Design of Machines and Mechanical Systems (PC-BTM711)

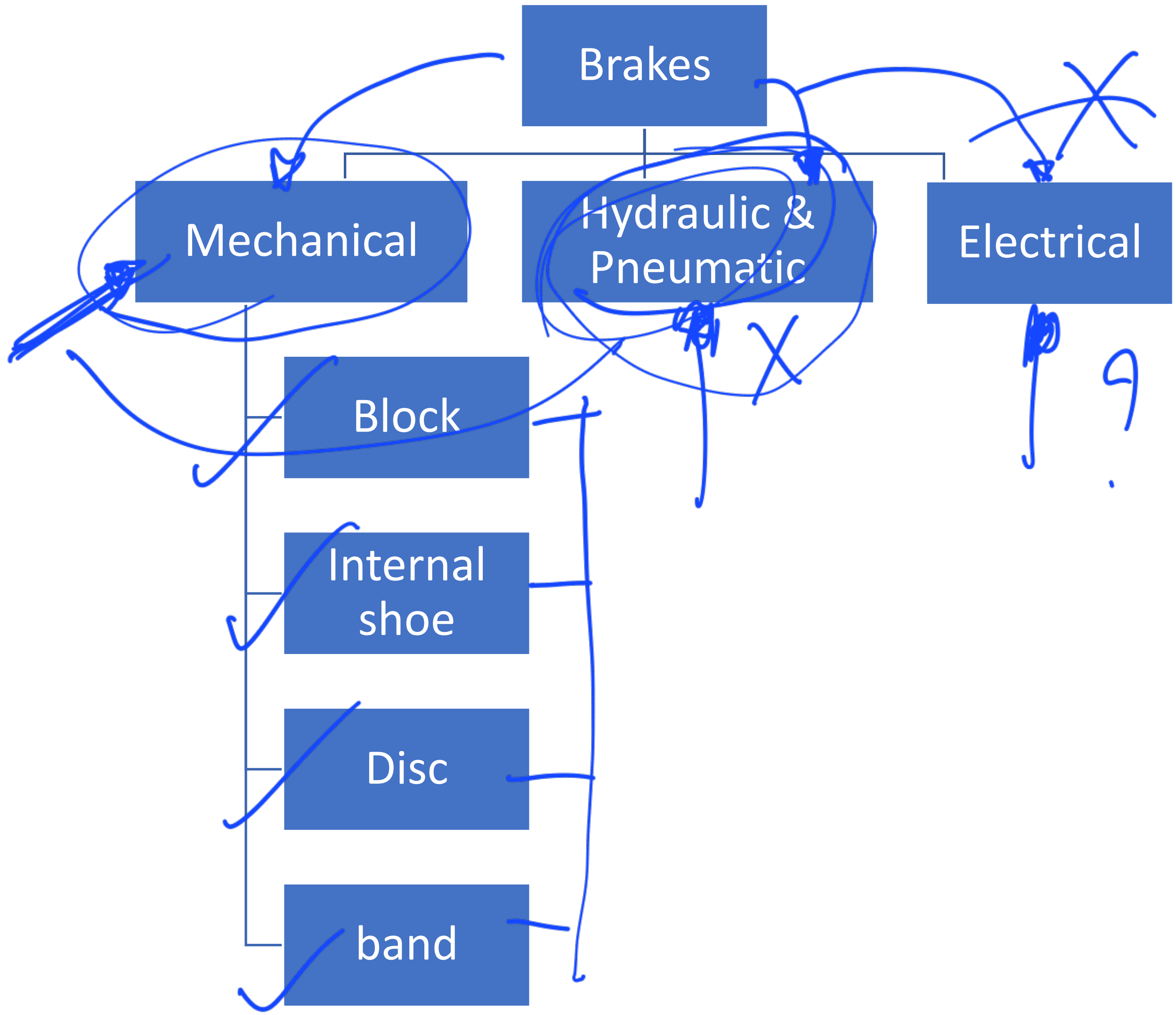
Session 15

Module 4: Design of Brakes

Session Outcomes

- Discuss different types of brakes
- Describe energy equations and torque capacity of brake
- Design block brake with short shoe

