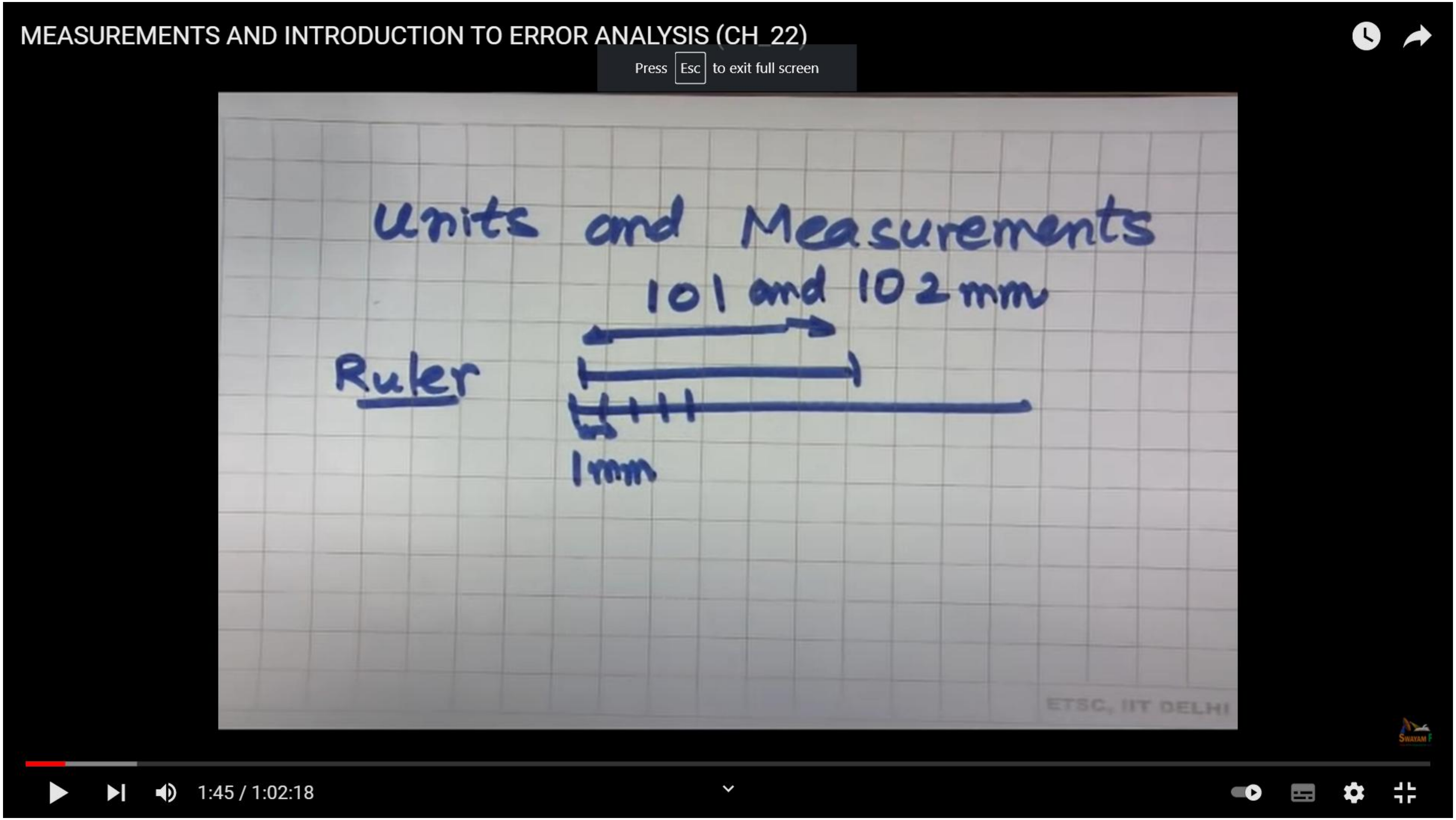
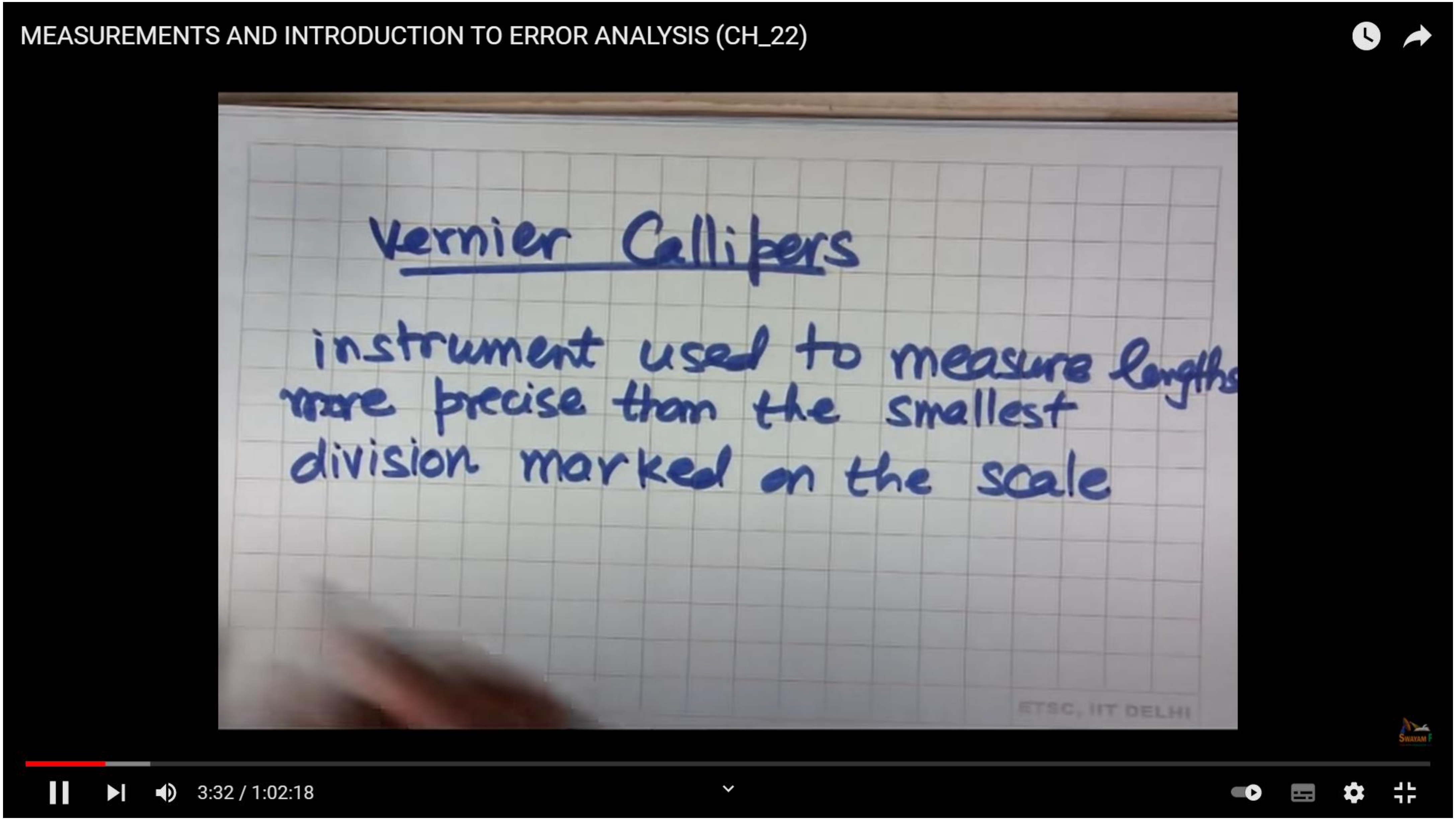
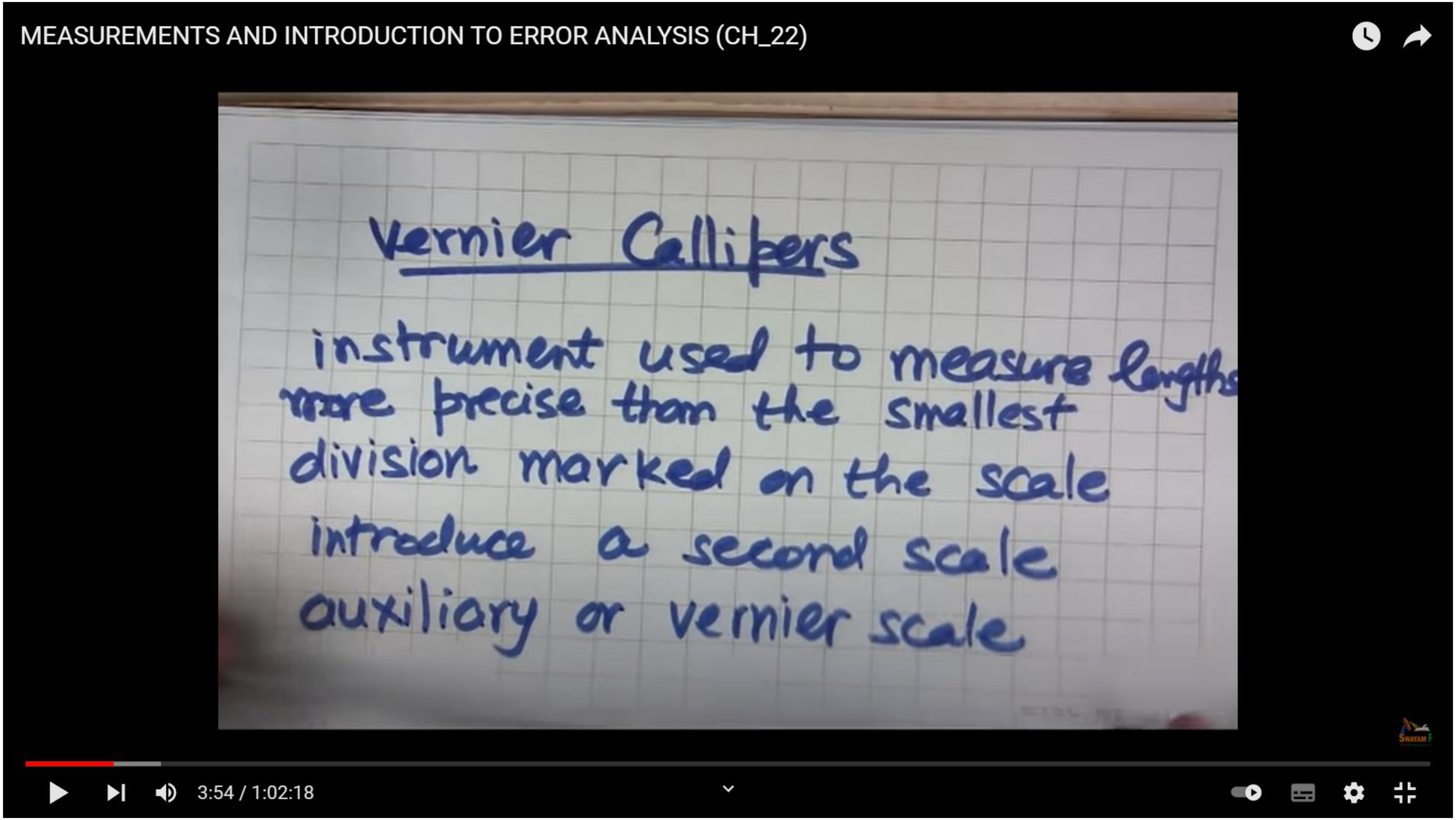

MEASUREMENTS AND INTRODUCTION TO ERROR ANALYSIS (CH_22)
Press Esc to exit full screen
Units and Measurements
101 and 102 mm
Ruler
1mm
ETSC, IIT DELHI
1:45 / 1:02:18


MEASUREMENTS AND INTRODUCTION TO ERROR ANALYSIS (CH_22)
Vernier Callipers
instrument used to measure lengths
more precise than the smallest
division marked on the scale
ETSC, IIT DELHI
3:32 / 1:02:18


MEASUREMENTS AND INTRODUCTION TO ERROR ANALYSIS (CH_22)
Vernier Callipers
instrument used to measure lengths
more precise than the smallest
division marked on the scale
introduce a second scale
auxiliary or vernier scale
3:54 / 1:02:18

MEASUREMENTS AND INTRODUCTION TO ERROR ANALYSIS (CH_22)

