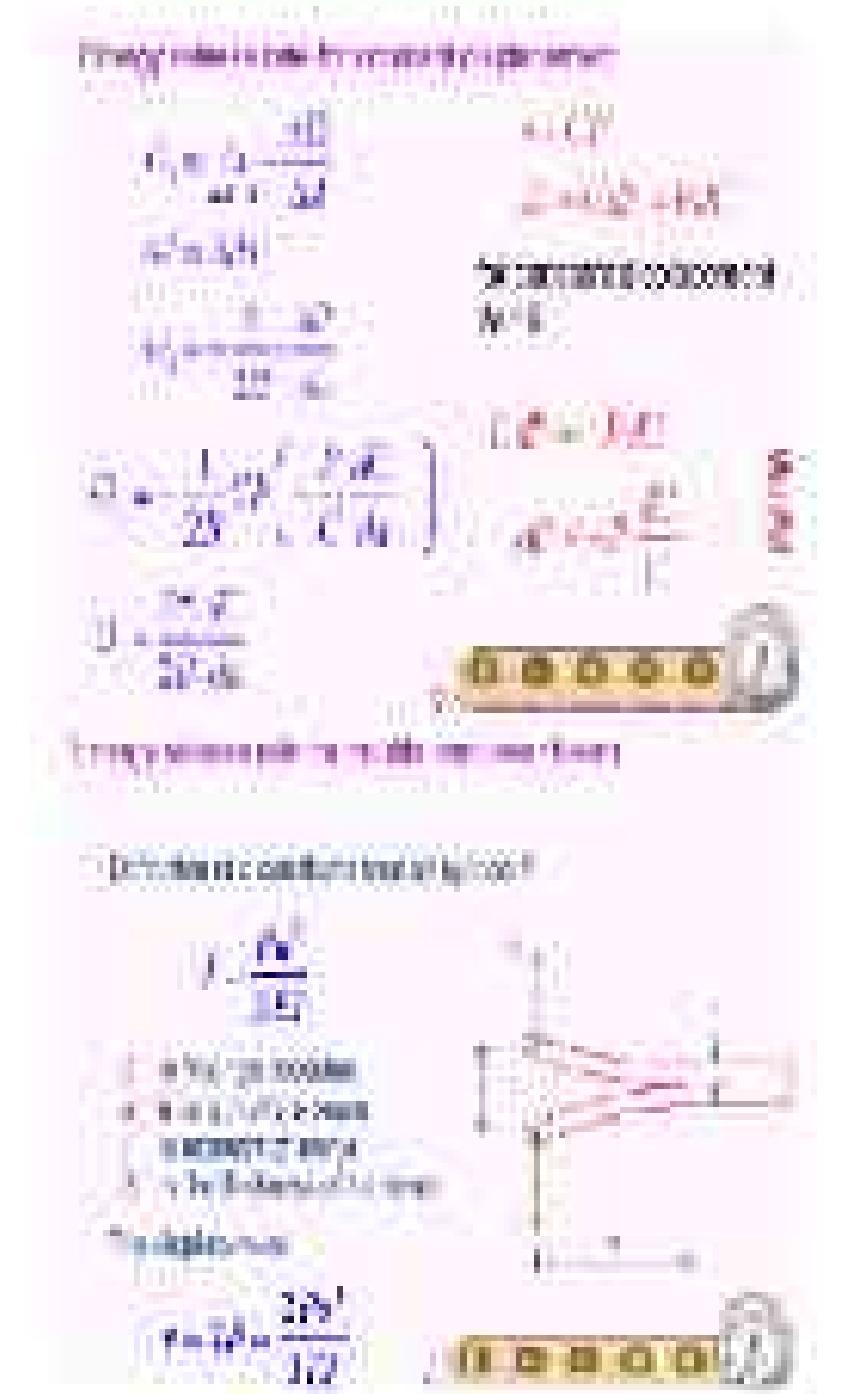
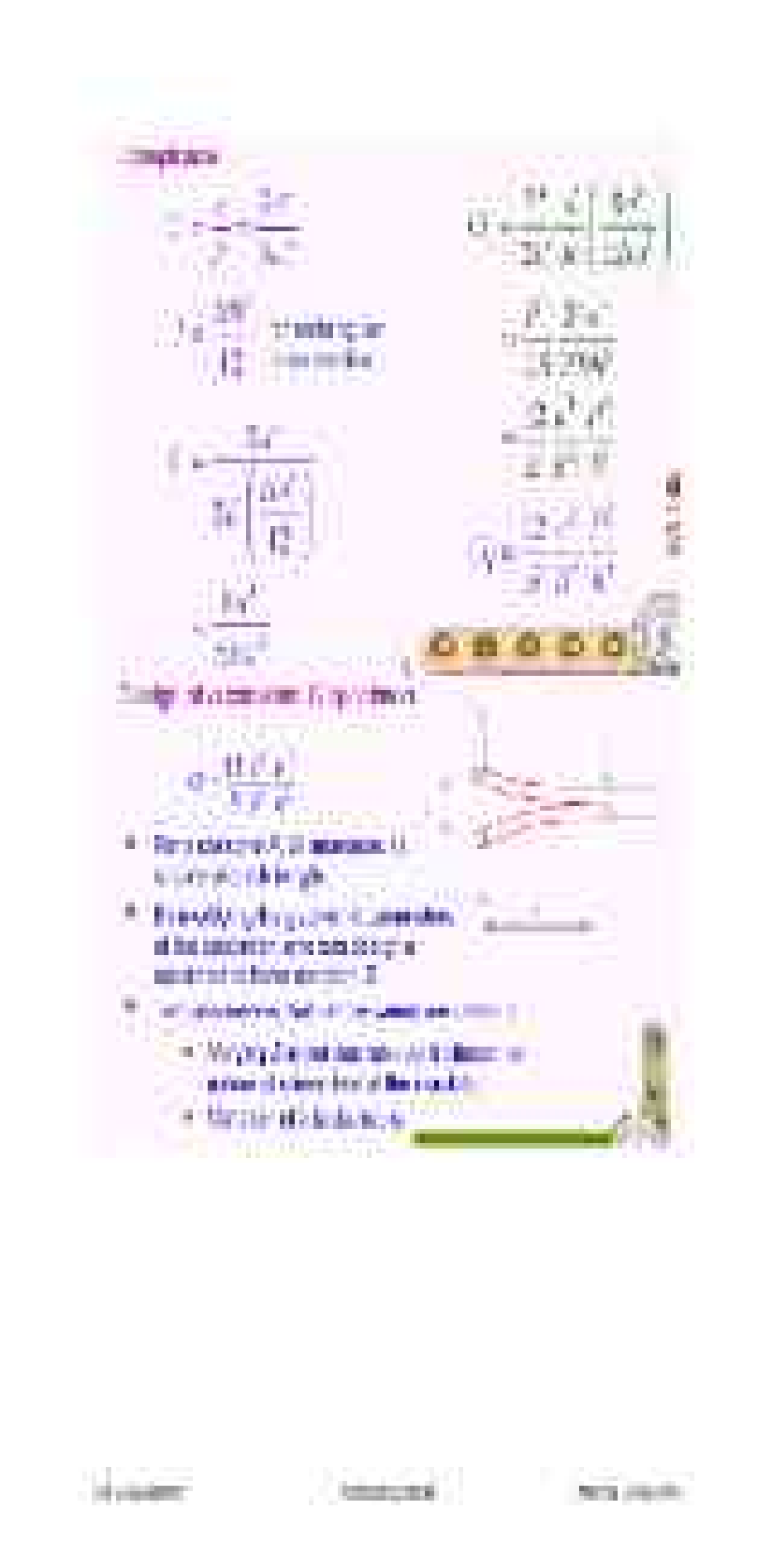
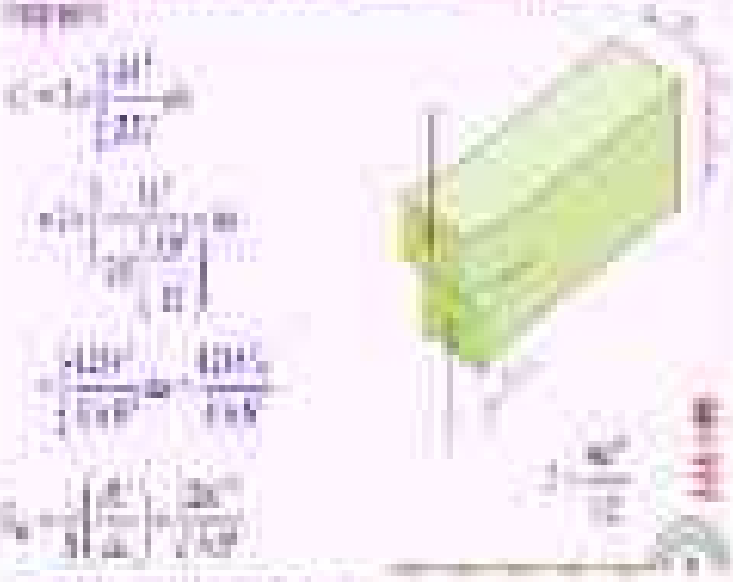