Classification of brakes



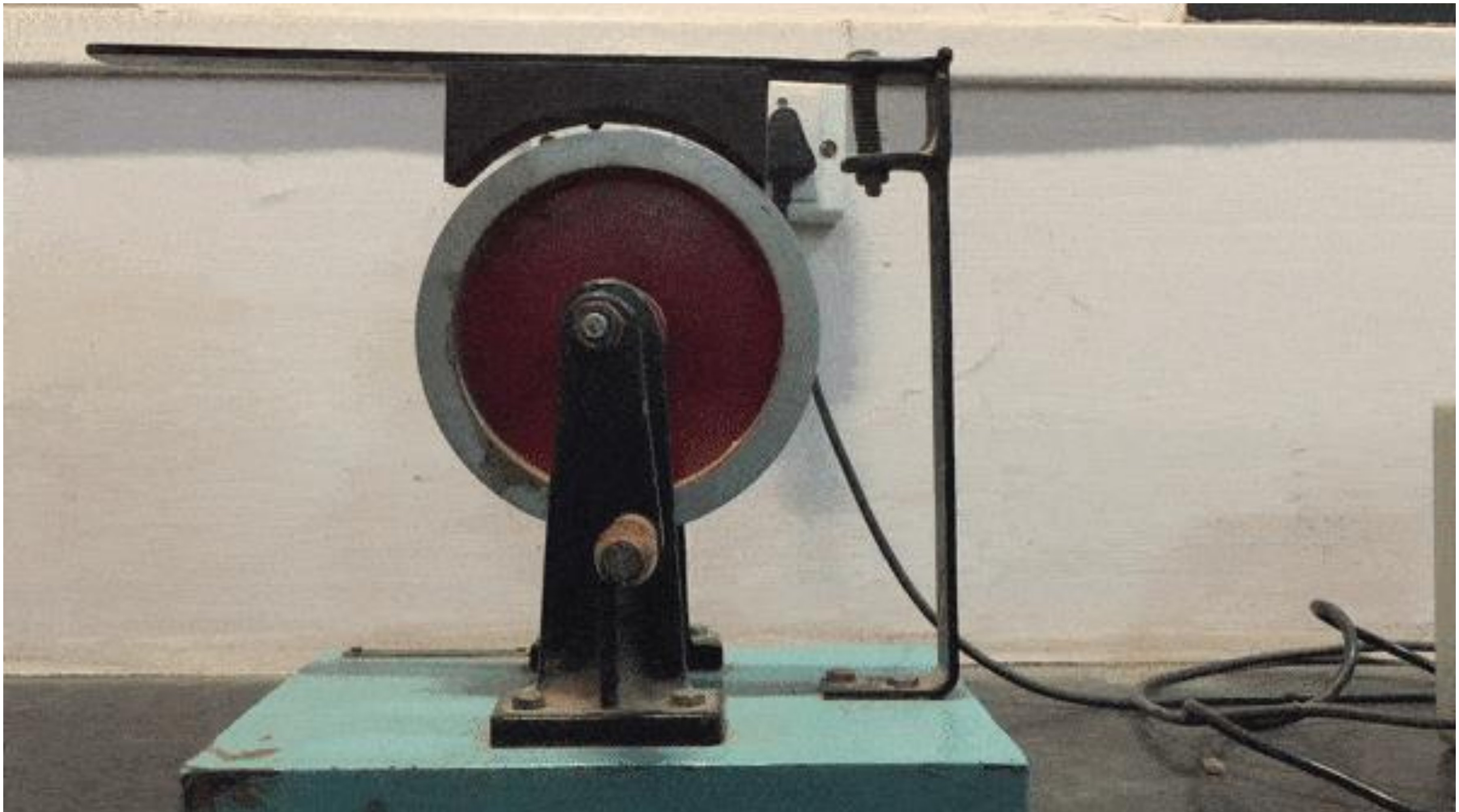
QUIZ

Mechanical Brakes

Which of the following statement about mechanical brakes is FALSE?

1) It is a friction device used to bring moving parts to rest
2) Heat dissipation is an important consideration in brake design
3) None of the above statements is FALSE