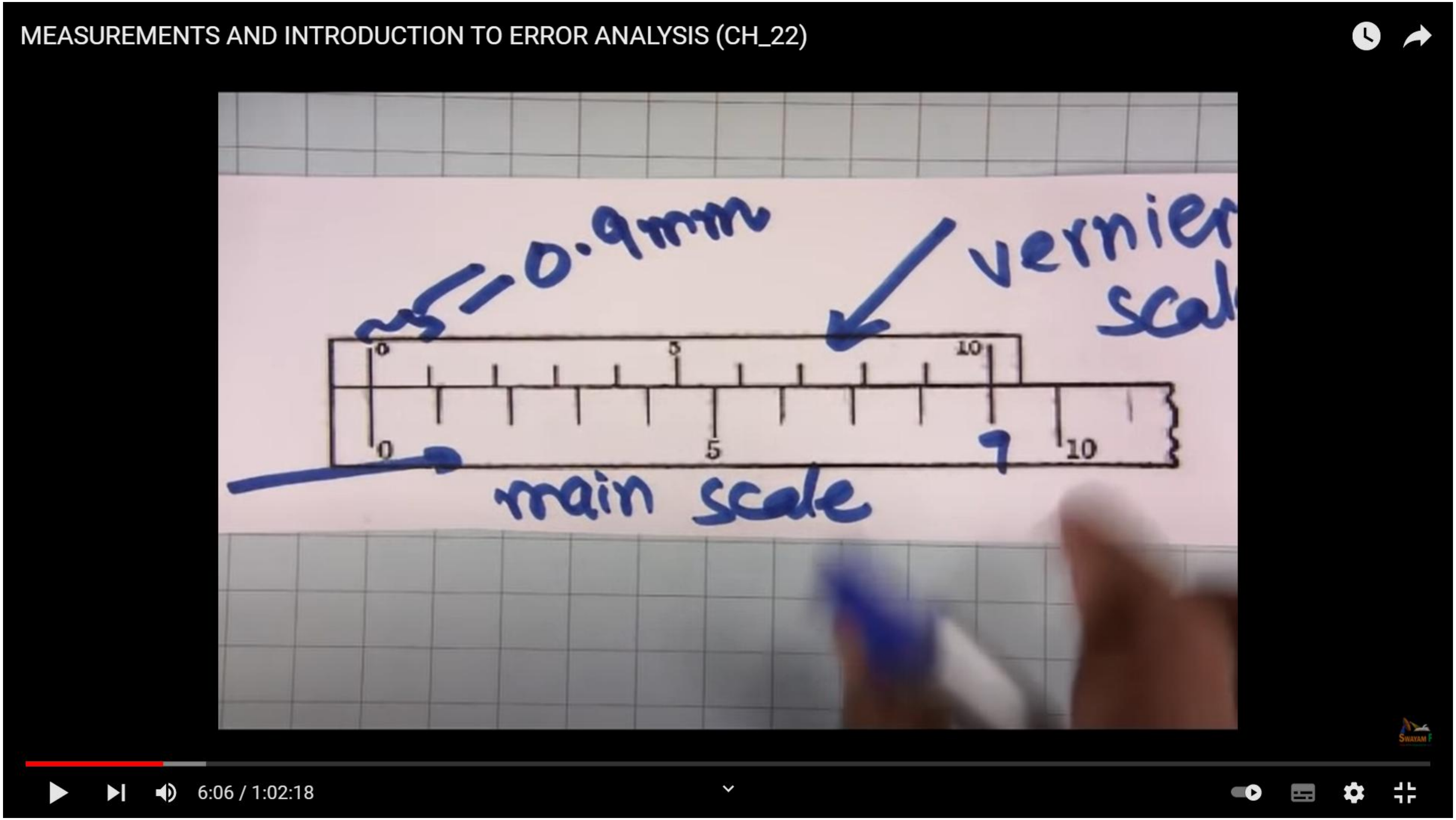
n divisions of vernier scale

$= (n-1)$ divisions of main scale

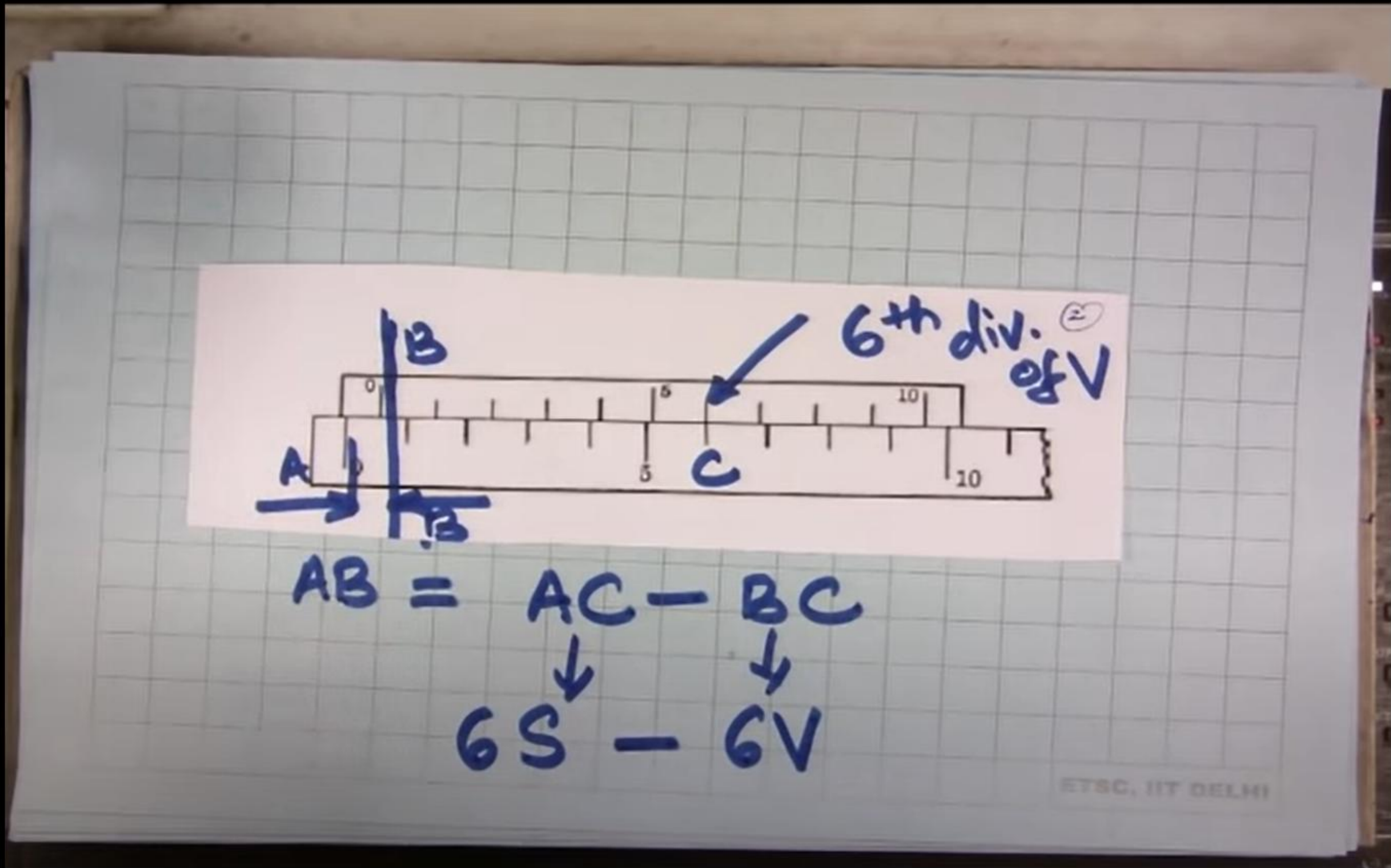
e.g. 10 divisions on V = 9 divisions on main scale,

1 division of V = $\frac{9}{10}$ division of S

S = 1 mm, V = 0.9 mm


MEASUREMENTS AND INTRODUCTION TO ERROR ANALYSIS (CH_22)
= 0.9mm
0
5
10
0
5
7
10
main scale
6:06 / 1:02:18

MEASUREMENTS AND INTRODUCTION TO ERROR ANALYSIS (CH_22)



8:10 / 1:02:18

MEASUREMENTS AND INTRODUCTION TO ERROR ANALYSIS (CH_22)

Least count of Vernier Calliper

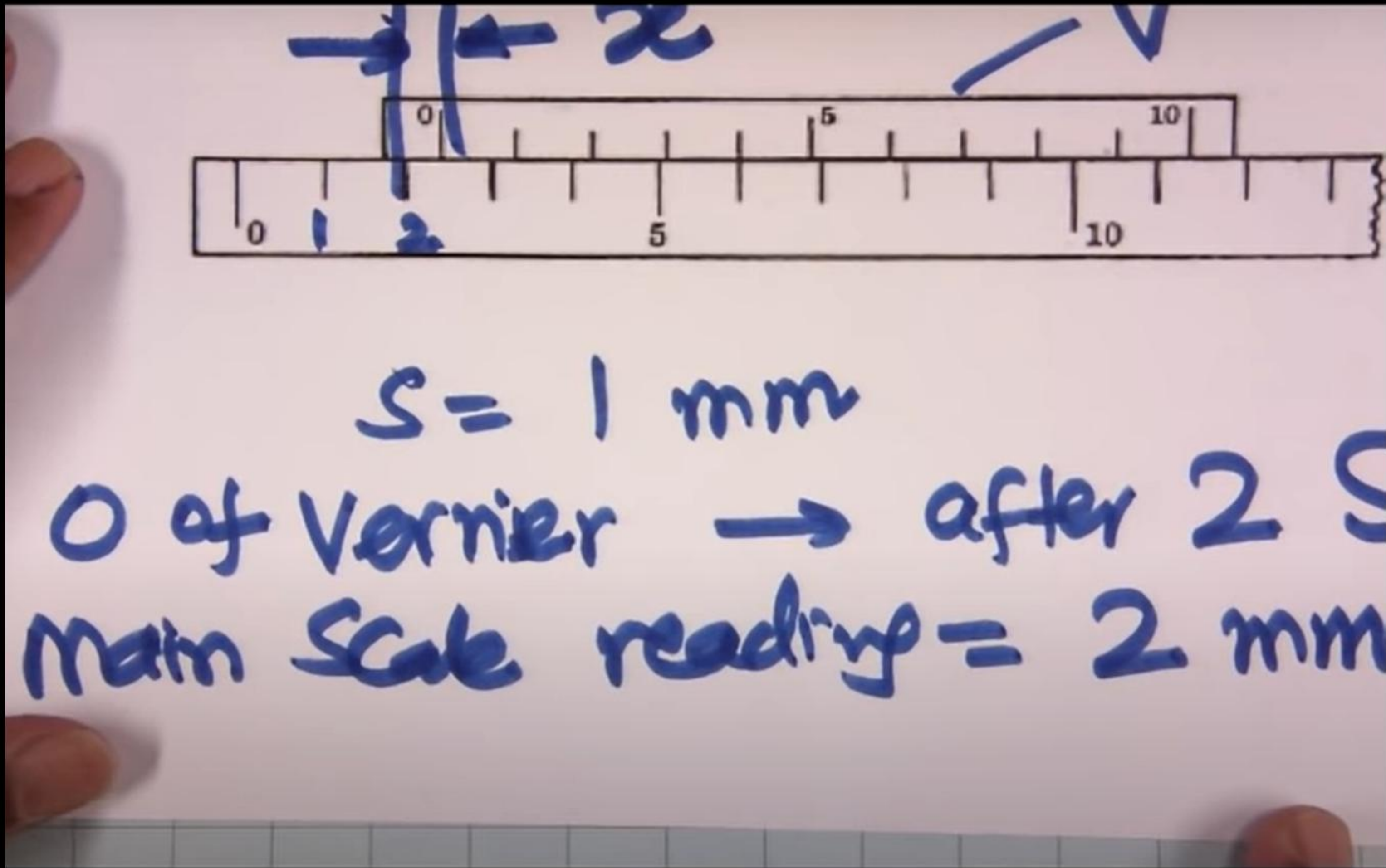
$$= S - V$$

$$nV = (n-1)S$$

$$V = \frac{n-1}{n} S$$

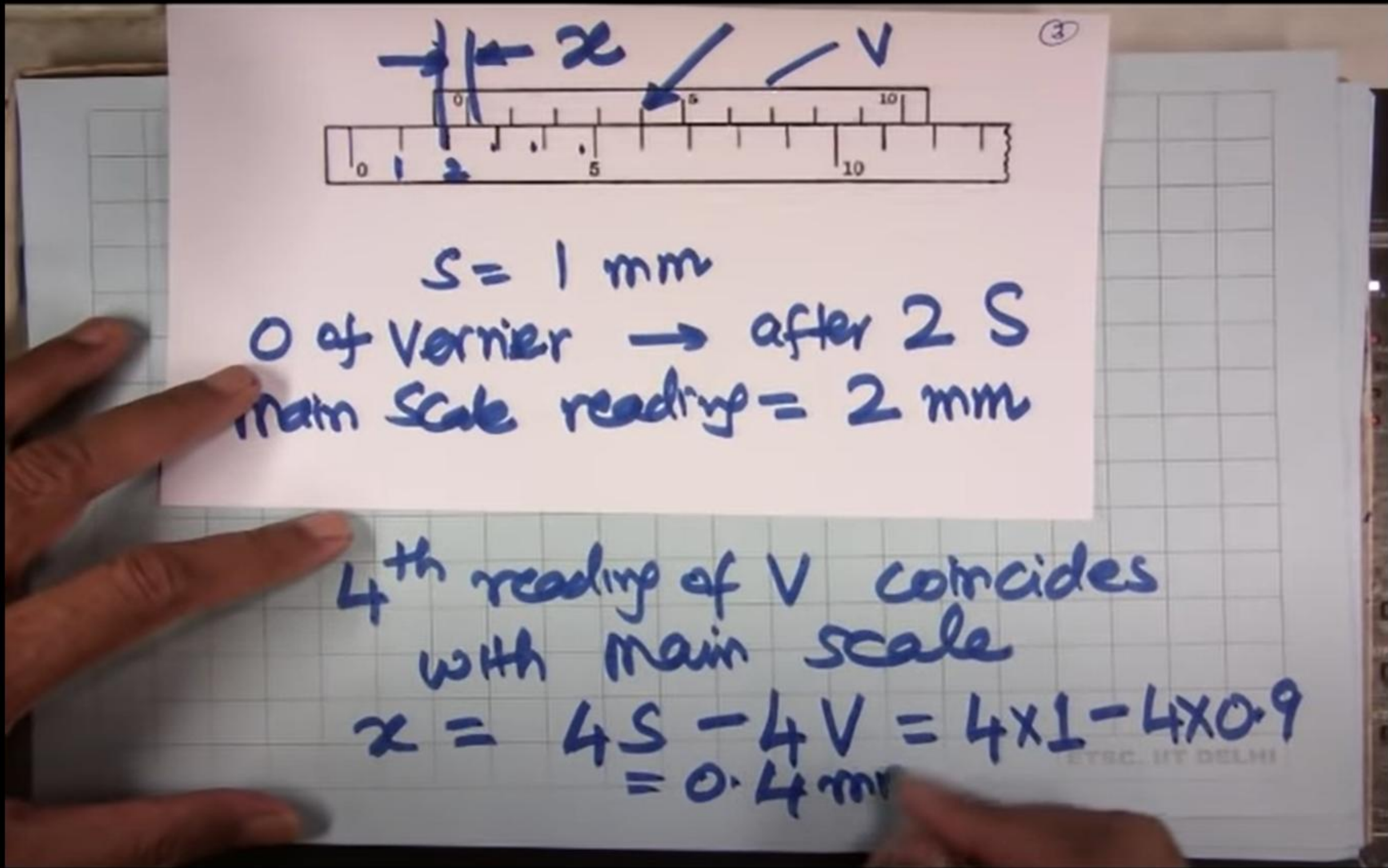
L.C. of Vernier Calliper $= S - \frac{n-1}{n} S = \frac{S}{n}$

MEASUREMENTS AND INTRODUCTION TO ERROR ANALYSIS (CH_22)