$$I_y = \frac{2\pi\rho}{3}\int_0^{R} x^3\sqrt{R^2-x^2}\,dx$$

$$\int_0^{R} x^3\sqrt{R^2-x^2}\,dx = \left[\frac{x^2}{3}\cdot\frac{(R^2-x^2)^{3/2}}{3/2} - \frac{2}{3}\cdot\frac{(R^2-x^2)^{5/2}}{5/2}\right]_0^{R}$$

$$= \left(0+\frac{R^5}{15}\right) - \left(-\frac{2}{15}R^5 - 0\right)$$

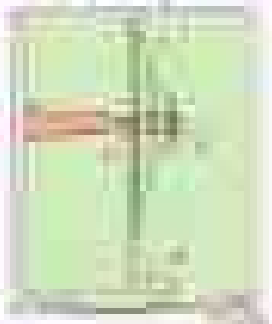
$$= \frac{R^5}{15} + \frac{2R^5}{15}$$

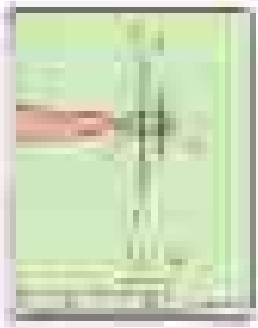
$$= \frac{R^5}{5}$$

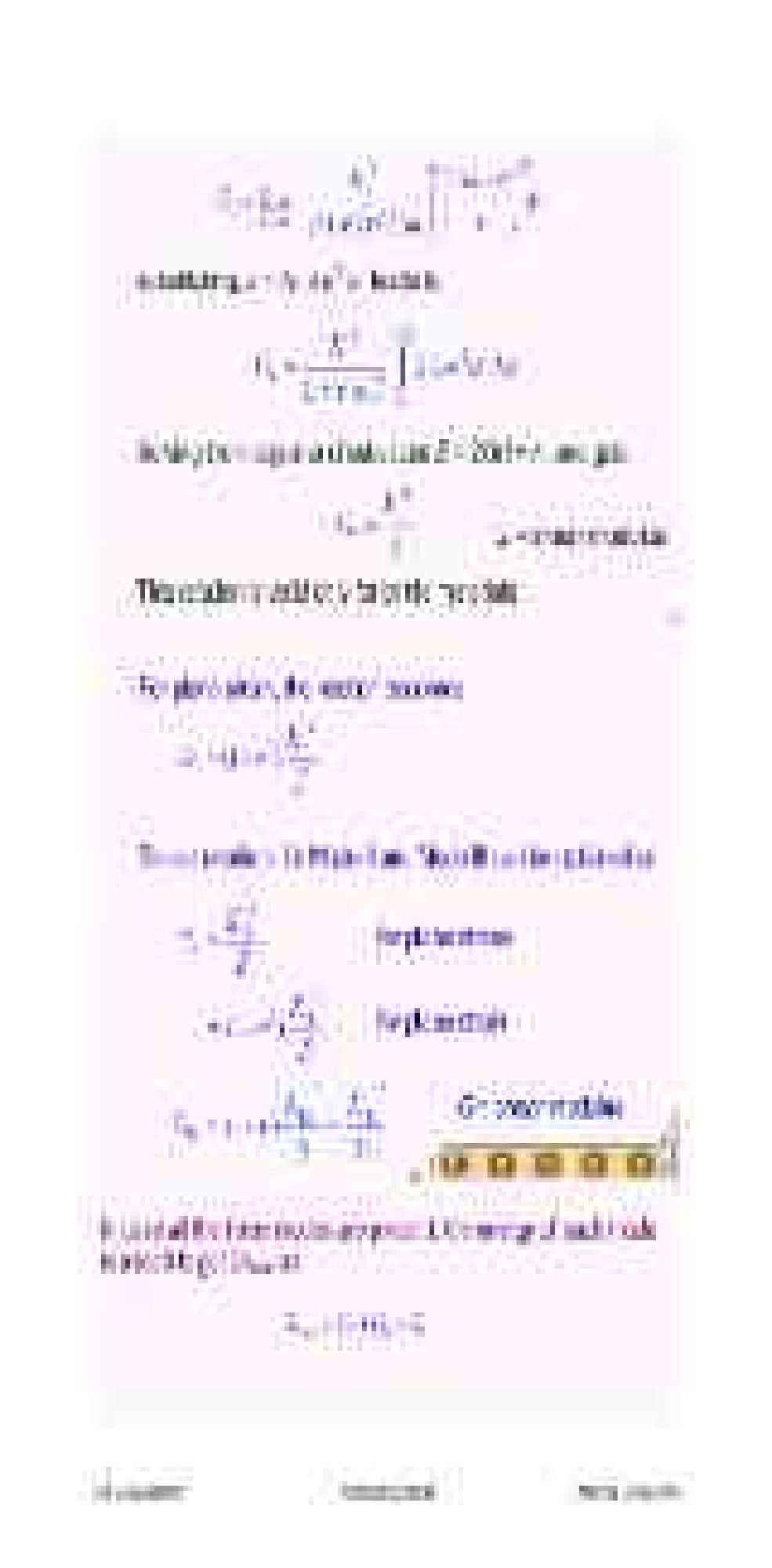
$$I_y = \frac{2\pi\rho}{3}\cdot\frac{R^5}{5}$$

$$I_y = \frac{2\pi\rho R^5}{15}$$

Energy released at O:







Necessary and Sufficient Conditions for Pareto Optimality

(Necessity Condition)

(Sufficiency Condition)