Block Brake



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Double Block Brake

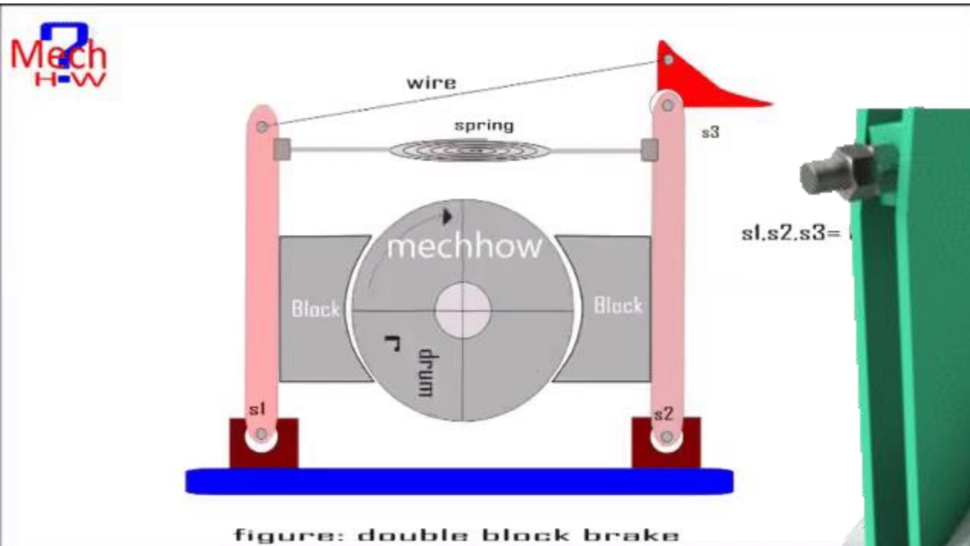
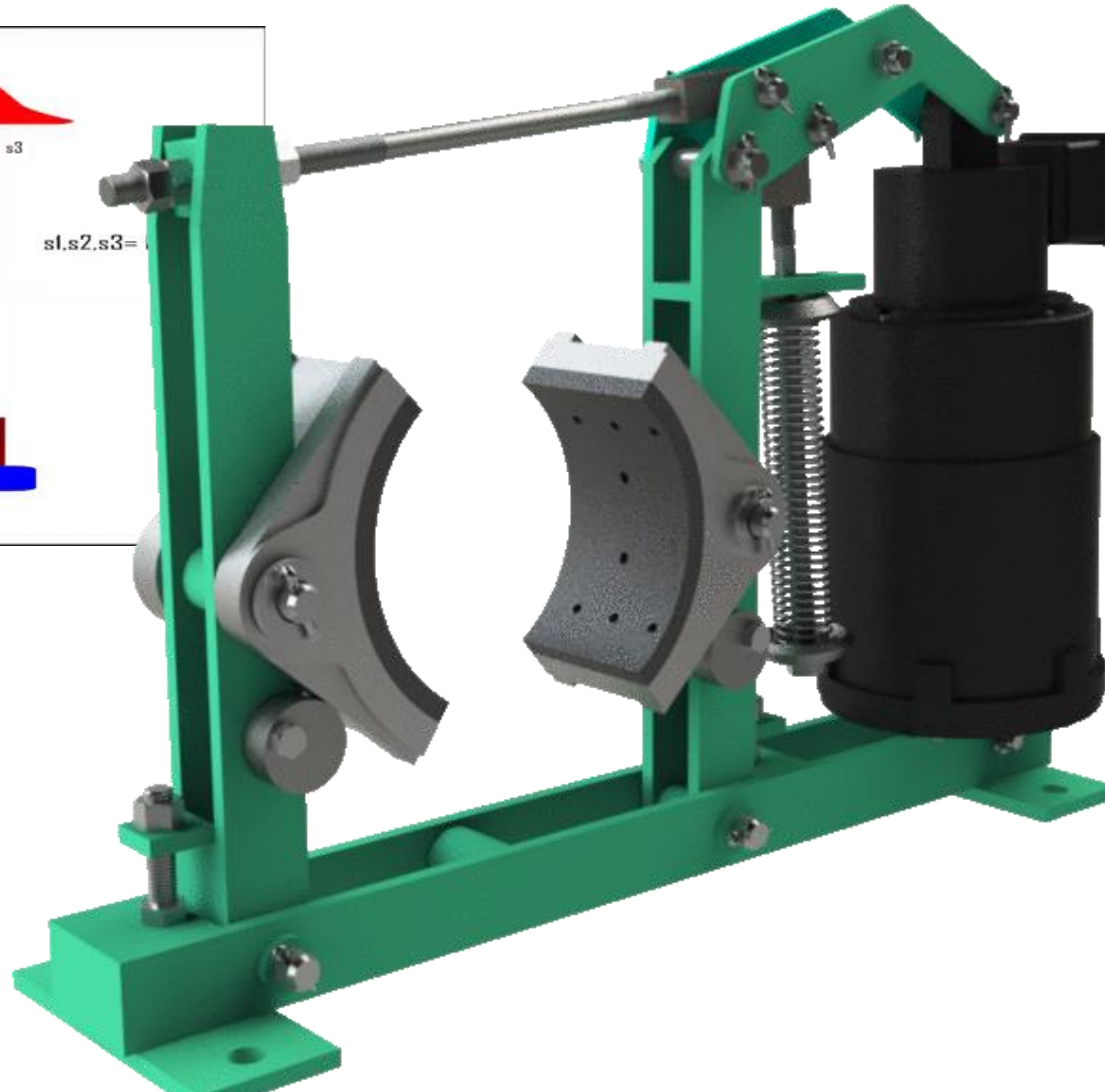


figure: double block brake



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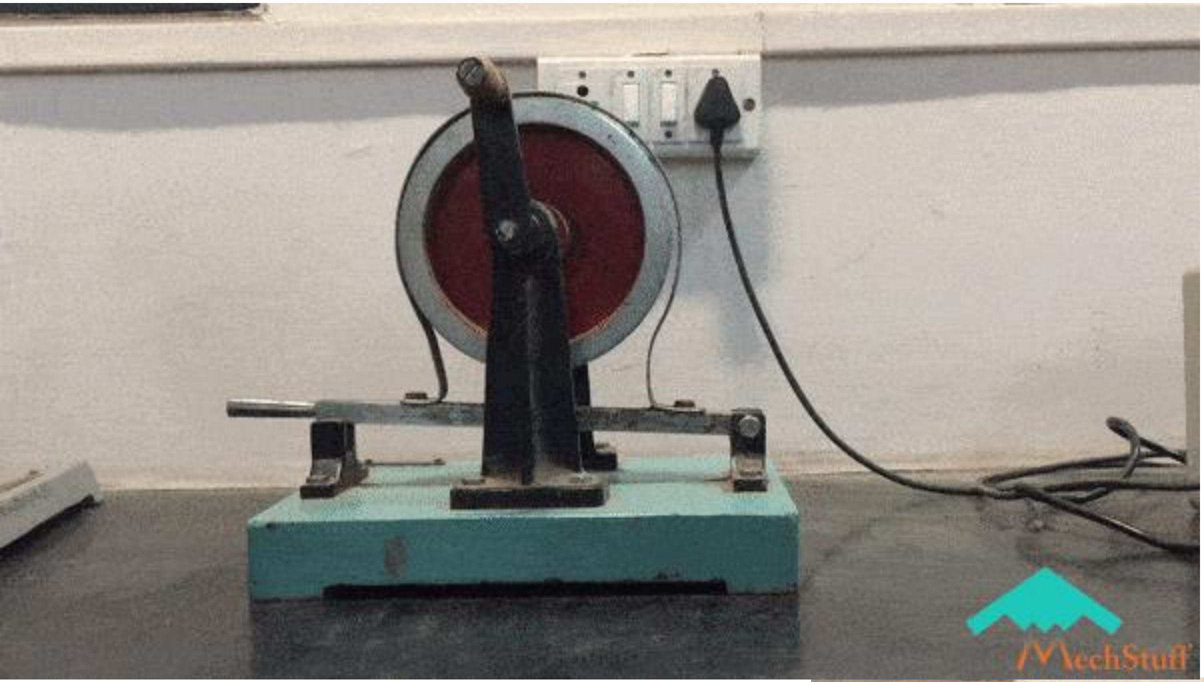
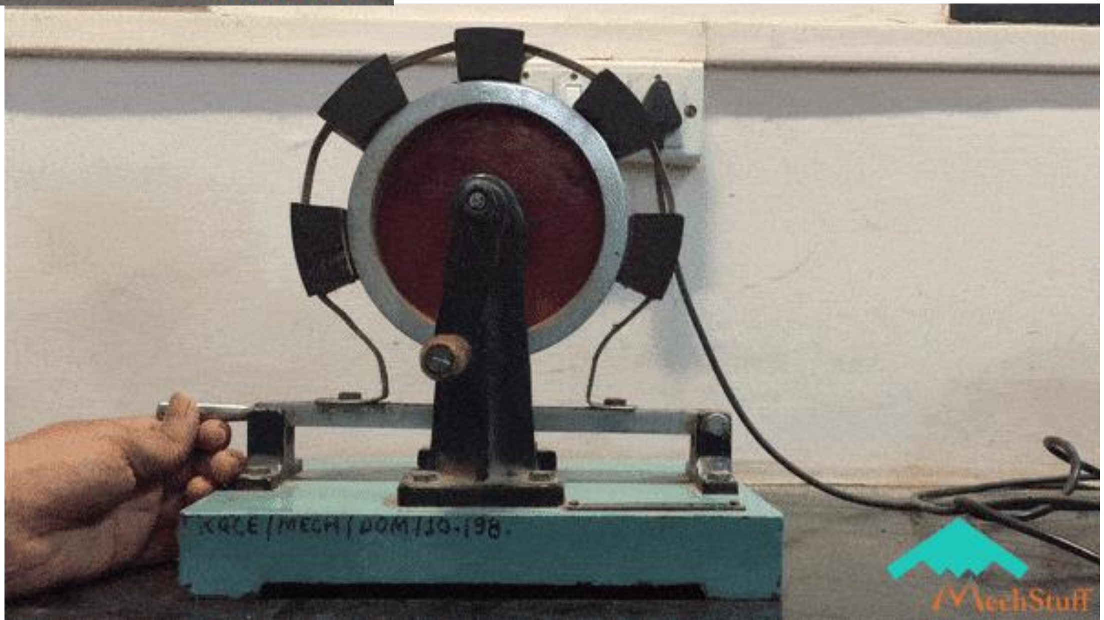
Band Brake