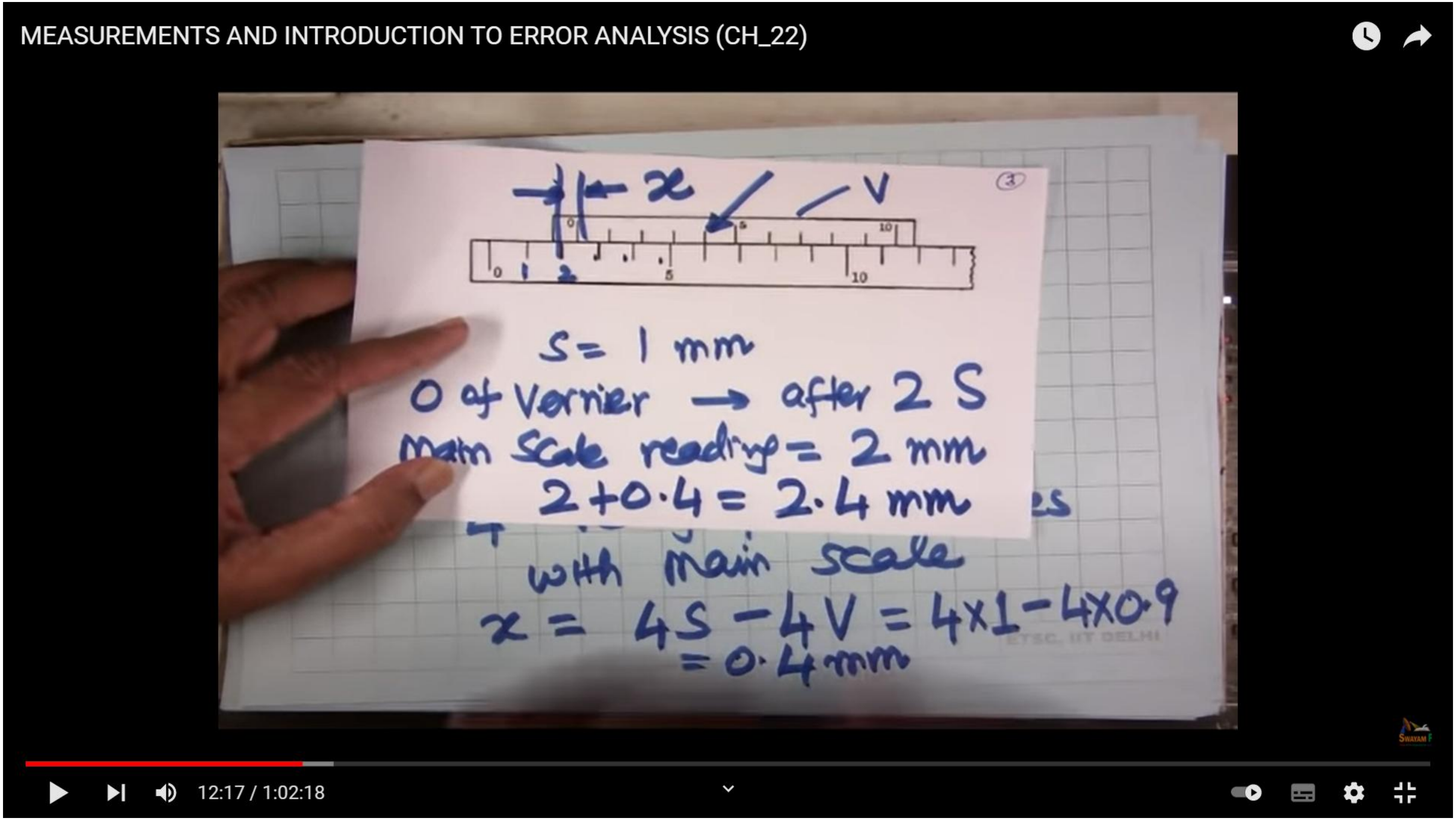


10:59 / 1:02:18

MEASUREMENTS AND INTRODUCTION TO ERROR ANALYSIS (CH_22)

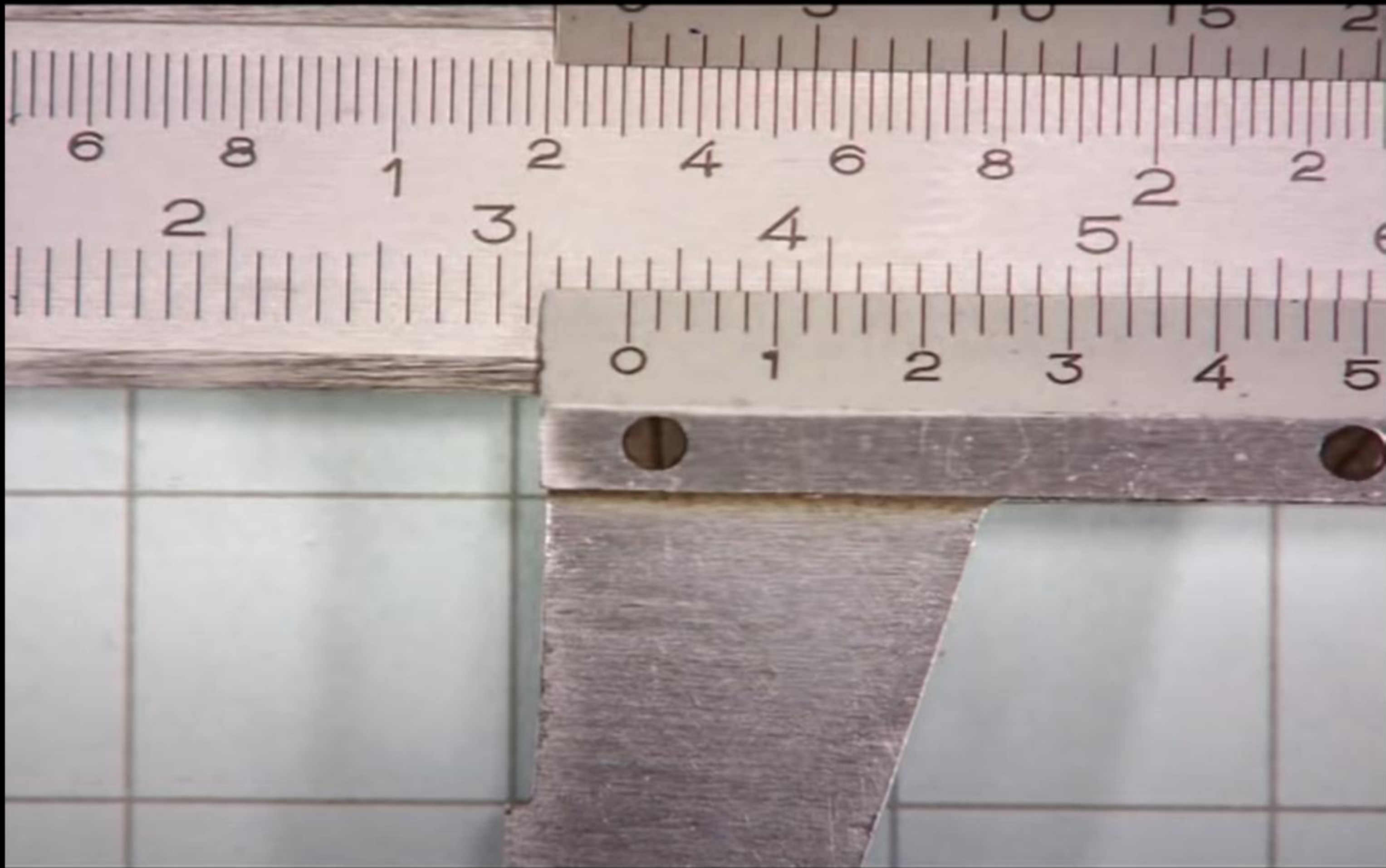


12:03 / 1:02:18


MEASUREMENTS AND INTRODUCTION TO ERROR ANALYSIS (CH_22)
x
V
S = 1 mm
0 of Vernier → after 2 S
Main Scale reading = 2 mm
2+0.4 = 2.4 mm
with main scale
x = 4S − 4V = 4×1 − 4×0.9
= 0.4 mm
12:17 / 1:02:18


MEASUREMENTS AND INTRODUCTION TO ERROR ANALYSIS (CH_22)
12:48 / 1:02:18

MEASUREMENTS AND INTRODUCTION TO ERROR ANALYSIS (CH_22)



14:43 / 1:02:18

MEASUREMENTS AND INTRODUCTION TO ERROR ANALYSIS (CH_22)

2 verniercallipers in which on mainscale 1 cm → 10 divisions

V_1 : $S_1 = 1mm$

V_2 $S_2 = 1mm$

16:10 / 1:02:18

MEASUREMENTS AND INTRODUCTION TO ERROR ANALYSIS (CH_22)

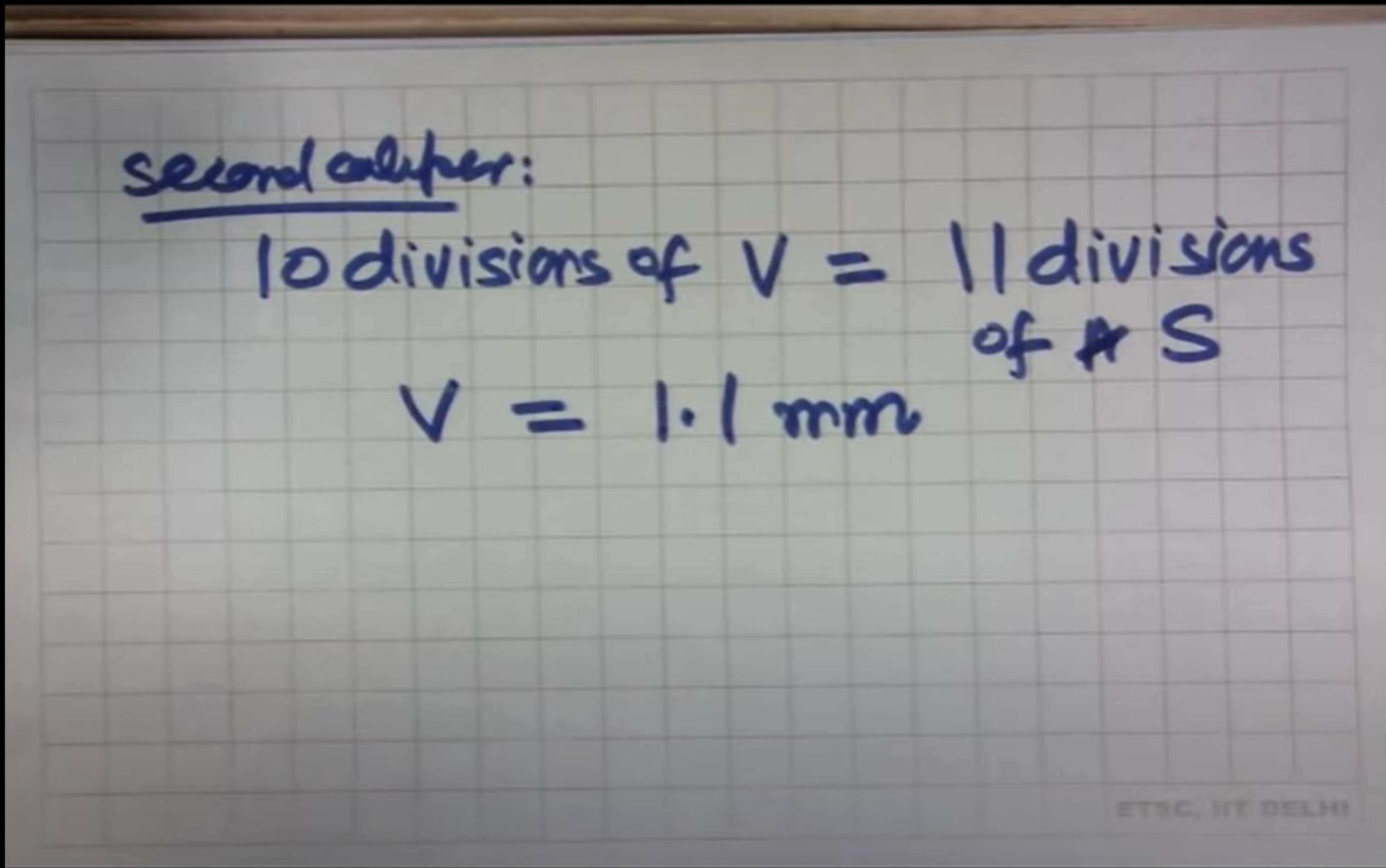
2 verniercallipers in which on mainscale 1 cm → 10 divisions

V_1 : S_1 = 1mm

V_2 S_2 = 1mm

Caliper 1: 10 equal divisions of vernier = 9 divisions of main scale

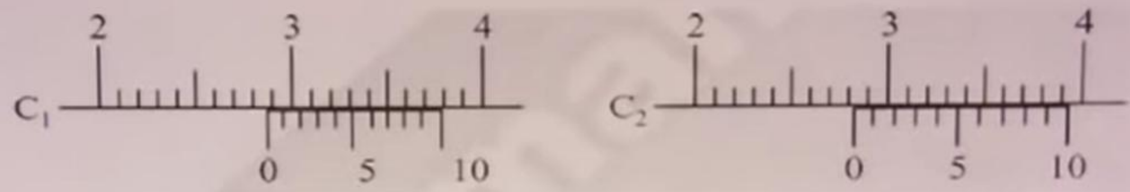
MEASUREMENTS AND INTRODUCTION TO ERROR ANALYSIS (CH_22)



17:31 / 1:02:18

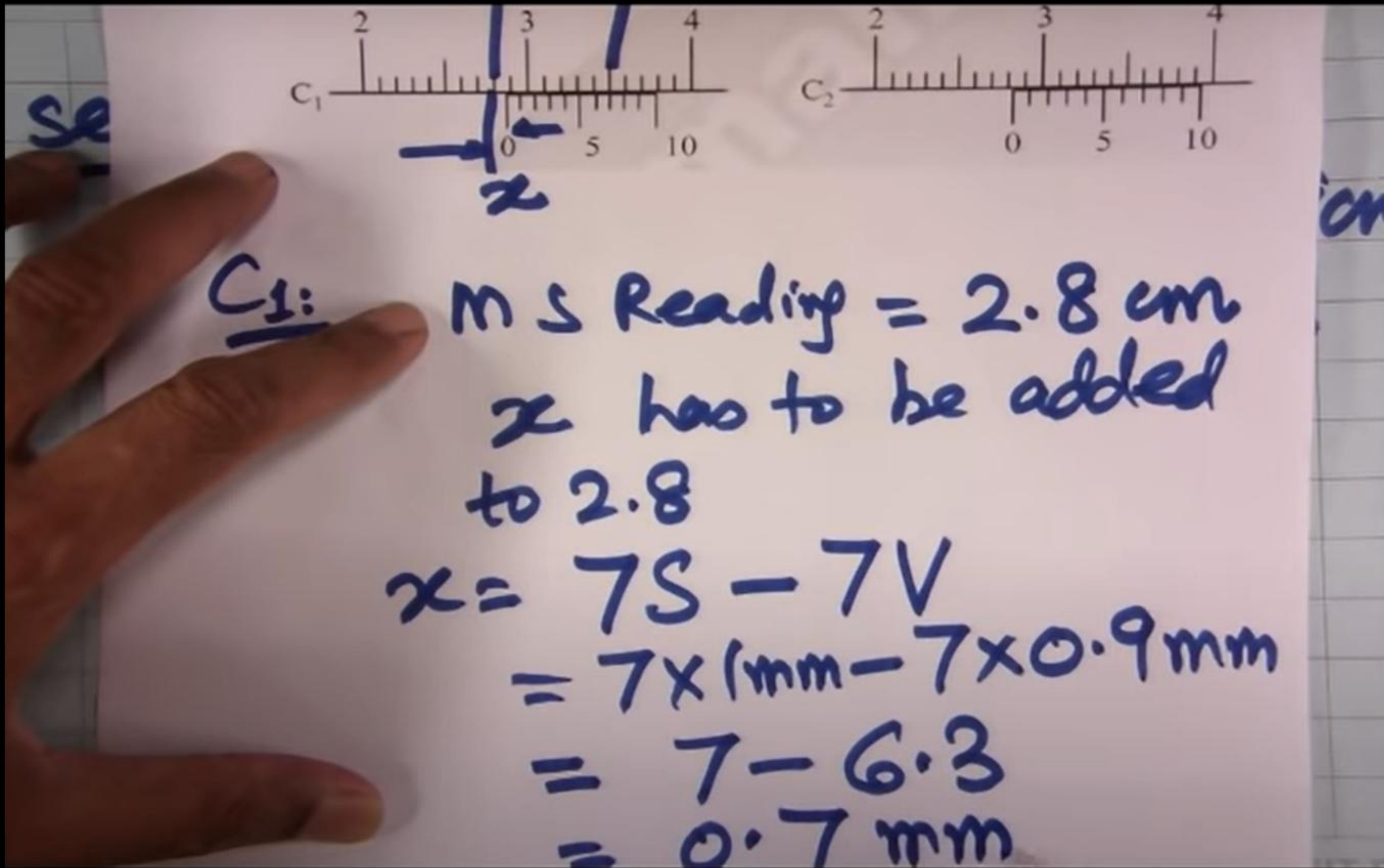
MEASUREMENTS AND INTRODUCTION TO ERROR ANALYSIS (CH_22)