Graphical Representation of Condition of Tension in a Belt in Motion

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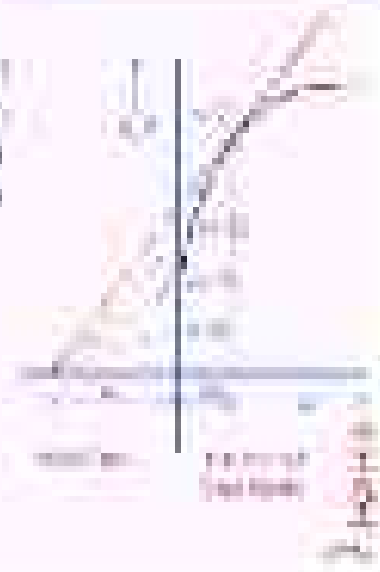
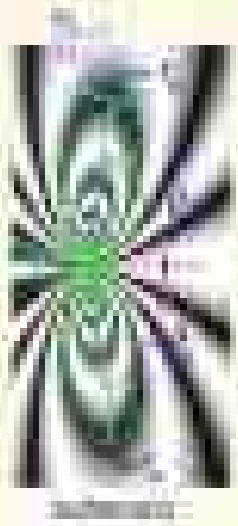
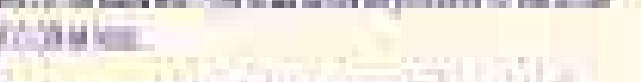
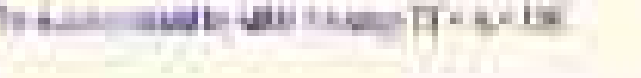




Exercices de la SEP



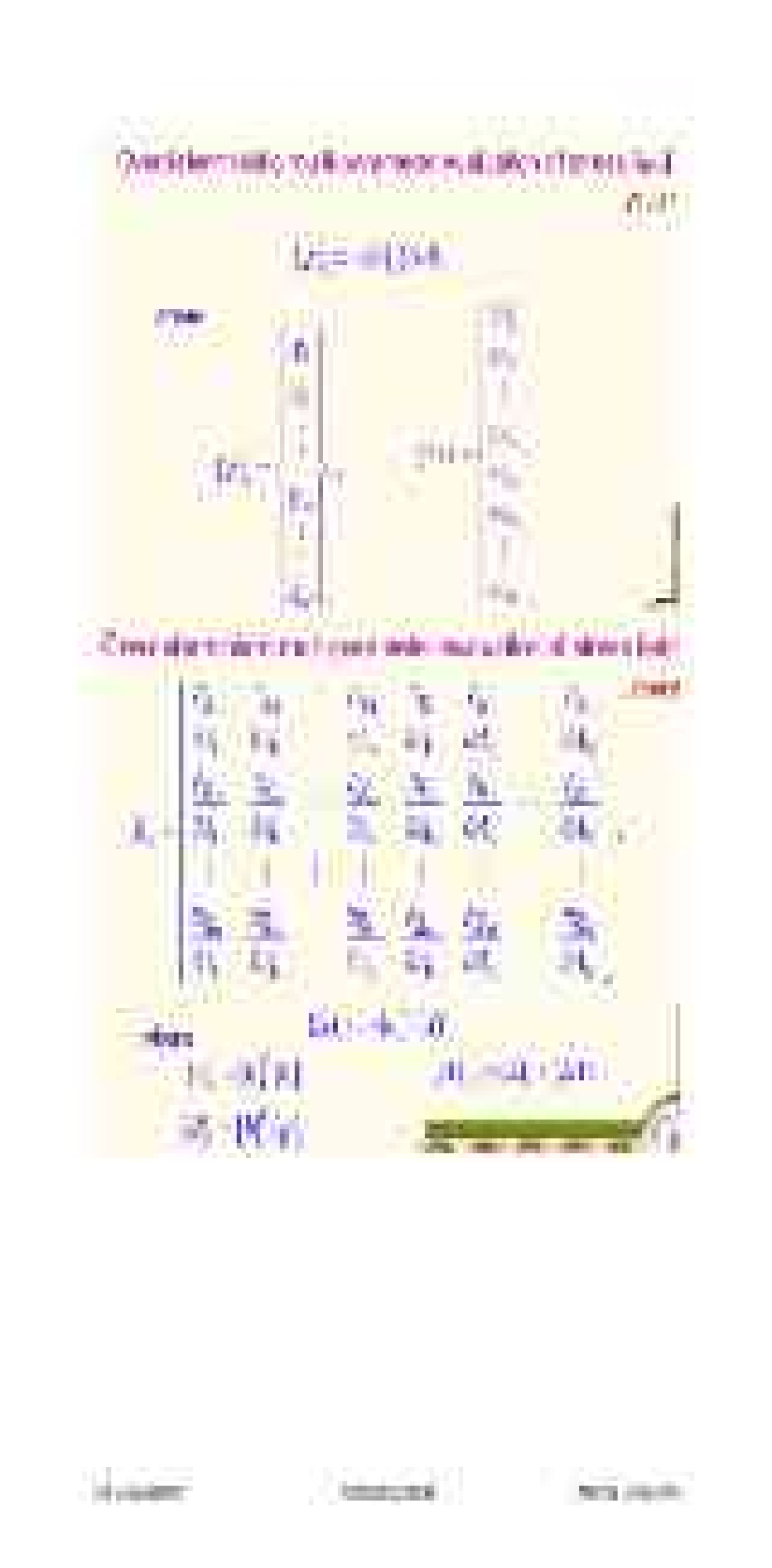


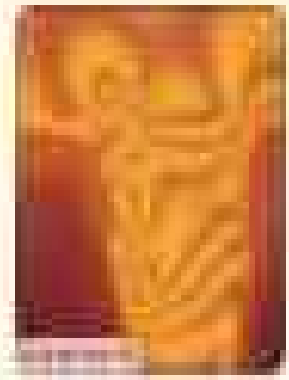
Condizioni di equilibrio statico di un corpo rigido

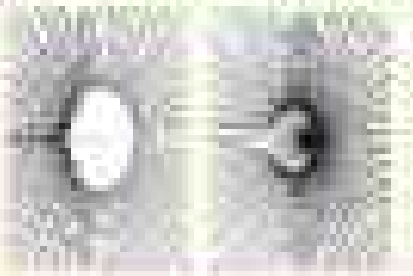
- Risultante delle forze esterne nulla: $\sum_i \vec{F}_{ext,i} = 0$
- Somma algebrica dei momenti delle forze esterne rispetto a un polo nulla:

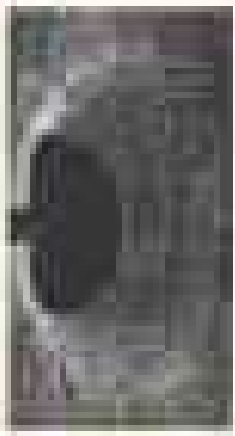
$$\sum_i \vec{M}_{O,ext,i} = \sum_i \vec{r}_{Oi} \times \vec{F}_{ext,i} = 0$$

- Se il corpo è vincolato, le reazioni vincolari sono determinate dalle condizioni di equilibrio









Formation of caustics

- The [illegible] family of the [illegible] light rays forms a caustic surface behind the object plane

- The caustic is given surface is perpendicular to the light rays and is called the caustic surface

Caustic curve

- The intersection of caustic surface with the image plane is called the caustic curve

- [illegible] Due to the angle the boundary line between the area of [illegible] and the surrounding area is [illegible]

- Accuracy in the determination of the size of the caustic curve greatly influences the accuracy of the evaluation of [illegible]