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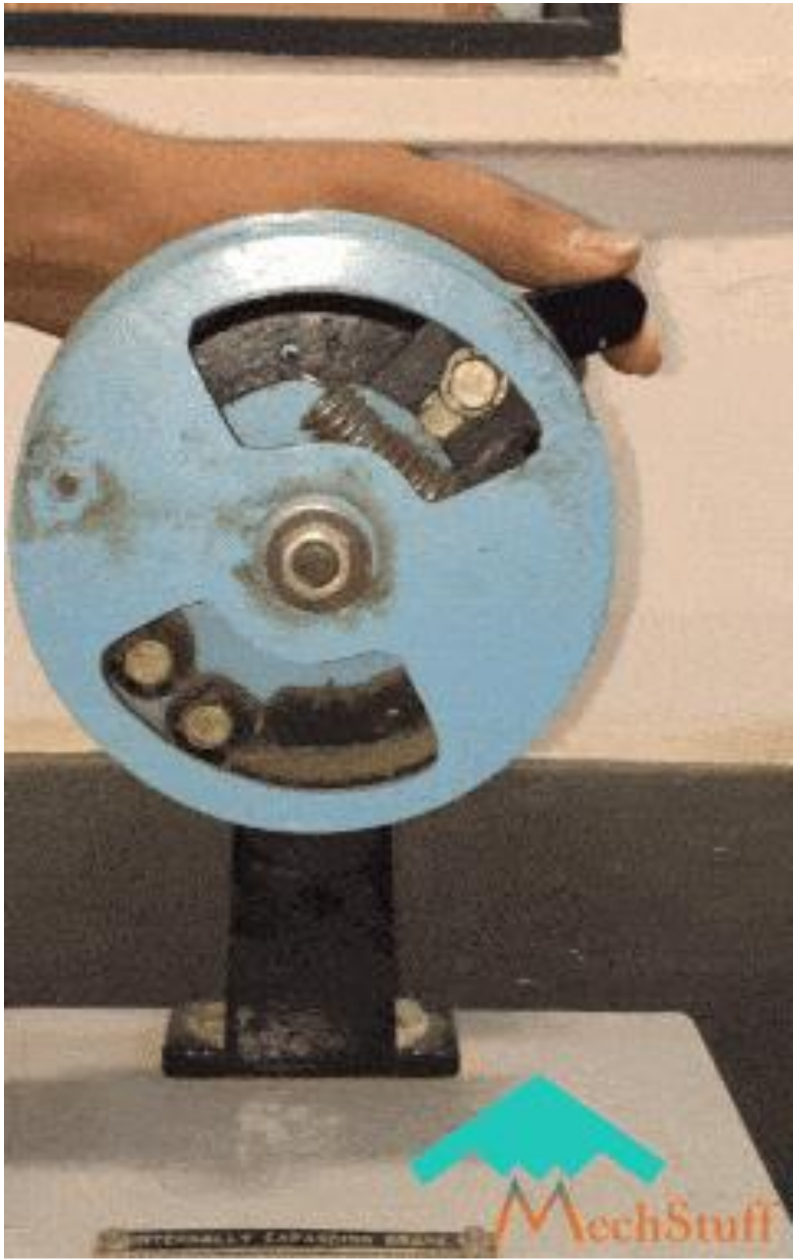
Internally Expanding Shoe Brake