The readings of the two calipers are shown in the figure. The measured values (in cm) by calipers C_1 and C_2, respectively, are :



17:54 / 1:02:18

MEASUREMENTS AND INTRODUCTION TO ERROR ANALYSIS (CH_22)



19:28 / 1:02:18

MEASUREMENTS AND INTRODUCTION TO ERROR ANALYSIS (CH_22)

C_1: M S Reading = 2.8 cm

x has to be added to 2.8

$x = 7S - 7V$

$= 7 \times 1\,mm - 7 \times 0.9\,mm$

$= 7 - 6.3$

$= 0.7\,mm$

reading by C_1 = 2.8 cm + 0.7 m

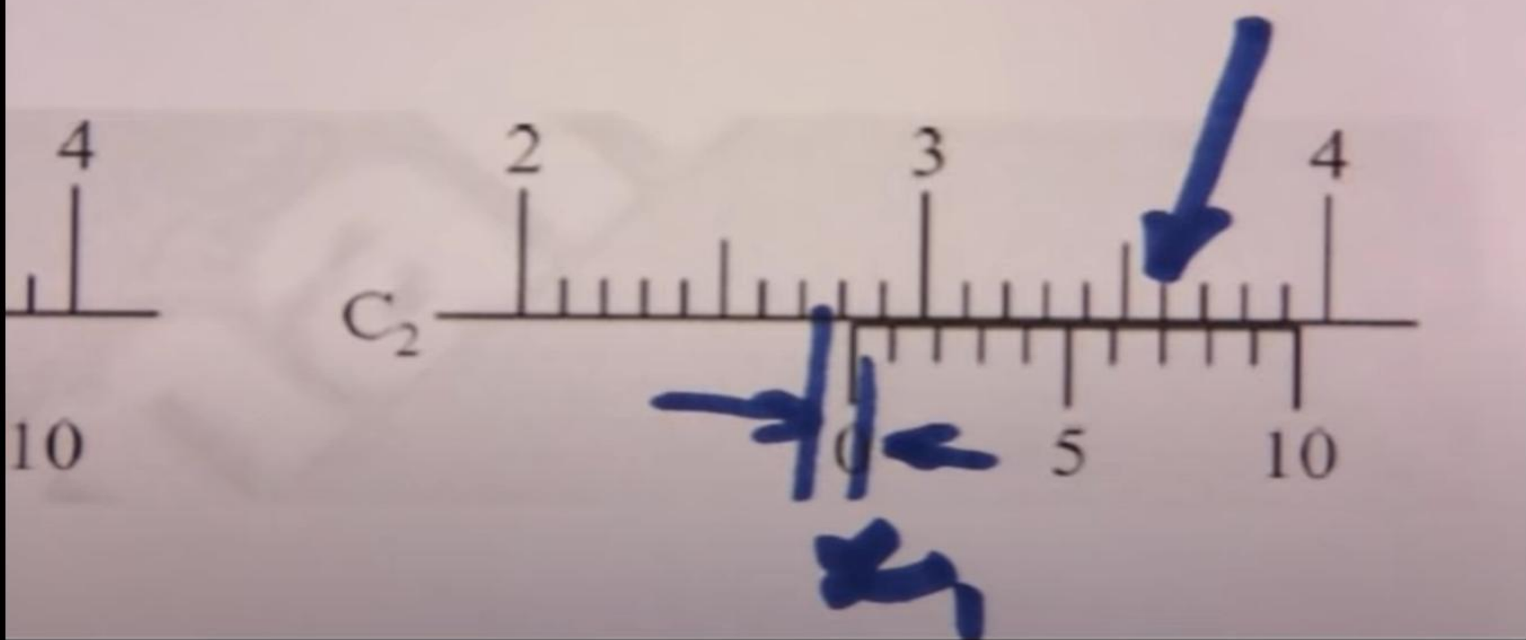
= 2.87 cm

19:51 / 1:02:18

MEASUREMENTS AND INTRODUCTION TO ERROR ANALYSIS (CH_22)

10 equal divisions that correspond to 11 main scale divisions.

e figure. The measured values (in cm) by calipers C_1 and C_2.



20:59 / 1:02:18

MEASUREMENTS AND INTRODUCTION TO ERROR ANALYSIS (CH_22)

x_1 has to be measured

x_1 = distance between main scale reading and zero of vernier

7^{th} reading of vernier matches 8^{th} reading of main scale

$$x_1 = 8S - 7V = 8\,mm - 7 \times 1.1\,mm$$
$$= 8 - 7.7\,mm$$
$$= 0.3\,mm$$

C_2 reading $= 2.8\,cm + 0.3\,mm = 2.83\,cm$

MEASUREMENTS AND INTRODUCTION TO ERROR ANALYSIS (CH_22)

Screw gauge and spherometer

Thread of a screw → helical shape ⇒ If we ~~to~~ make rotation on the thread of screw, ~~we~~ also make an axial movement.

24:06 / 1:02:18

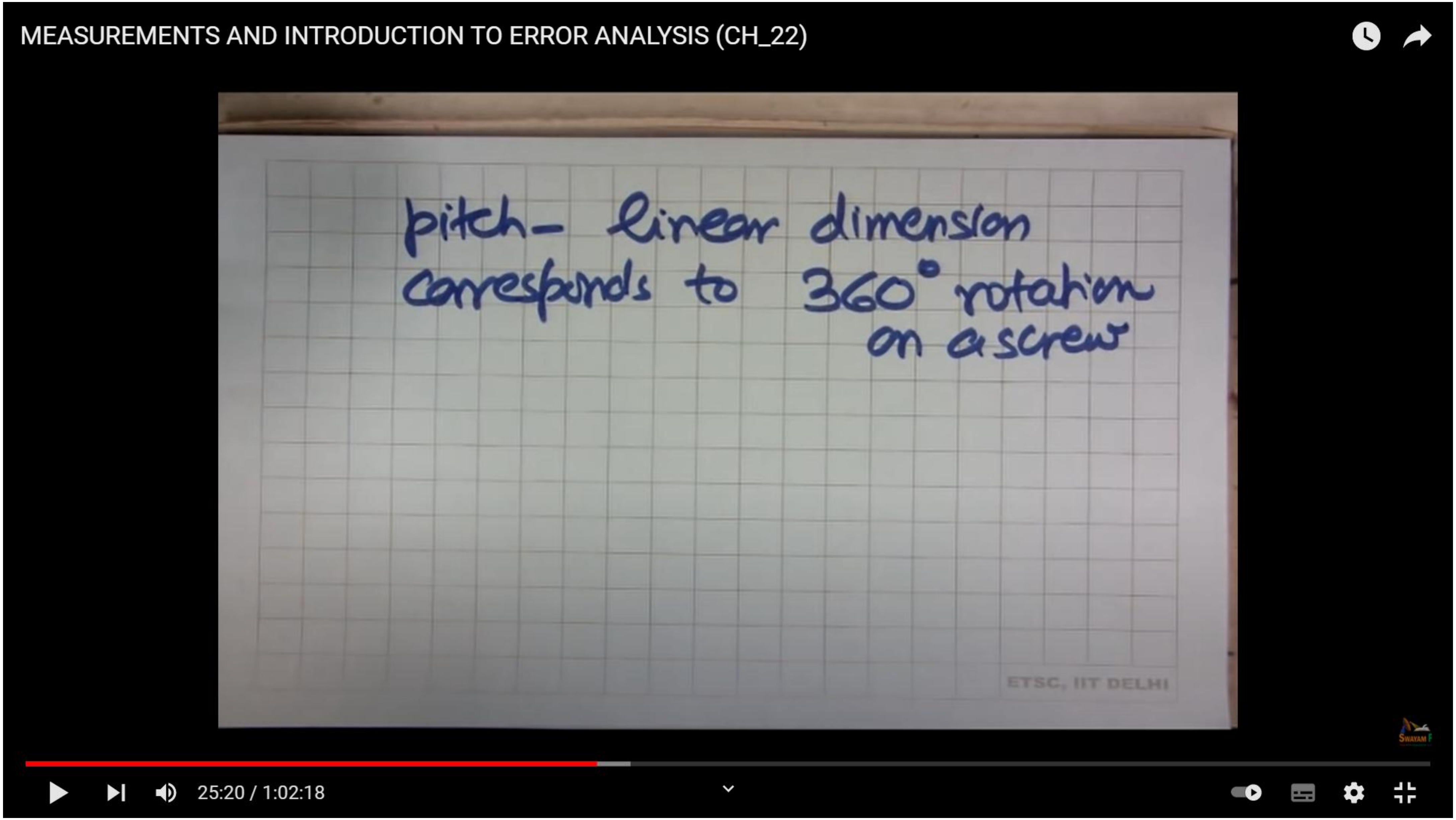
MEASUREMENTS AND INTRODUCTION TO ERROR ANALYSIS (CH_22)

Screw gauge and spherometer

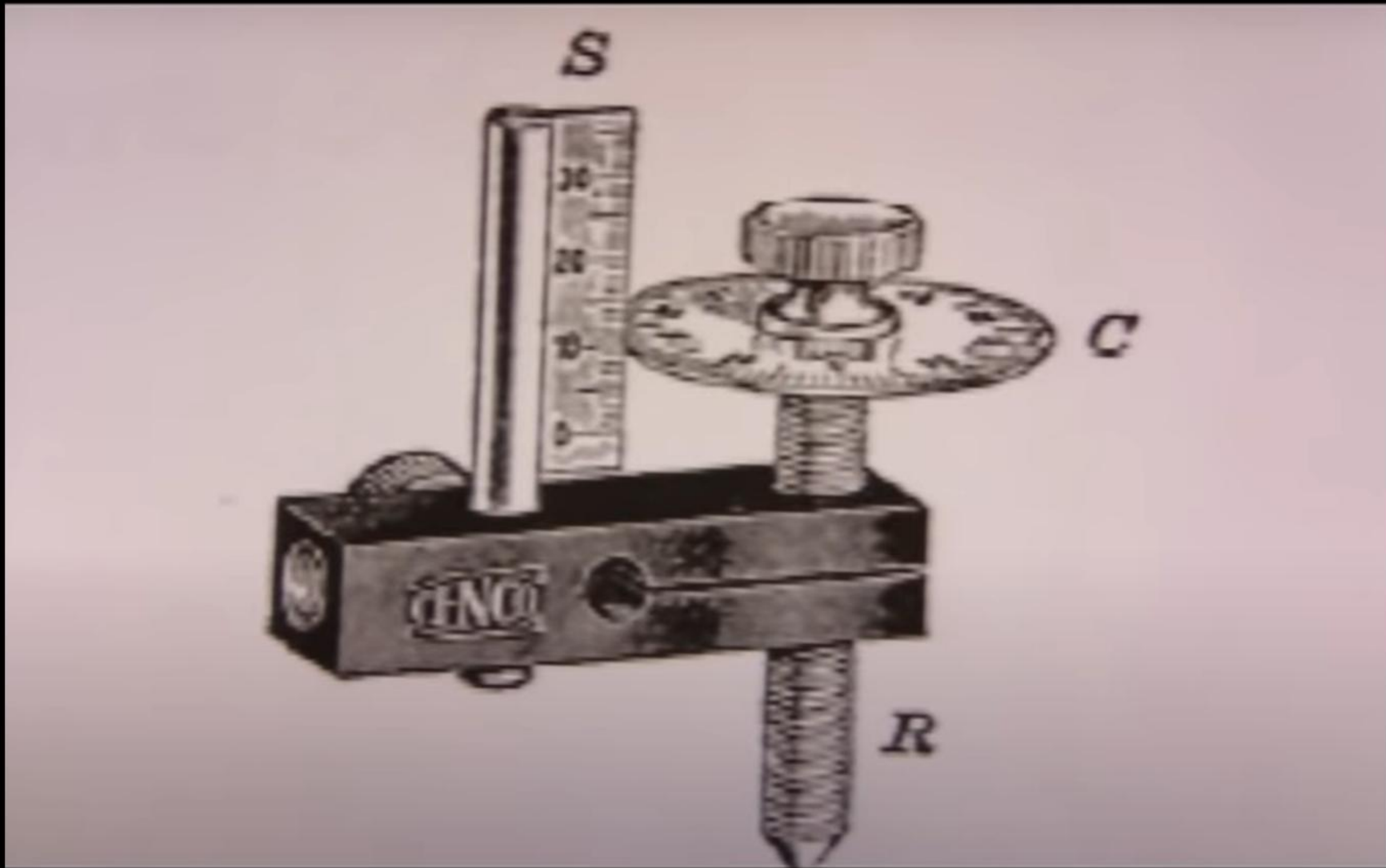
Thread of a screw → helical shape ⇒ If we make rotation on the thread of screw, we also make an axial movement.

The axial distance moved when we complete 1 revolution on screw = pitch

24:42 / 1:02:18


MEASUREMENTS AND INTRODUCTION TO ERROR ANALYSIS (CH_22)
pitch – linear dimension
corresponds to 360° rotation
on a screw
ETSC, IIT DELHI
25:20 / 1:02:18

MEASUREMENTS AND INTRODUCTION TO ERROR ANALYSIS (CH_22)



26:20 / 1:02:18

MEASUREMENTS AND INTRODUCTION TO ERROR ANALYSIS (CH_22)

Pitch of the screw corresponds to the smallest reading of main scale.
We rotate the spindle by 1 revolution and observe the axial distance moved on the mainscale.

Typically $\sim$ 0·5 mm or 1 mm

27:50 / 1:02:18

MEASUREMENTS AND INTRODUCTION TO ERROR ANALYSIS (CH_22)

Pitch of the screw corresponds to the smallest reading of main scale.

We rotate the spindle by 1 revolution and observe the axial distance moved on the mainscale.

Typically ~ 0.5 mm or 1 mm

Circular scale enables us to read fractional reading

28:19 / 1:02:18

MEASUREMENTS AND INTRODUCTION TO ERROR ANALYSIS (CH_22)

Let no. of divisions on circular scale be n.

Let pitch of the screw be p.

Least count of the screw $= \frac{p}{n}$

If circular scale reading $= m$.

extra distance/ length to be added to main scale reading $= m \times \frac{p}{n}$.