Introduction

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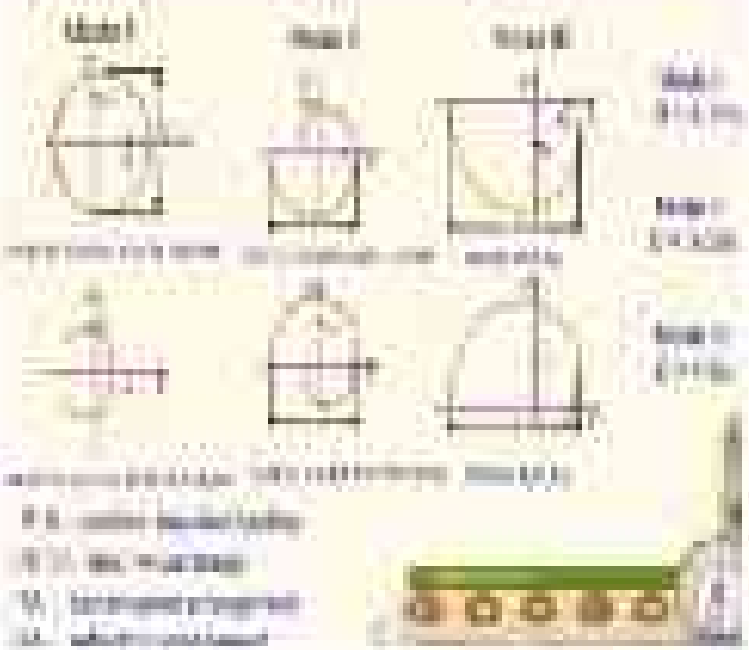
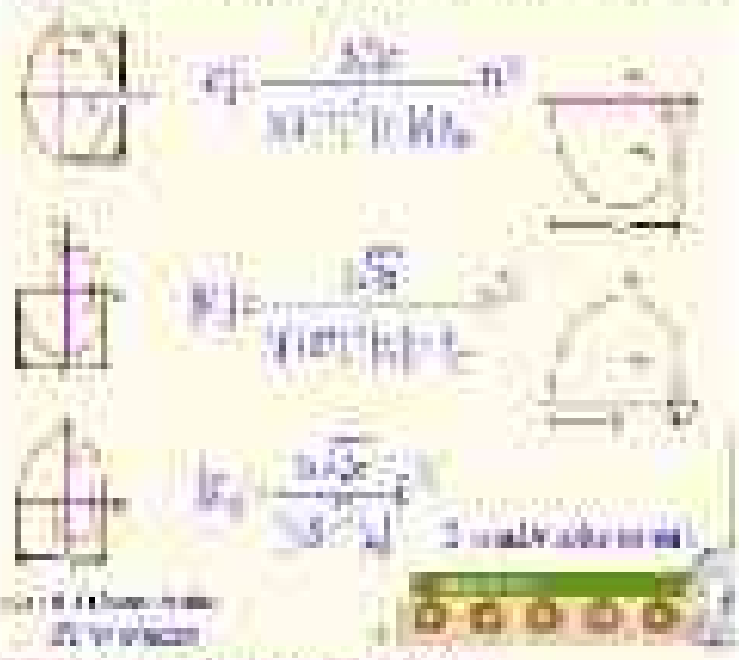
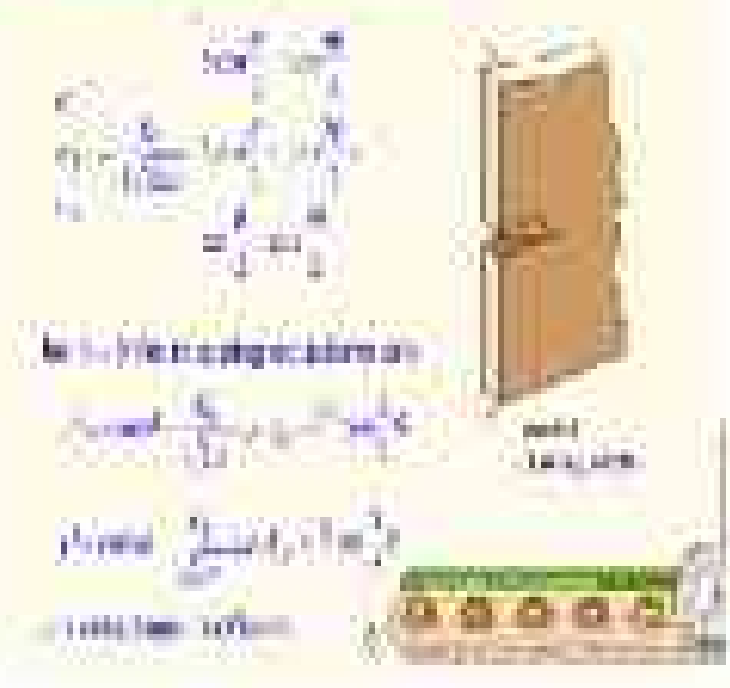
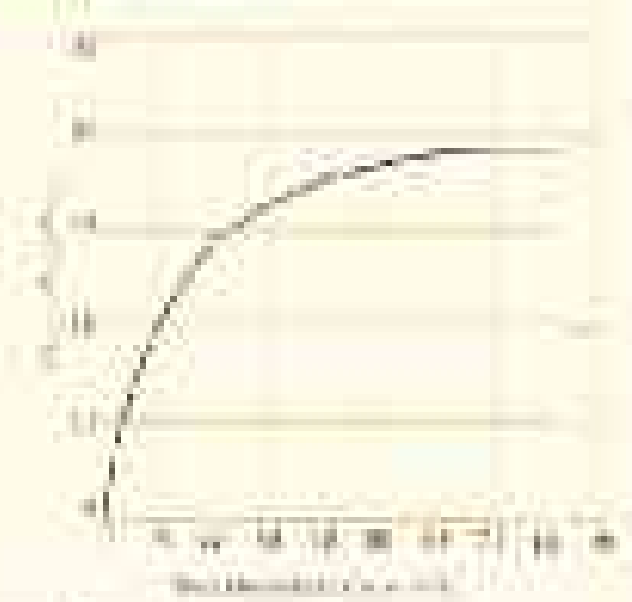


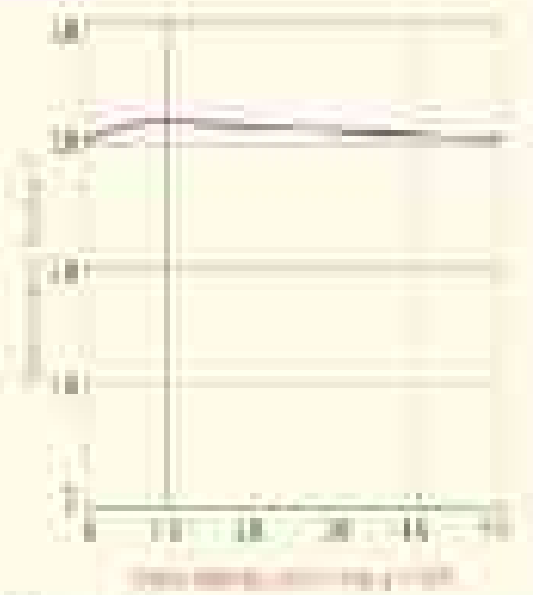




Determination of ΔF (cm)