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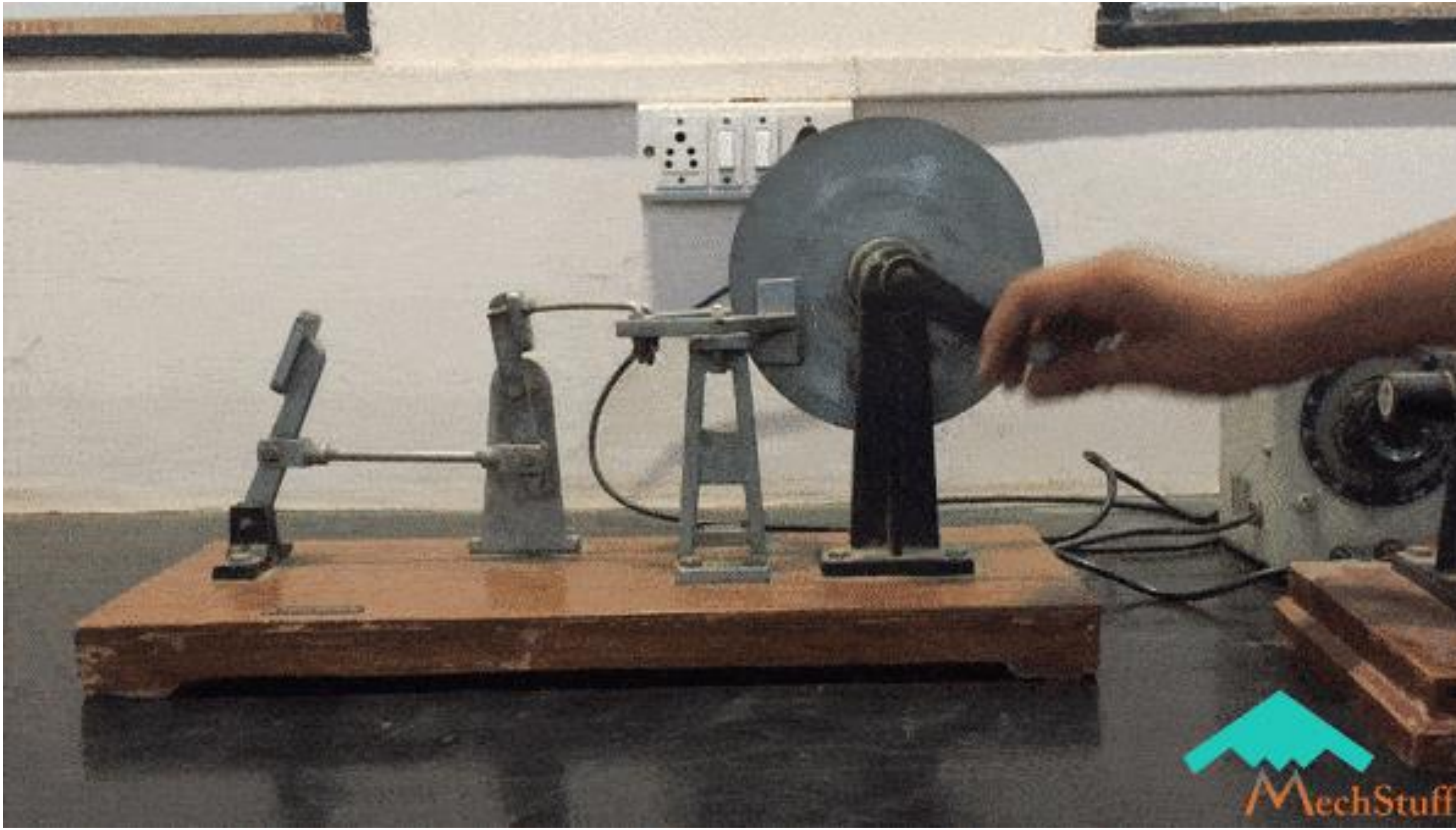
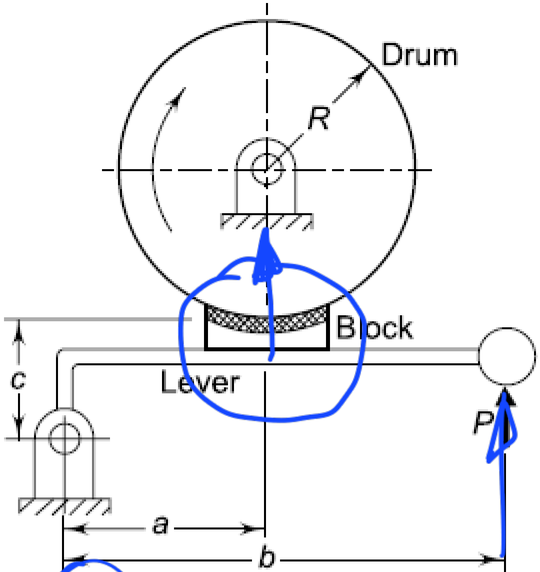
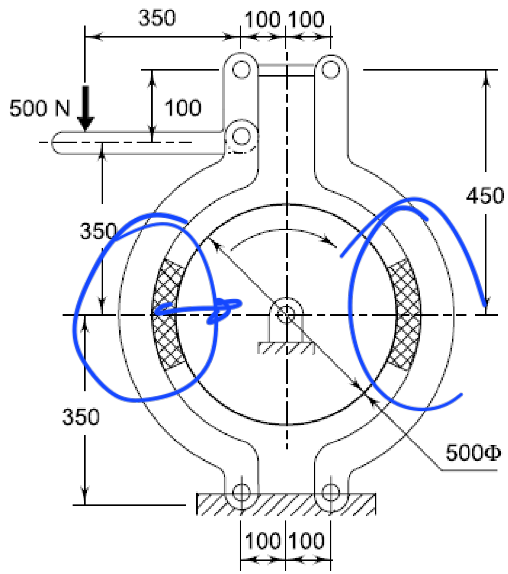
Disk Brake