29:41 / 1:02:18

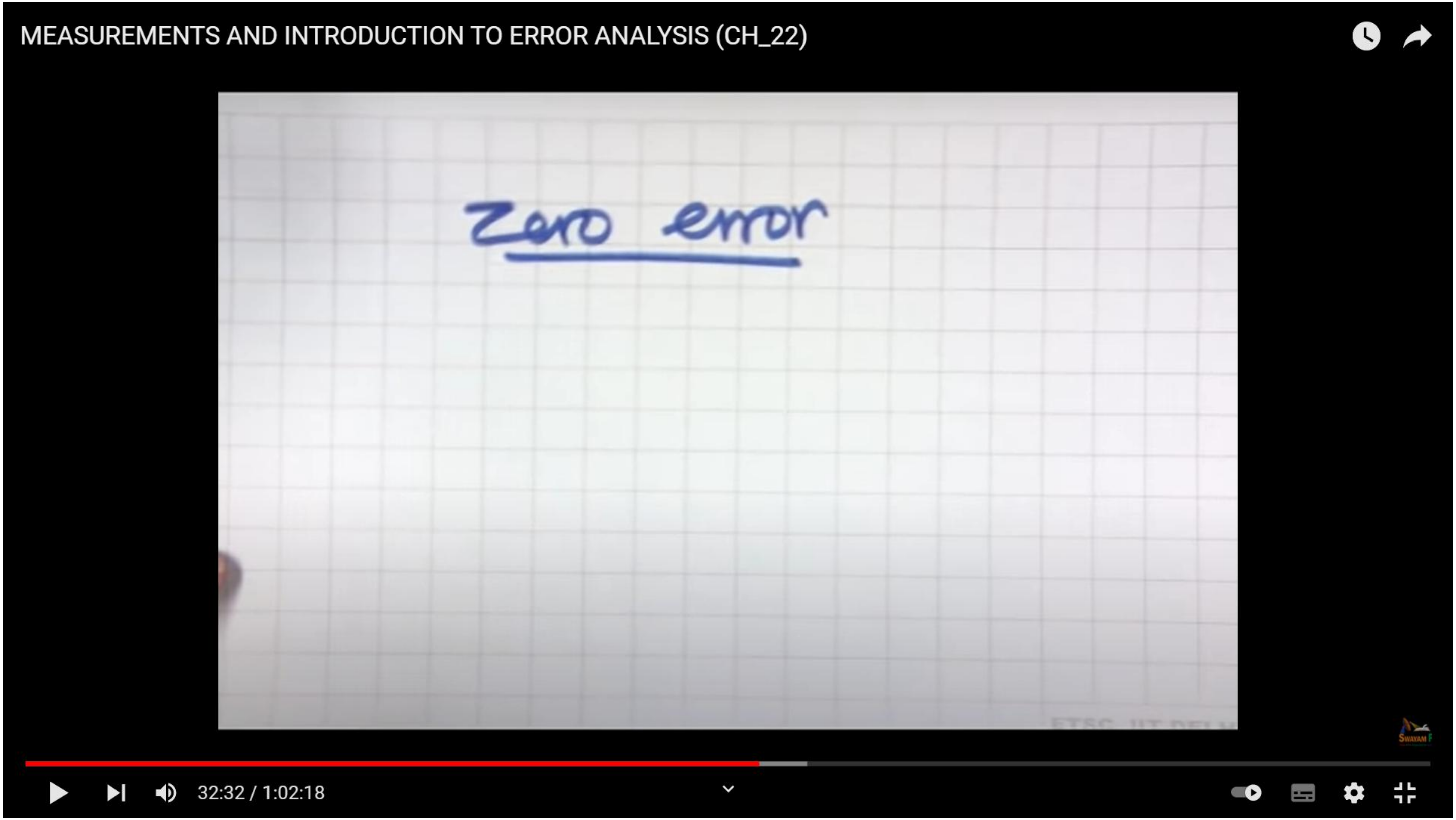
MEASUREMENTS AND INTRODUCTION TO ERROR ANALYSIS (CH_22)

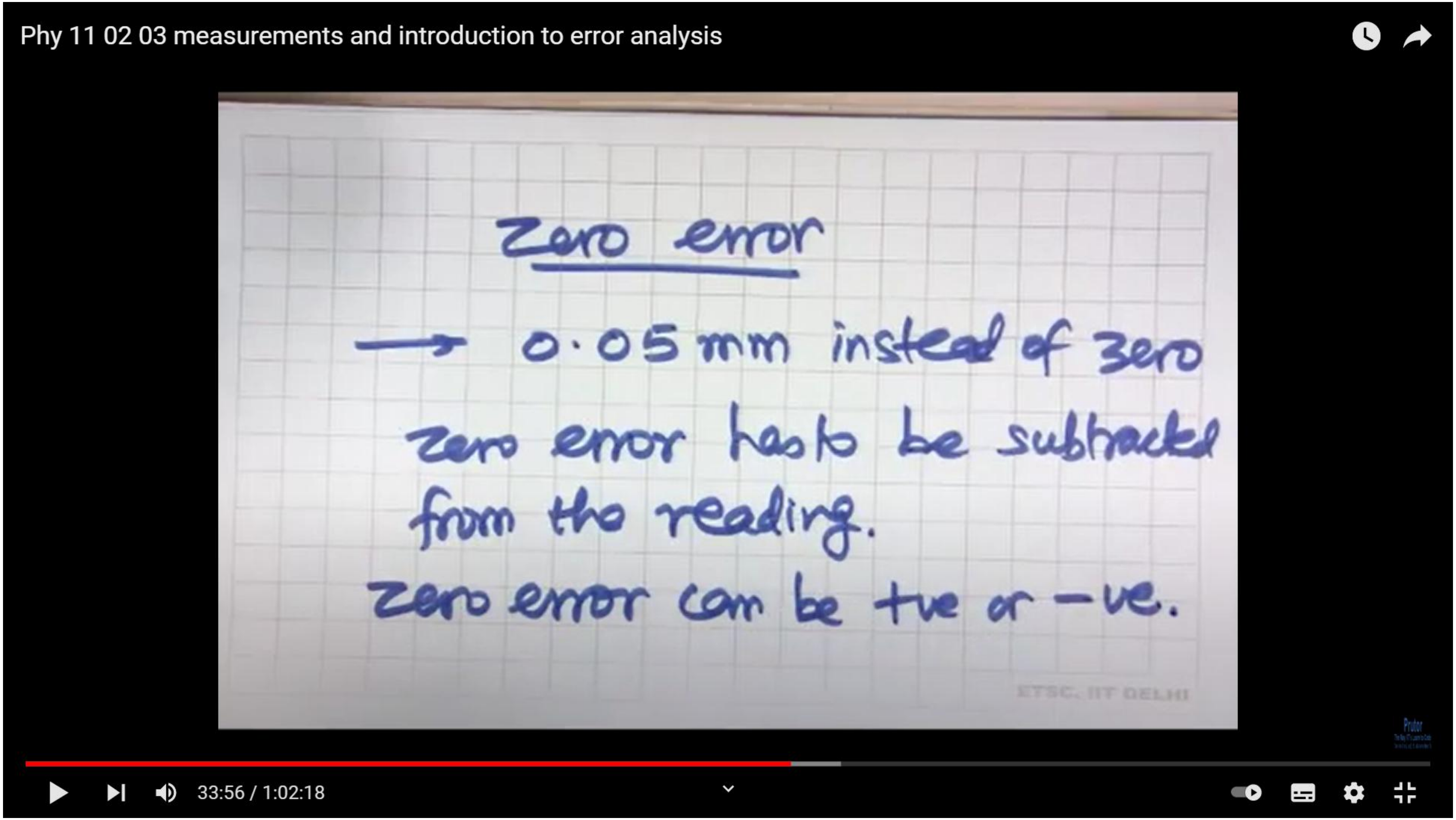
For eg. $p = 0.5\text{ mm}$

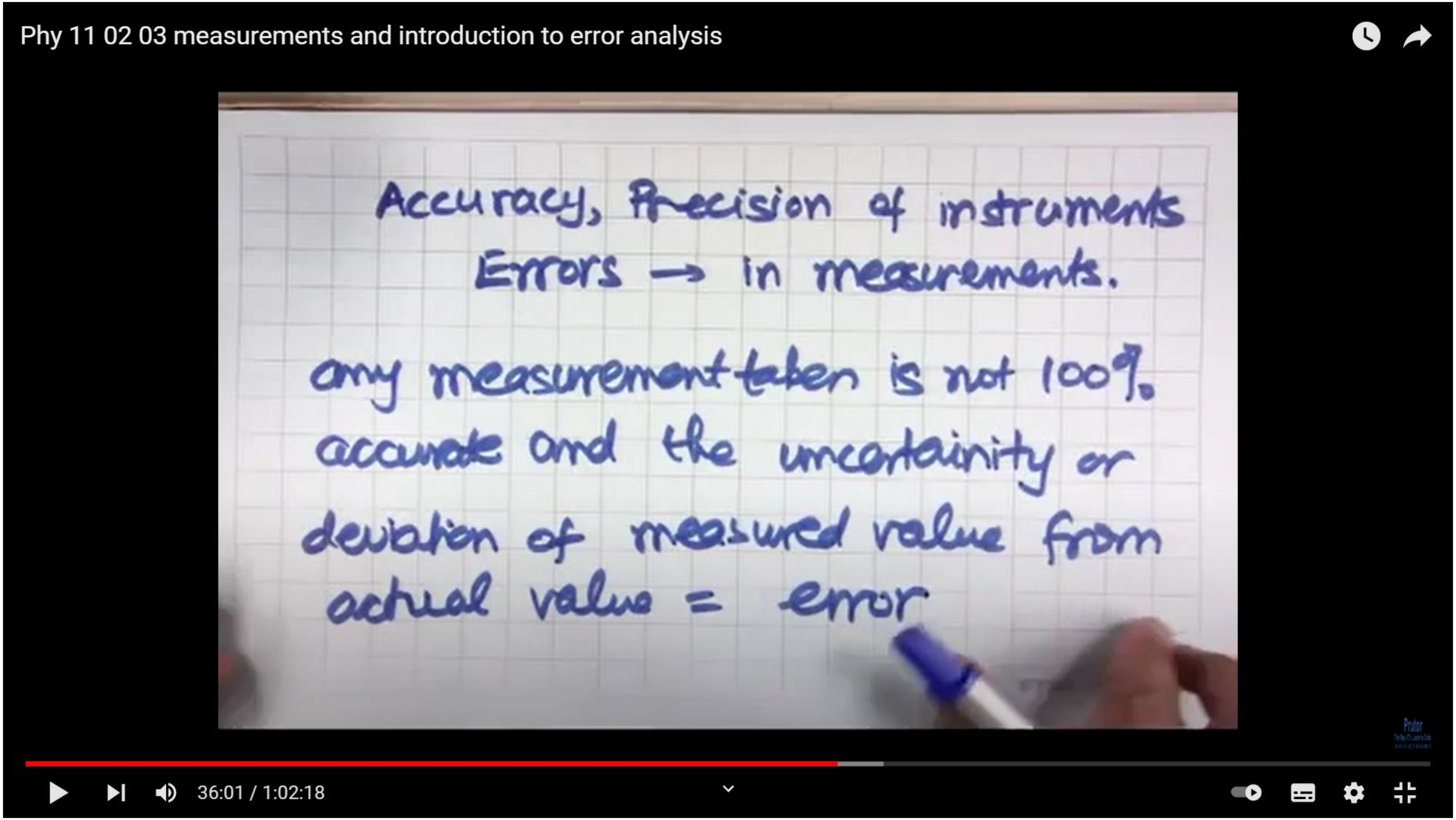
$n = 50$

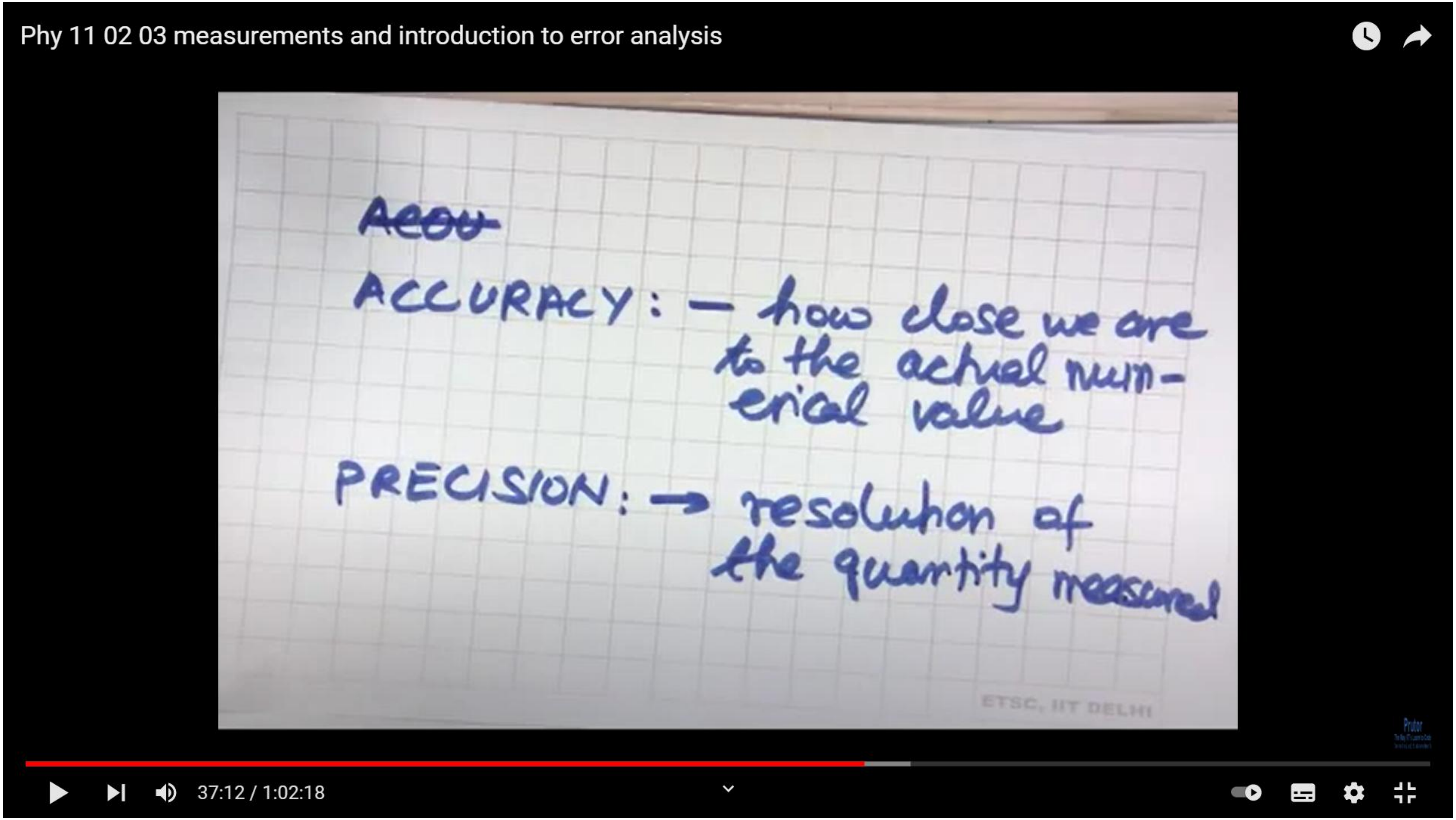
$$\text{Least Count} = \frac{0.5}{50} = 0.01\text{ mm}$$