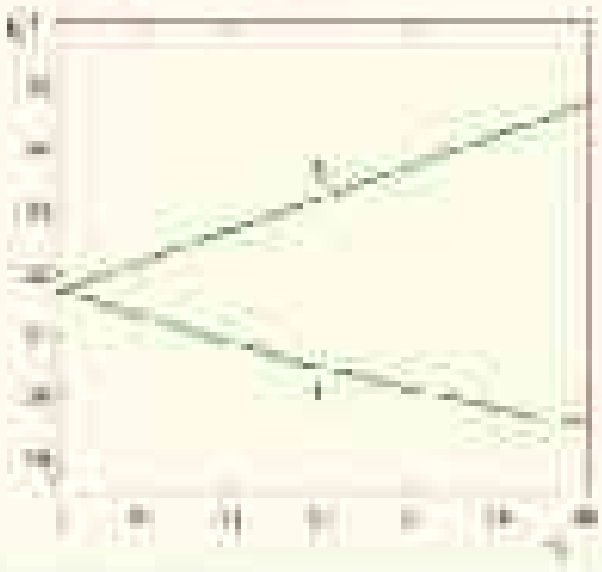
Geometry factor f

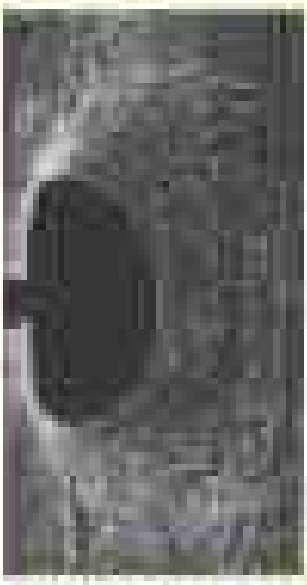


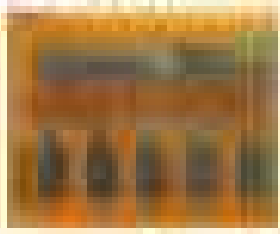
Caustics in optical (lenslet-based) models

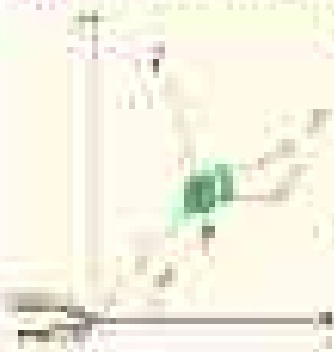
$$h_c = \frac{3\sqrt{3}\,d}{16\left|\frac{n_{lens}}{n_{medium}} - 1\right|}$$

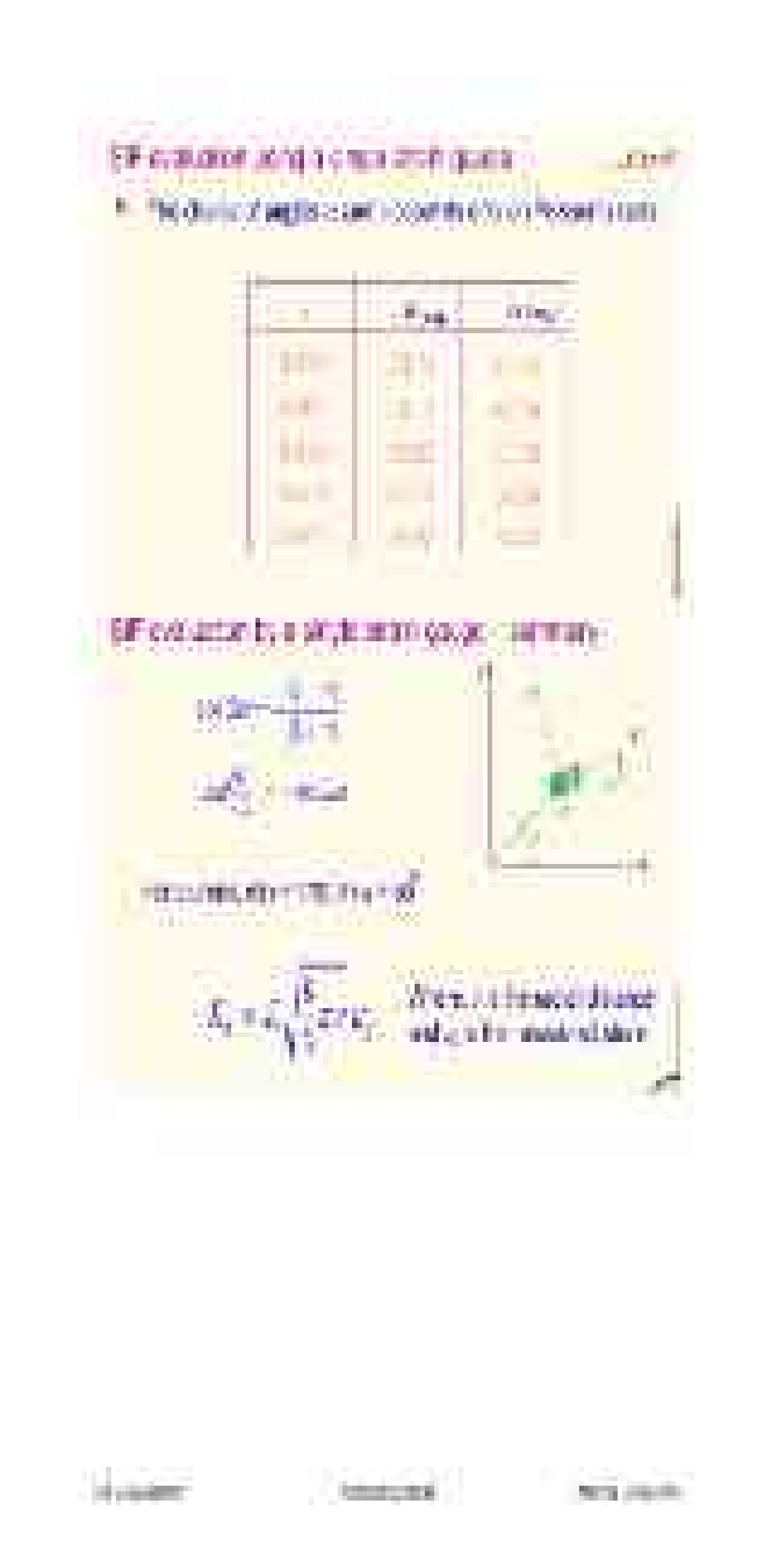
Caustics in acoustic (underwater) models