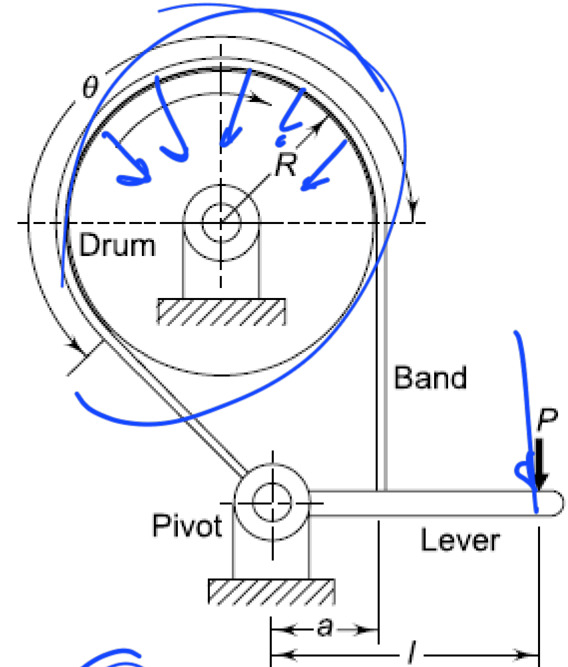
Classification of brakes



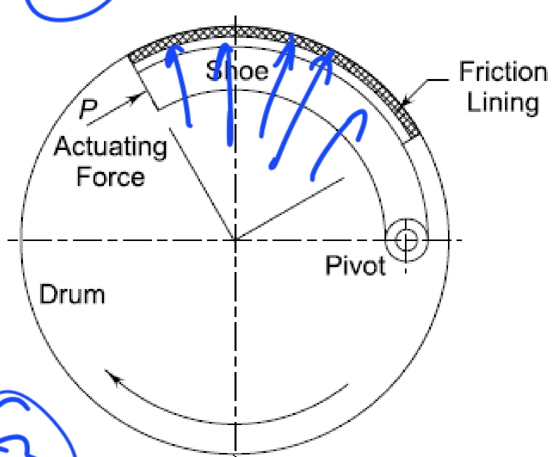
Block brake



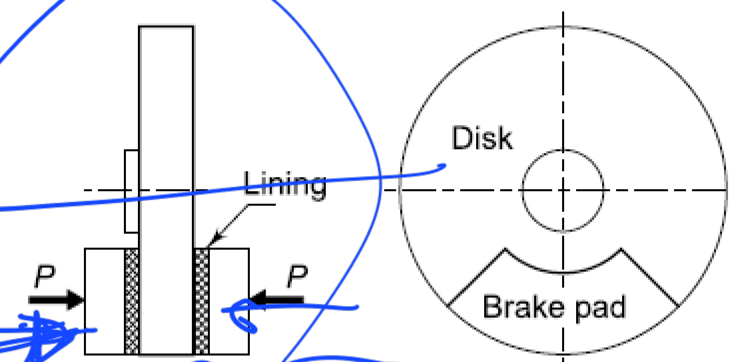
Double Block brake



Band brake



Internal expanding shoe brake



Disc brake

Ref: Bhandari V.B., Design of Machine Elements (2017)

QUIZ

Features of Mechanical Brakes

Which of the following statement about mechanical brakes is FALSE?

1) Mechanical brakes are classified as block, shoe, disk and band brake
2) In disk brakes the direction of actuating force is radial
3) None of the above statements is FALSE

Energy Equation

- **Energy absorbed by brake =** $M_t\theta$
  - M_t is braking torque capacity
  - θ is angle in radians through which drum rotates during braking period

- **Energy to be absorbed**

$$E = \frac{1}{2}m(v_1^2 - v_2^2) + \frac{1}{2}I(\omega_1^2 - \omega_2^2) + mgh$$

QUIZ

Torque Capacity of Brakes

Which of the following statement about the torque capacity of brake is TRUE?

1) For the same energy absorption, a brake with lower torque capacity will lead to lower angular movement of brake drum before stopping
2) The torque capacity of brake does not depend upon type of brake lining material
3) None of the above statements are TRUE

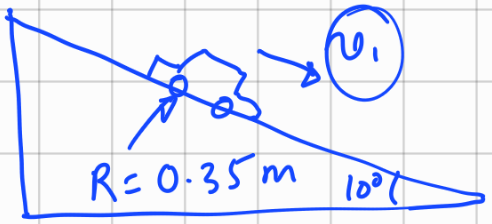
Example-1: Energy Equations

A four wheeled automobile car has total mass of 1000 kg. The mass M.I. of each wheel about a transverse axis through its c.g. is 0.5 kg-m^2. The rotating and reciprocating parts of engine and the transmission system are equivalent to mass M.I. of 2.5 kg-m^2, which rotate at 5 times the road wheel speed.