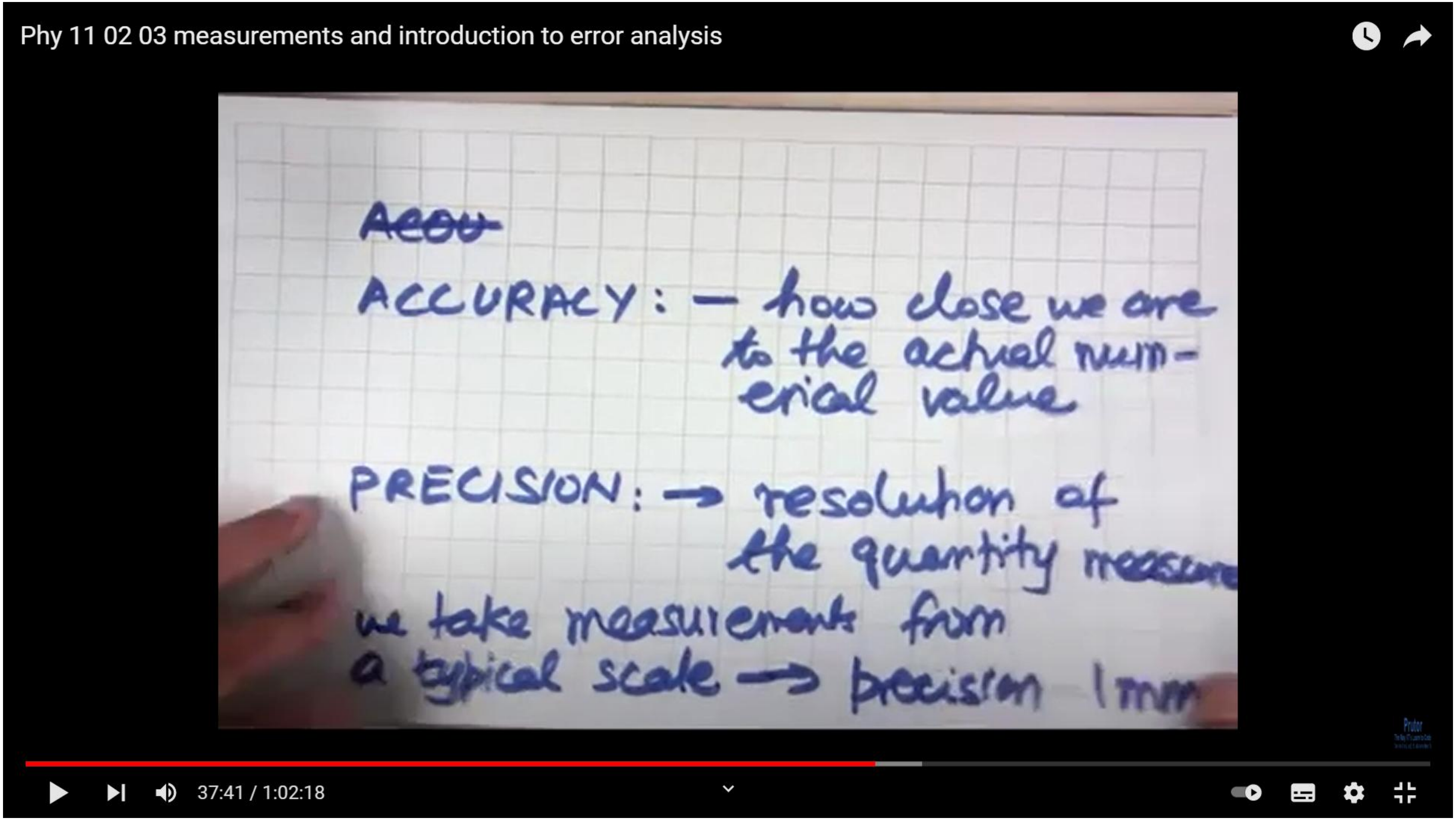

MEASUREMENTS AND INTRODUCTION TO ERROR ANALYSIS (CH_22)
0-25mm
0.01mm
31:15 / 1:02:18

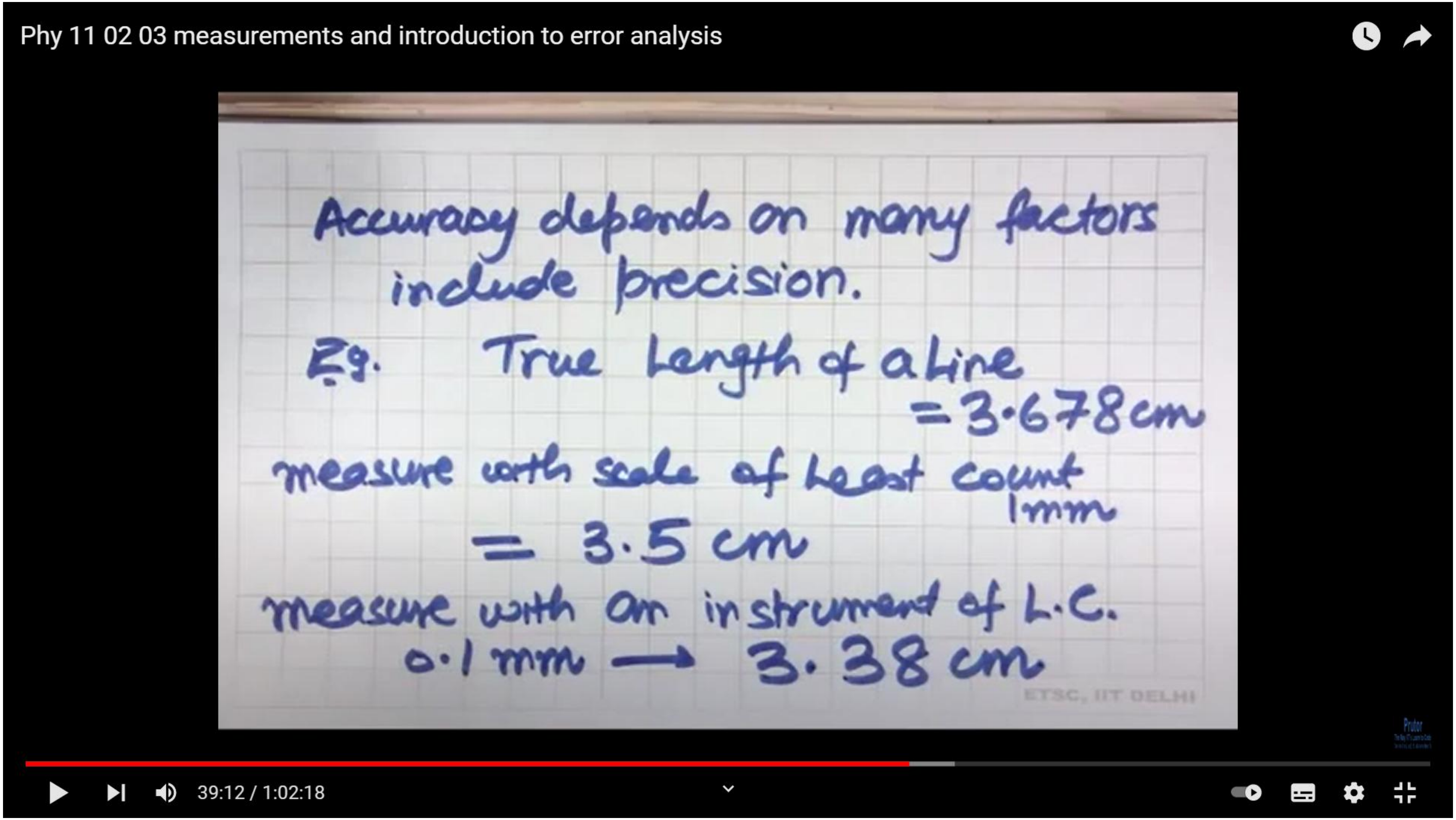

MEASUREMENTS AND INTRODUCTION TO ERROR ANALYSIS (CH_22)
Zero error
32:32 / 1:02:18


Phy 11 02 03 measurements and introduction to error analysis
Zero error
→ 0·05 mm instead of zero
zero error has to be subtracted
from the reading.
zero error can be +ve or -ve.
ETSC, IIT DELHI
33:56 / 1:02:18


Phy 11 02 03 measurements and introduction to error analysis
Accuracy, Precision of instruments
Errors → in measurements.
any measurement taken is not 100%
accurate and the uncertainity or
deviation of measured value from
actual value = error
36:01 / 1:02:18


Phy 11 02 03 measurements and introduction to error analysis
~~Accu~~
ACCURACY: — how close we are to the actual num-erical value
PRECISION: → resolution of the quantity measured
ETSC, IIT DELHI
37:12 / 1:02:18


Phy 11 02 03 measurements and introduction to error analysis
ACCURACY: — how close we are to the actual numerical value
PRECISION: → resolution of the quantity measure
we take measurements from a typical scale → precision 1mm
37:41 / 1:02:18


Phy 11 02 03 measurements and introduction to error analysis
Accuracy depends on many factors
include precision.
Eg. True Length of a Line
= 3.678 cm
measure with scale of Least count
1mm
= 3.5 cm
measure with an instrument of L.C.
0.1 mm → 3.38 cm
ETSC, IIT DELHI
39:12 / 1:02:18

Phy 11 02 03 measurements and introduction to error analysis

Systematic errors.

errors tend to be in 1 direction, i.e. they are either +ve or −ve.

a) Instrumental error →
calibration of instrument is not perfect. zero error

Phy 11 02 03 measurements and introduction to error analysis

b) Experimental Technique:

e.g. temperature of human body

thermometer under tongue

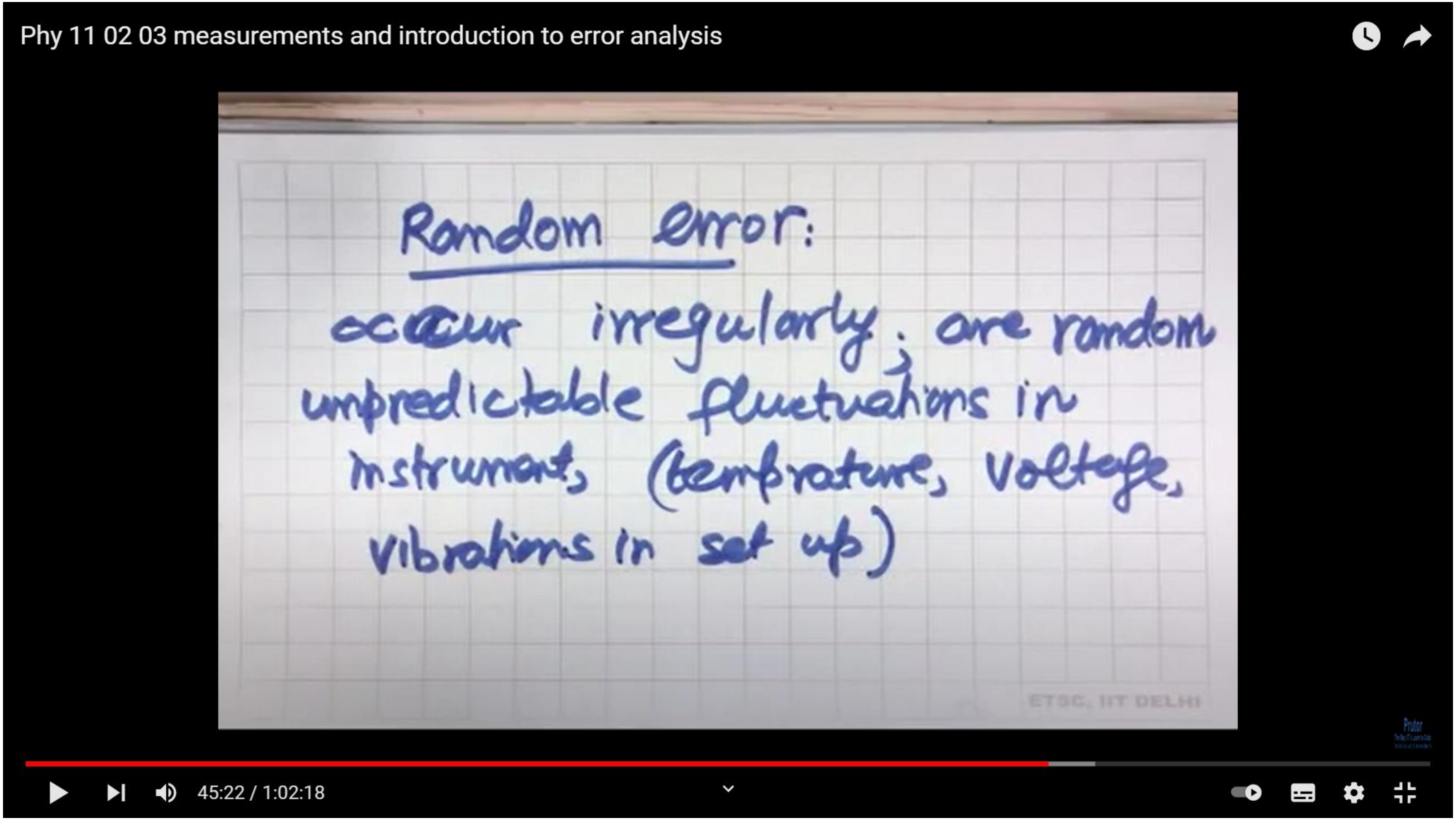
under armpit

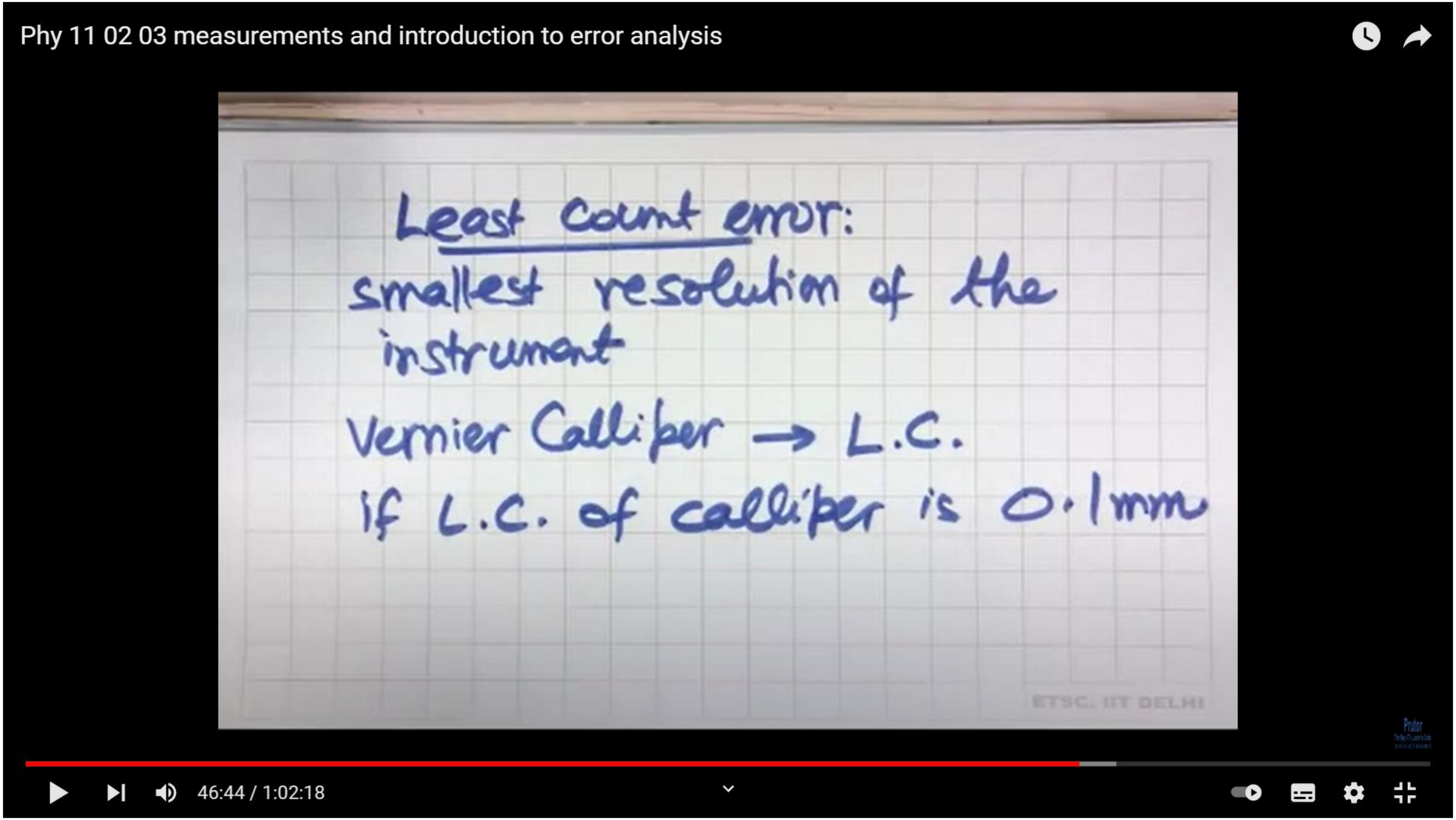
c) Personal errors:

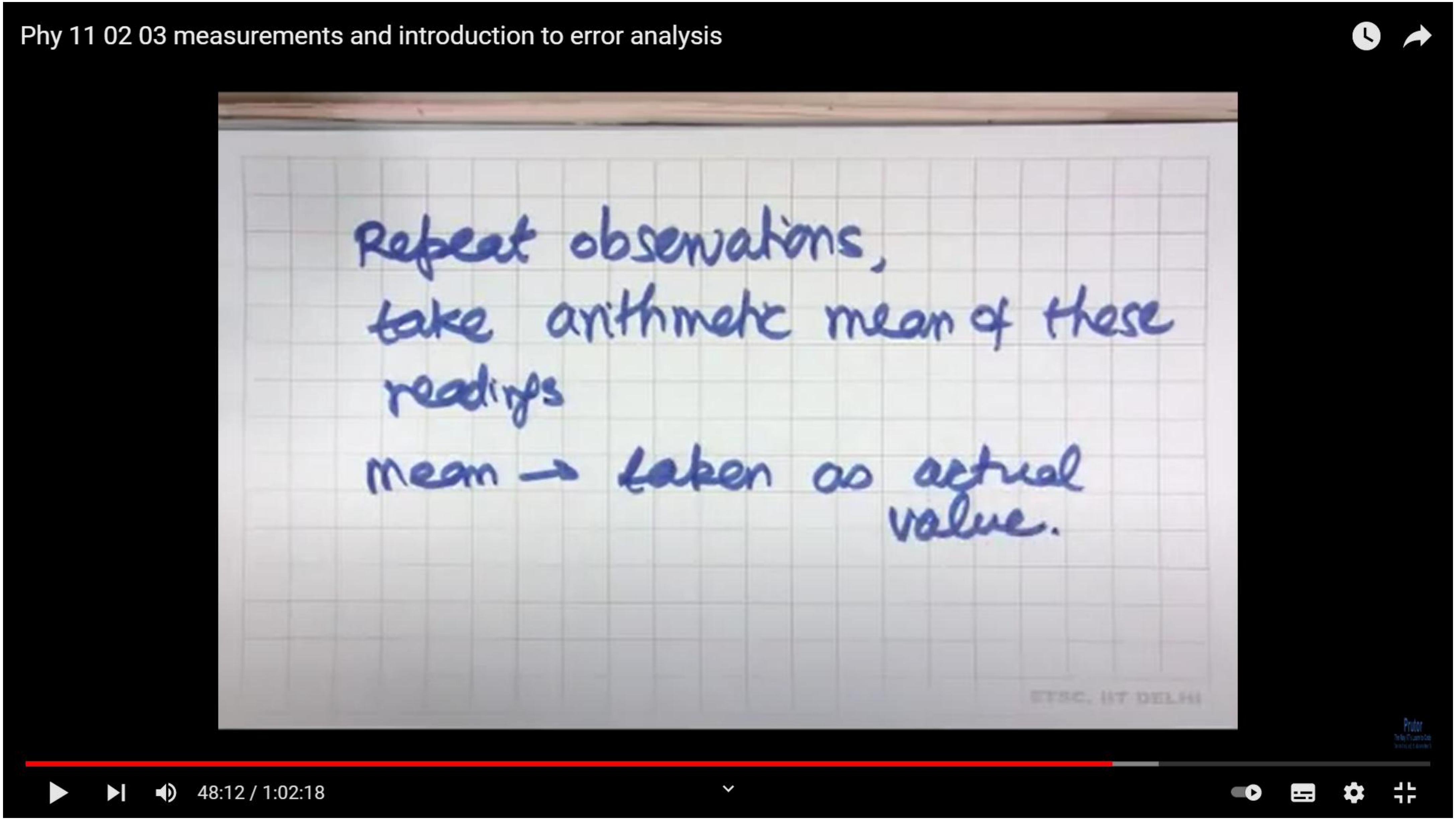
individual bias, setting,

carelessness of observer.

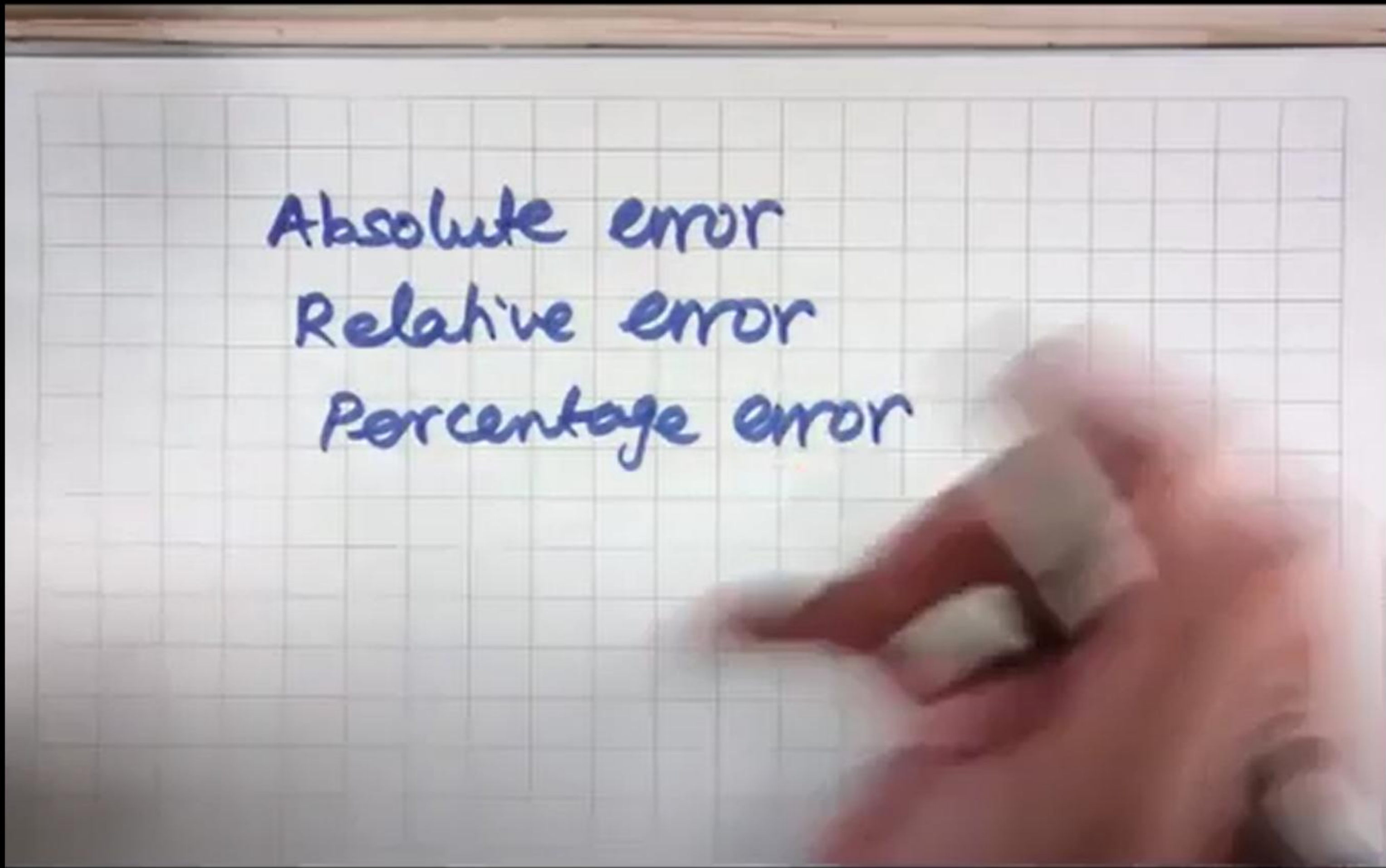
43:32 / 1:02:18


Phy 11 02 03 measurements and introduction to error analysis
Random error:
occur irregularly; are random
unpredictable fluctuations in
instrument, (temprature, voltage,
vibrations in set up)
ETSC, IIT DELHI
45:22 / 1:02:18

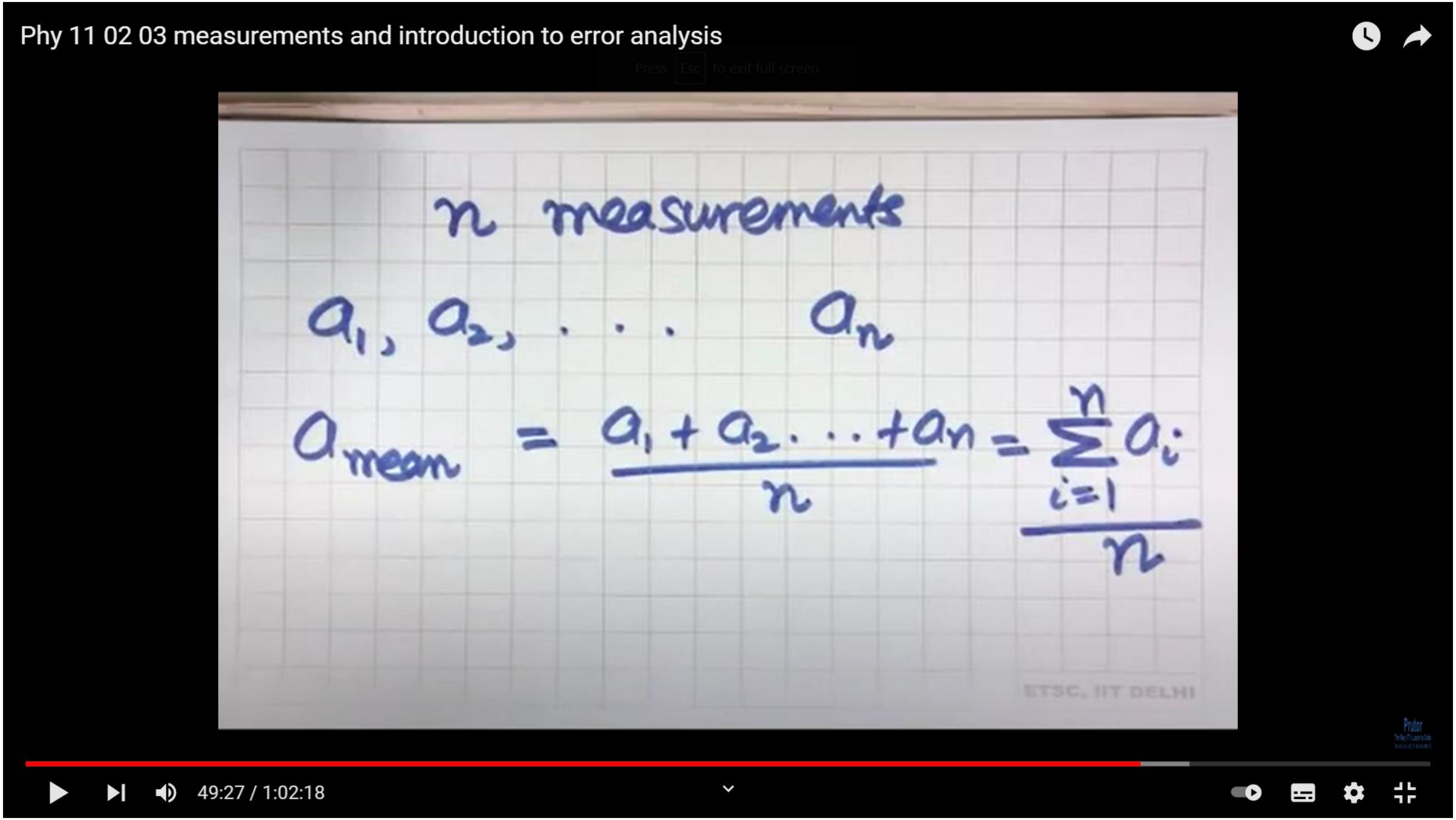

Phy 11 02 03 measurements and introduction to error analysis
Least count error:
smallest resolution of the instrument
Vernier Calliper → L.C.
if L.C. of calliper is 0.1mm
ETSC, IIT DELHI
46:44 / 1:02:18


Phy 11 02 03 measurements and introduction to error analysis
Repeat observations,
take arithmetic mean of these
readings
mean → taken as actual
value.
ETSC, IIT DELHI
48:12 / 1:02:18

Phy 11 02 03 measurements and introduction to error analysis



48:42 / 1:02:18


Phy 11 02 03 measurements and introduction to error analysis
n measurements
$a_1, a_2, \ldots a_n$
$a_{mean} = \frac{a_1 + a_2 \ldots + a_n}{n} = \frac{\sum_{i=1}^{n} a_i}{n}$
ETSC, IIT DELHI
49:27 / 1:02:18

Phy 11 02 03 measurements and introduction to error analysis

magnitude of difference between individual measurement and true measurement = absolute error

$$|\Delta a_i| = |a_i - a_{mean}|$$

50:41 / 1:02:18

Phy 11 02 03 measurements and introduction to error analysis

$a_1, \ldots \ldots a_n$

true value not known, mean is taken as true value.