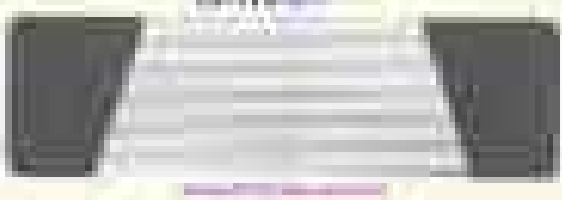


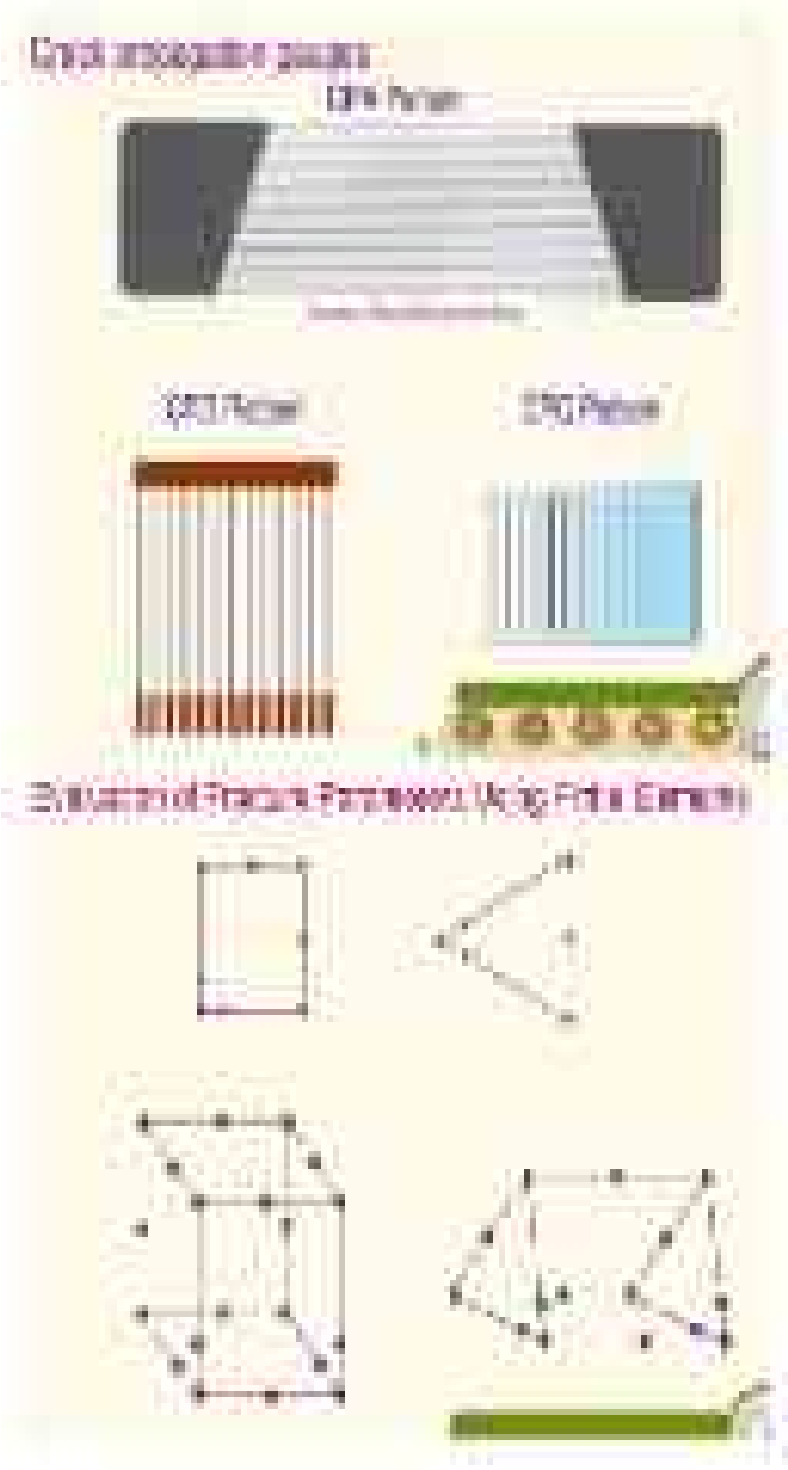


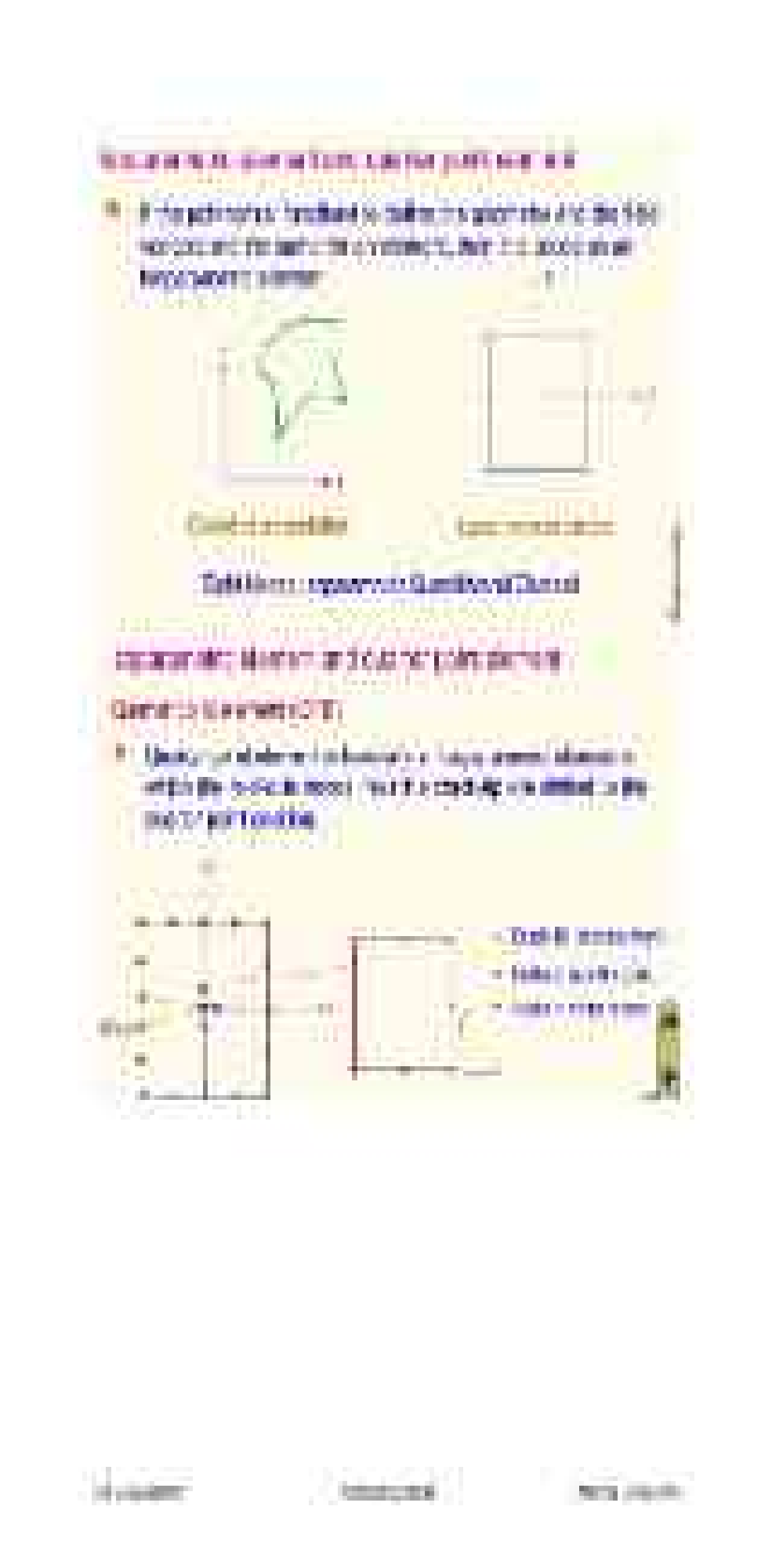












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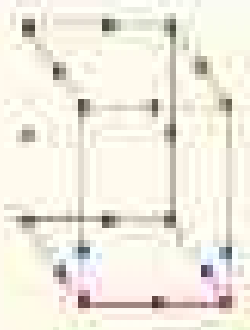

Reconstruction of an arbitrary convex polygon

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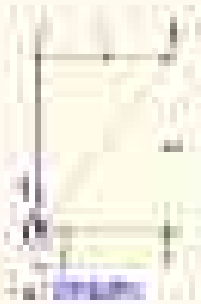

Reconstruction of an arbitrary convex polygon

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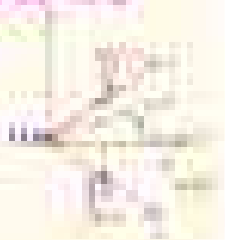

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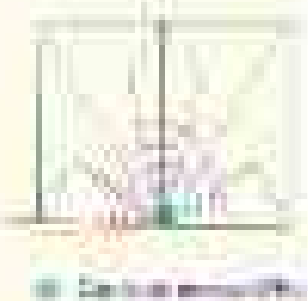