The rolling radius of wheel is 0.35 m. The car is descending at 100 kmph on a road with 10^o downward inclination. When brakes are applied, the car de-accelerates at 0.5g. There are brakes on all four wheels. Calculate:

- The energy absorbed by each wheel
- Toque capacity of each brake

Ref: Bhandari V.B., Design of Machine Elements (2017)



(i) Energy to be absorbed

(a) KE of car

$v_1 = 100$ kmph $= 27.78$ m/s

$v_2 = 0$

$KE_{car} = \frac{1}{2} m (v_1^2 - v_2^2)$

$= \frac{1}{2} \times 1000 \times (27.78^2 - 0^2)$

$= 385,864.2$ J

(ii) KE of wheels

$\omega_1 = \frac{v_1}{R} = \frac{27.78}{0.35} = 79.37 \frac{rad}{s}$

$\omega_2 = 0$

$KE_{wheel} = \frac{1}{2} I_w (w_1^2 - w_2^2)$

$= \frac{1}{2} \times (0.5 \times 4)(79.37^2 - 0^2)$

$= 6299.6$ J

(iii) KE of engine & tr. parts

$w_1' = 5 w_1 = 396.85$ rad/s , $w_2' = 0$

$KE_{engine} = \frac{1}{2} I' (w_1'^2 - w_2'^2)$

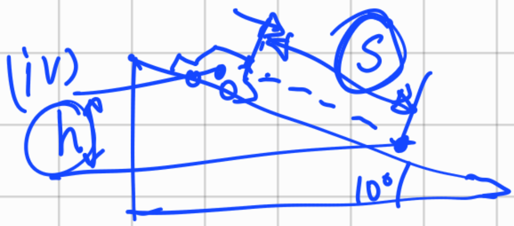
$= \frac{1}{2} \times 2.5 (396.85^2 - 0^2)$

$= 196,862.4$ J

$a_1 = 0.5g$

$v_1 = 27.78$ m/s

(iv)



(iv) PE calc

$2aS = v_1^2 - v_2^2$

$2 \times (0.5 \times 9.81) \times S = 27.78^2 - 0^2$

$\Rightarrow S = 78.67$ m

$$h = S \cdot \sin 10^\circ = 13.66 \text{ m}$$

$$PE = 1000 \times 9.81 \times 13.66 = 134{,}004.6 \text{ J}$$

Energy to be absorbed by each wheel brakes

$$E = \frac{1}{4}\left[385{,}864.2 + 6{,}299.6 + 196{,}862.4 + 134{,}004.6\right]$$