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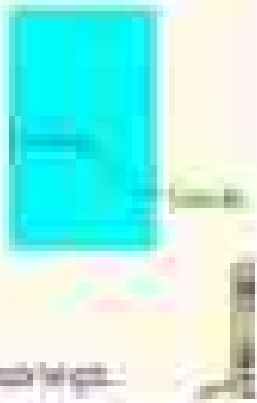

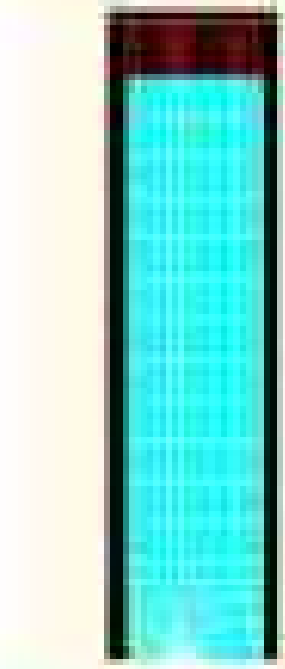

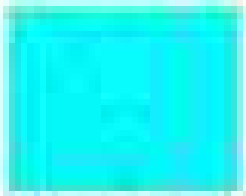

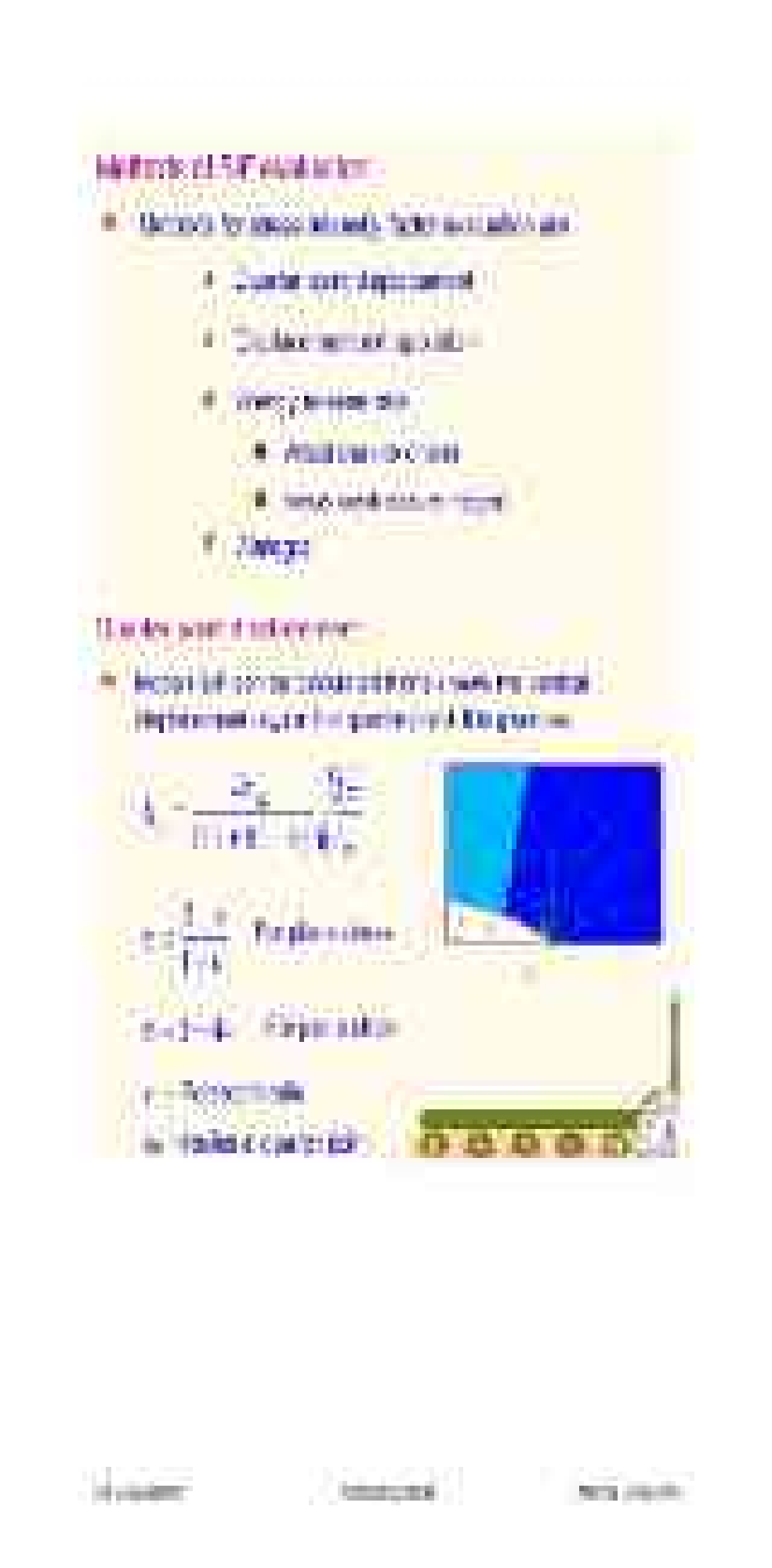

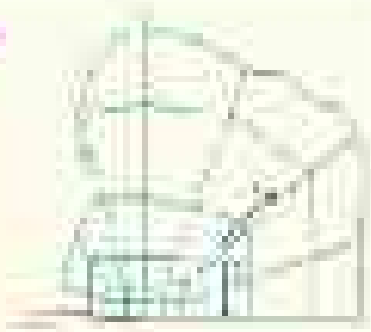

Turbomachinery applications

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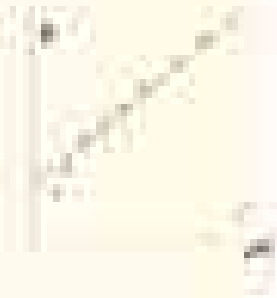

Energy conservation (2-in)

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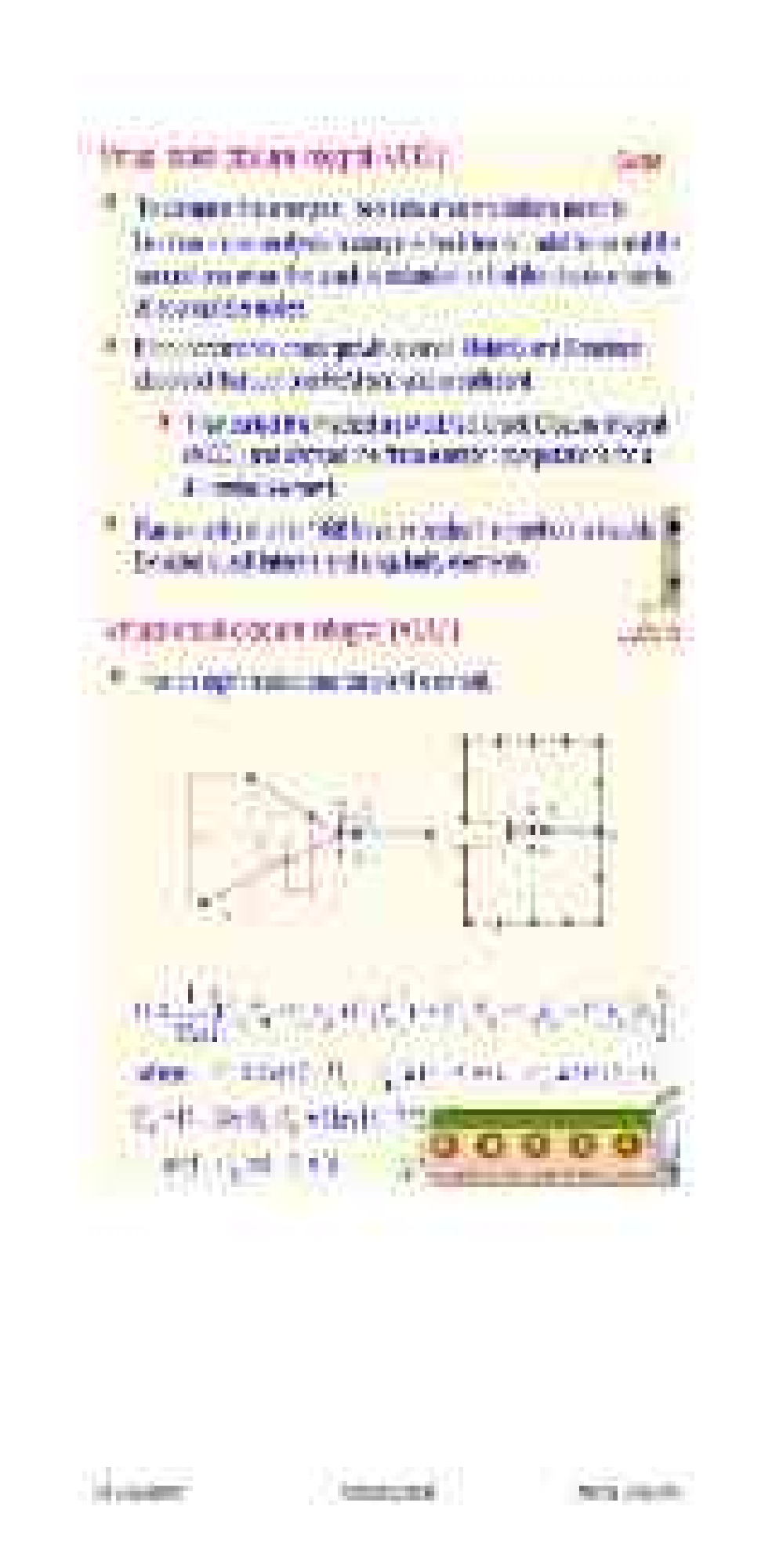

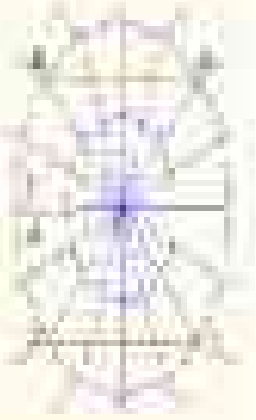

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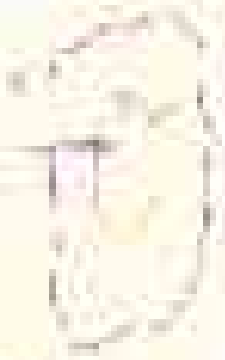

Where

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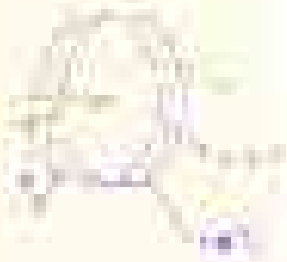

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Error propagation

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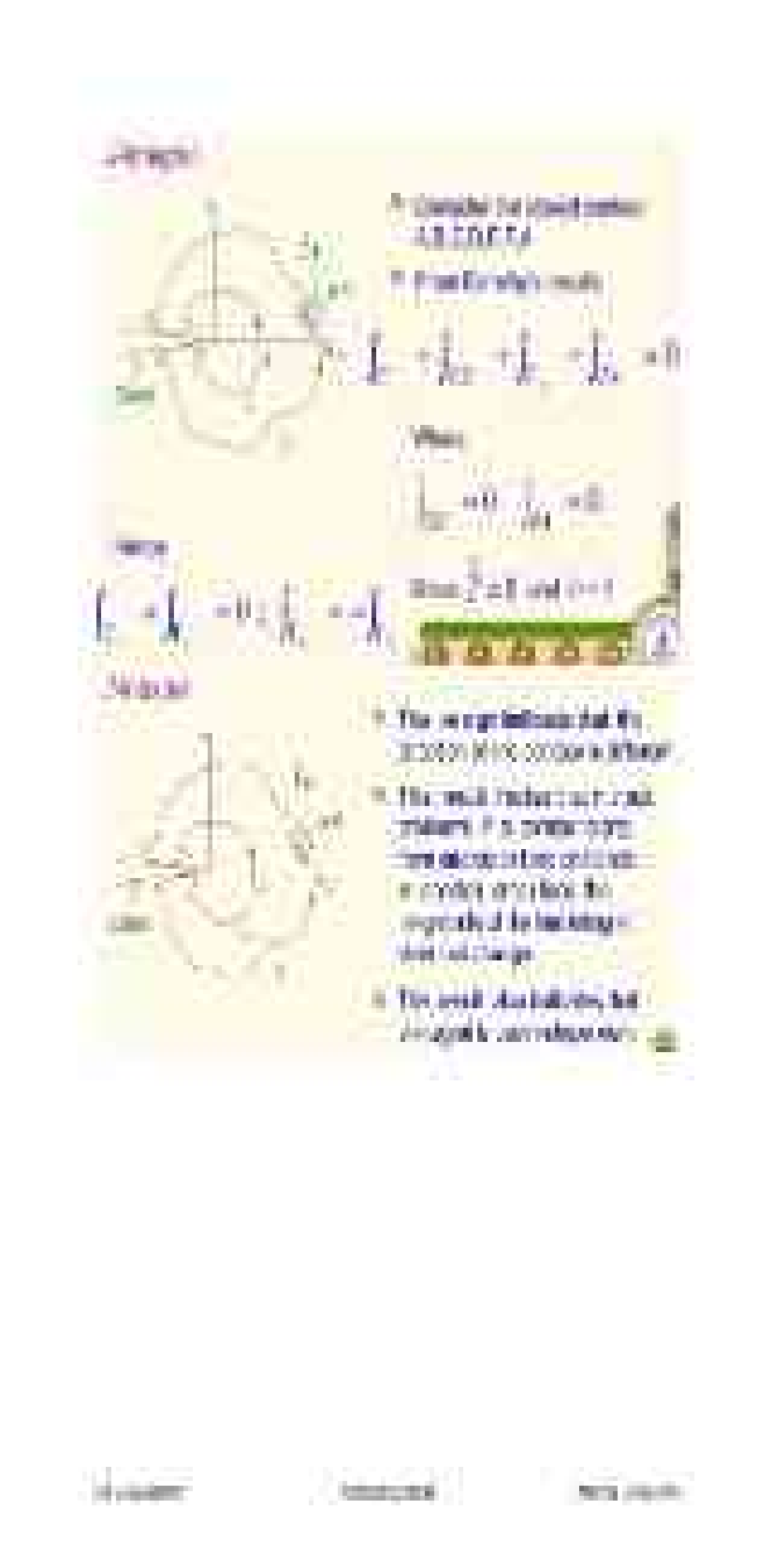
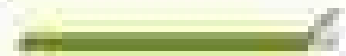
Push-stopover Models

Push-stopover Models





[illegible] Muscle Behavior

- [illegible]
- [illegible]
- [illegible]

[illegible] Biomechanical Determinants

- [illegible]
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- [illegible]
- [illegible]