$$= 180{,}757.7 \text{ J}$$

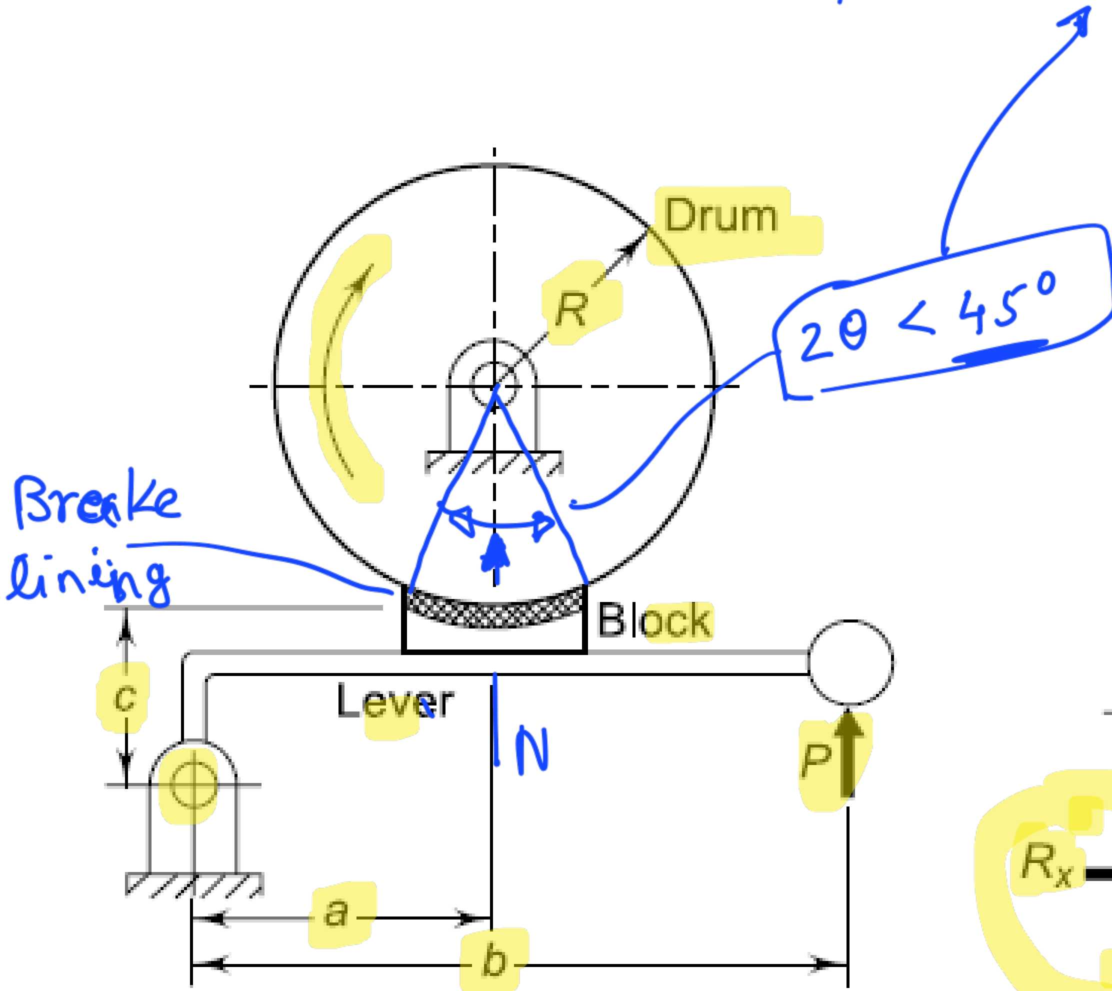
(b) Torque capacity of brake

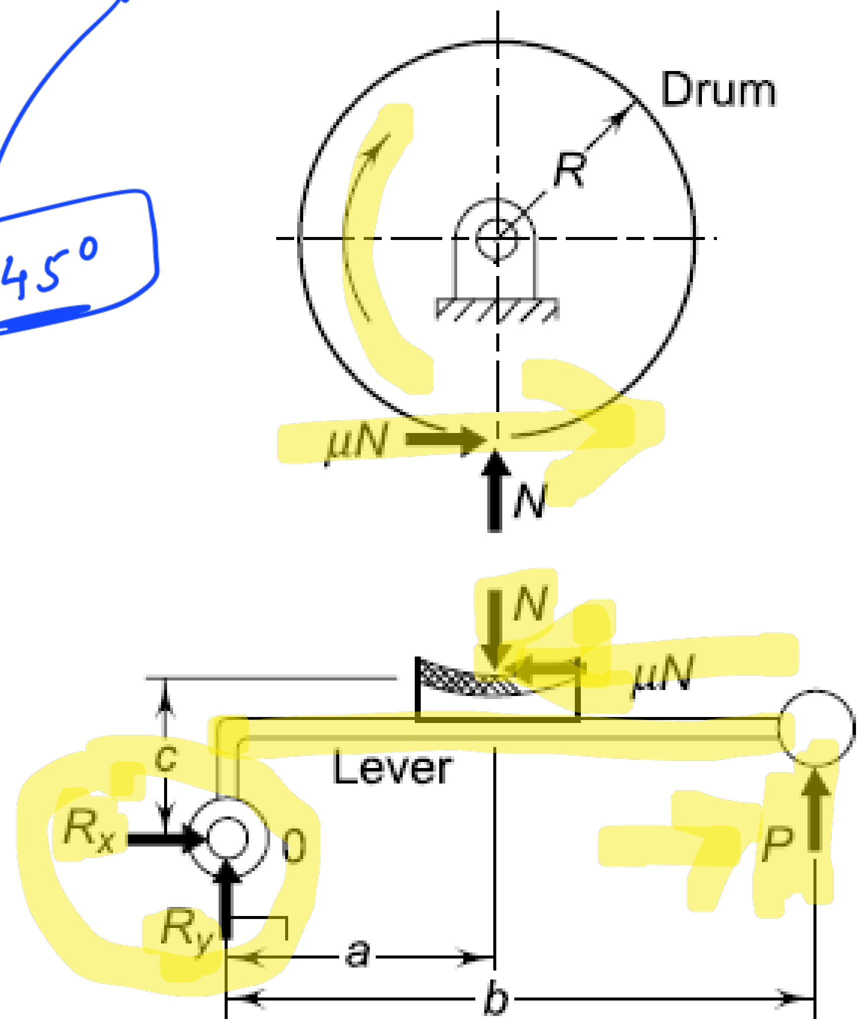
✓ $E = M_t \times \theta$ ✓

$$\theta = \frac{S}{R_{wheel}} = \frac{78.67}{0.35} = 224.8 \text{ rad}$$

$$M_t = \frac{E}{\theta} = 804.1 \text{ N.m}$$

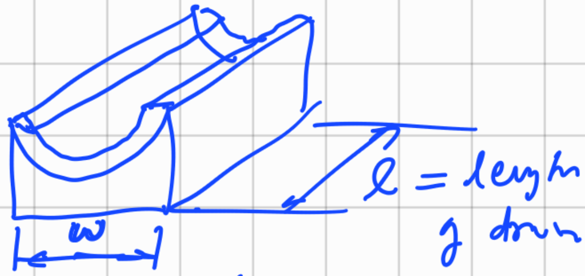
Block brake with short shoe





Ref: Bhandari V.B., Design of Machine Elements (2017)

Braking torque

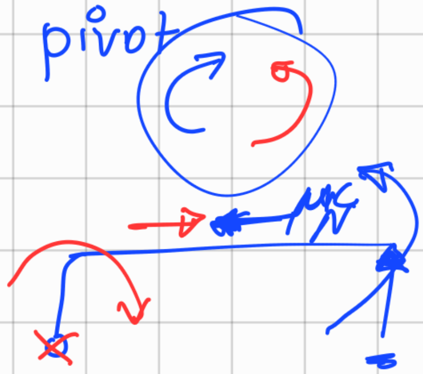


$$M_t = \mu N \cdot R$$

p = permissible pressure between brake & drum

$$N = p \times w \times l$$

Taking moment of all forces @ pivot



$$Pb - Na + (\mu N) \cdot c = 0$$

$$P = \left(\frac{a - \mu c}{b}\right) N$$

(1) partially self energizing design

$a - \mu c > 0$, $P = +ve$

(2) $a - \mu c = 0 \Rightarrow P = 0$

Self-locking brake → lack of control → undesirable

(3) $a - \mu c < 0$