$$a_{mean} = \frac{a_1 + a_2 \ldots + a_n}{n}$$

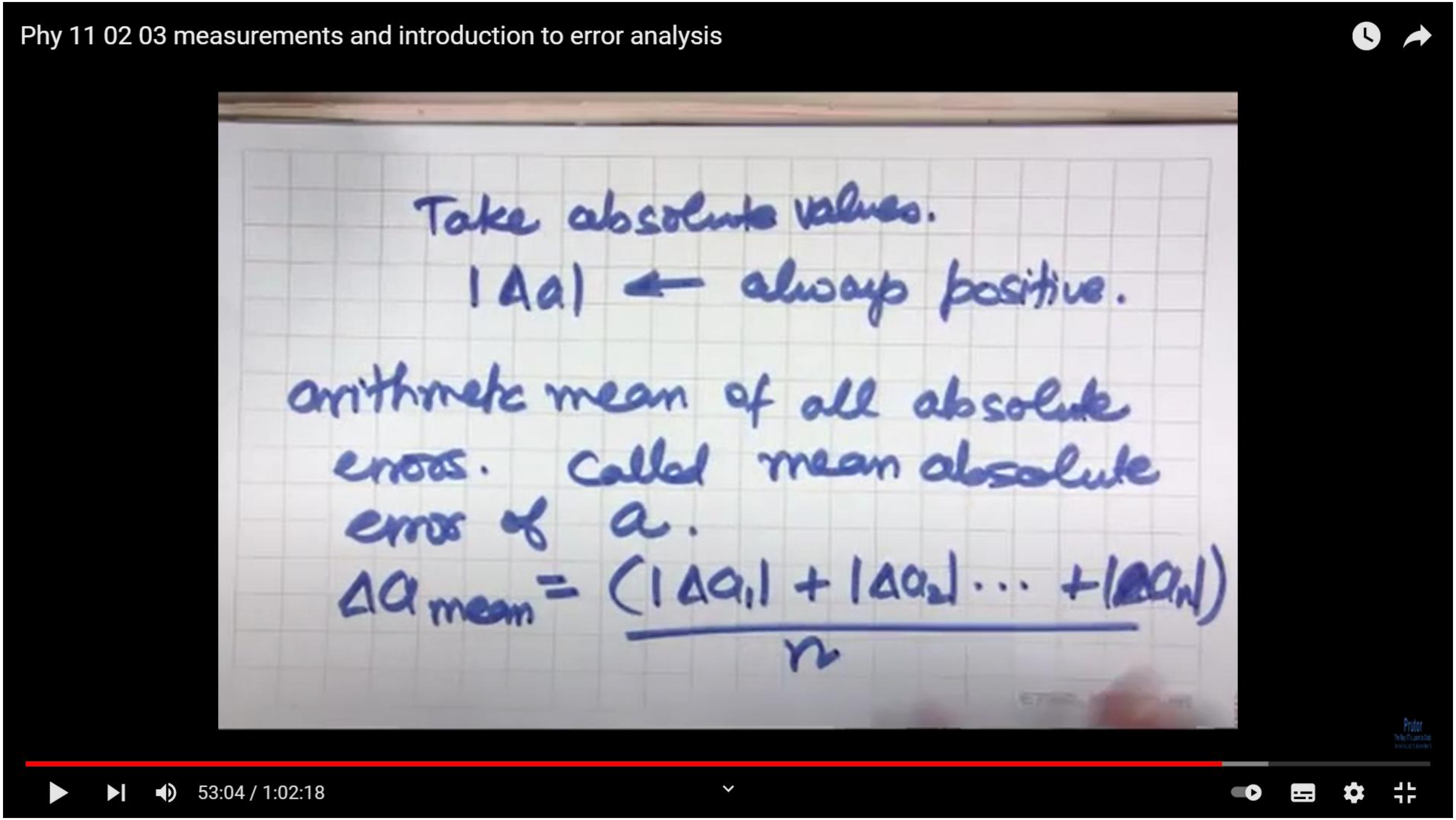
$$\Delta a_1 = a_1 - a_{mean}$$

$$\Delta a_2 = a_2 - a_{mean}$$

$$\vdots$$

$$\Delta a_n = a_n - a_{mean}$$

51:45 / 1:02:18

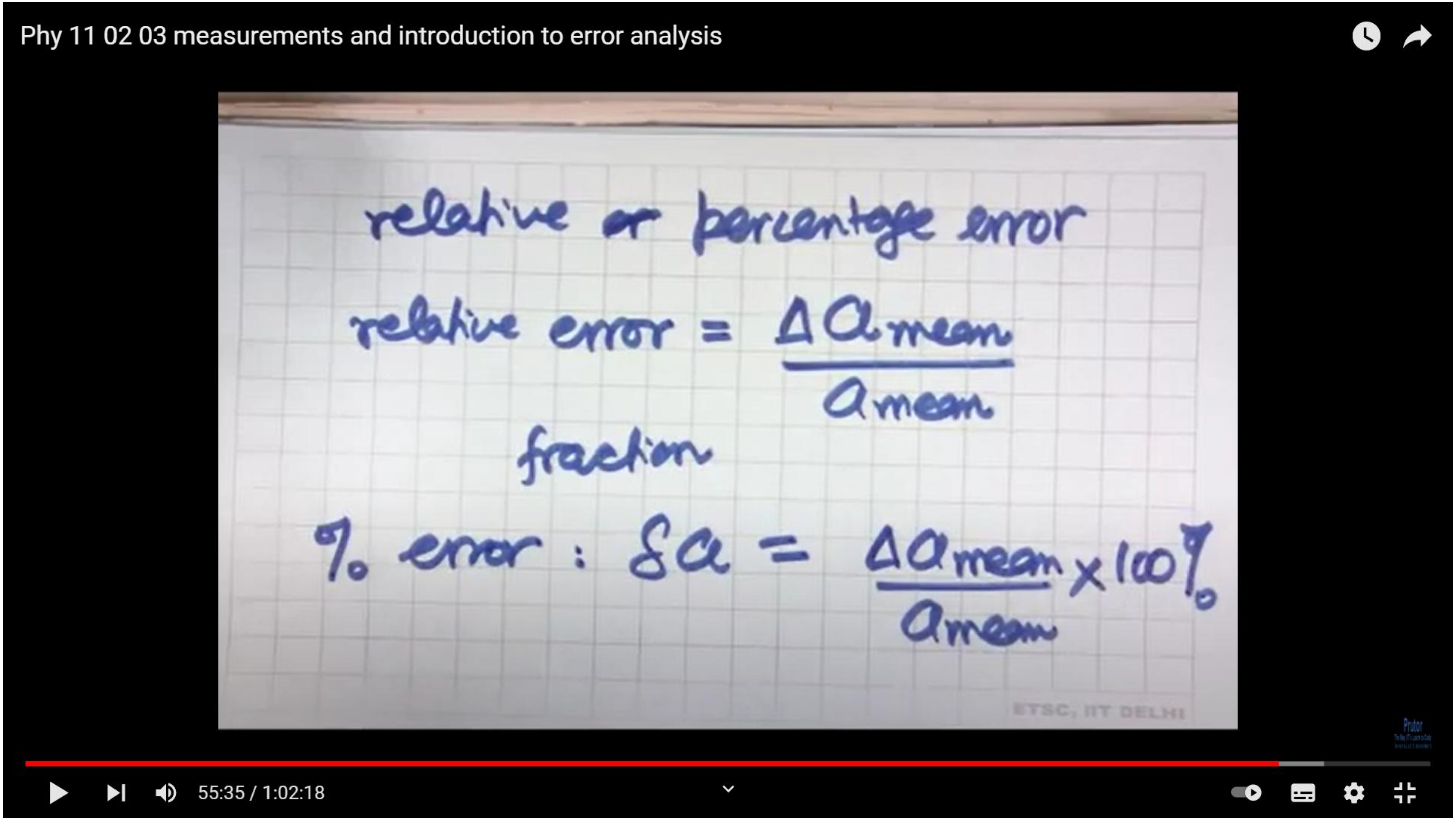

Phy 11 02 03 measurements and introduction to error analysis
Take absolute values.
|Δa| ← always positive.
arithmetic mean of all absolute errors. Called mean absolute error of a.
Δa_mean = (|Δa1| + |Δa2| ... + |Δan|) / n
53:04 / 1:02:18

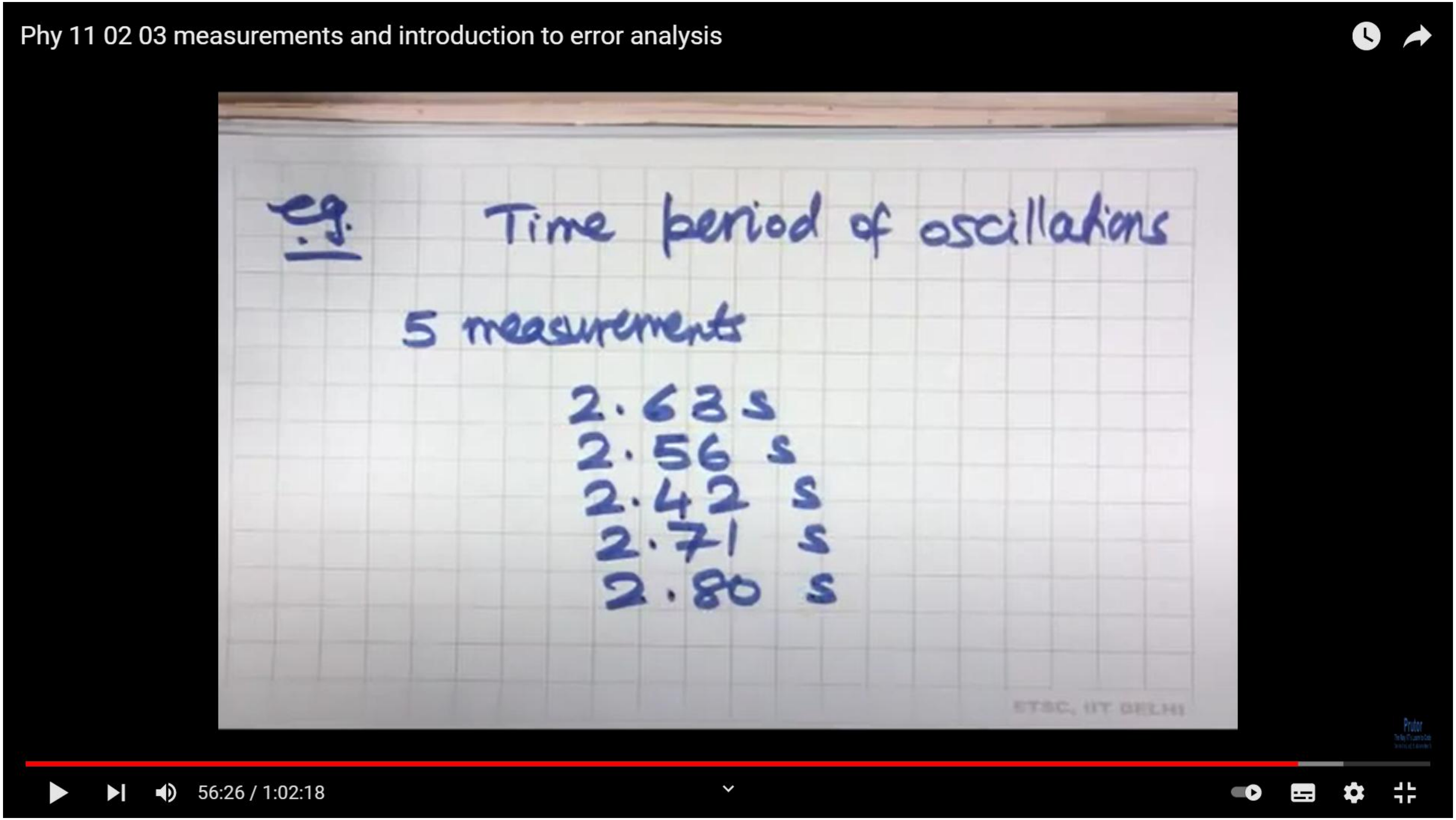
Phy 11 02 03 measurements and introduction to error analysis

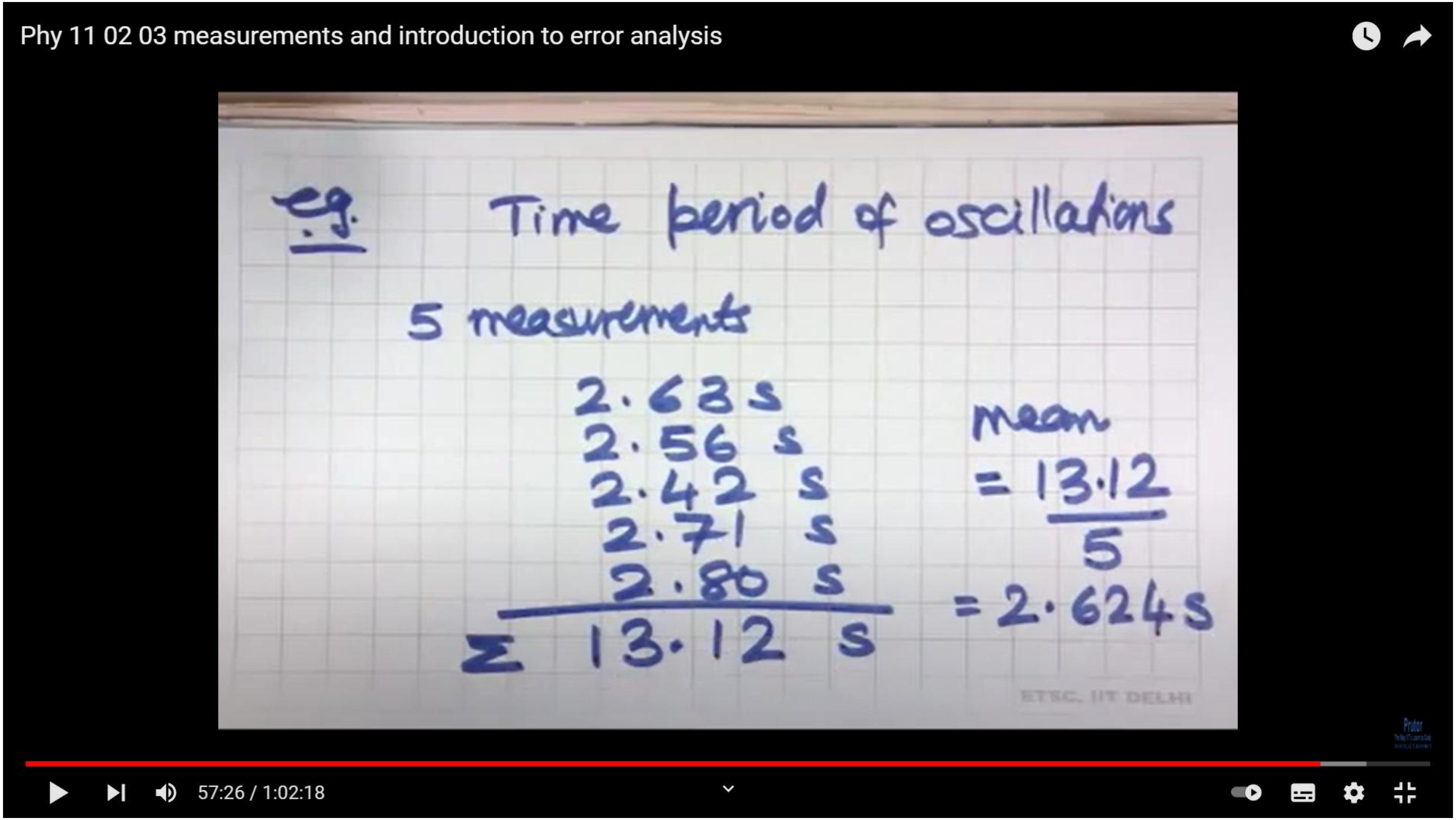
Single measurement, we expect this to be in range

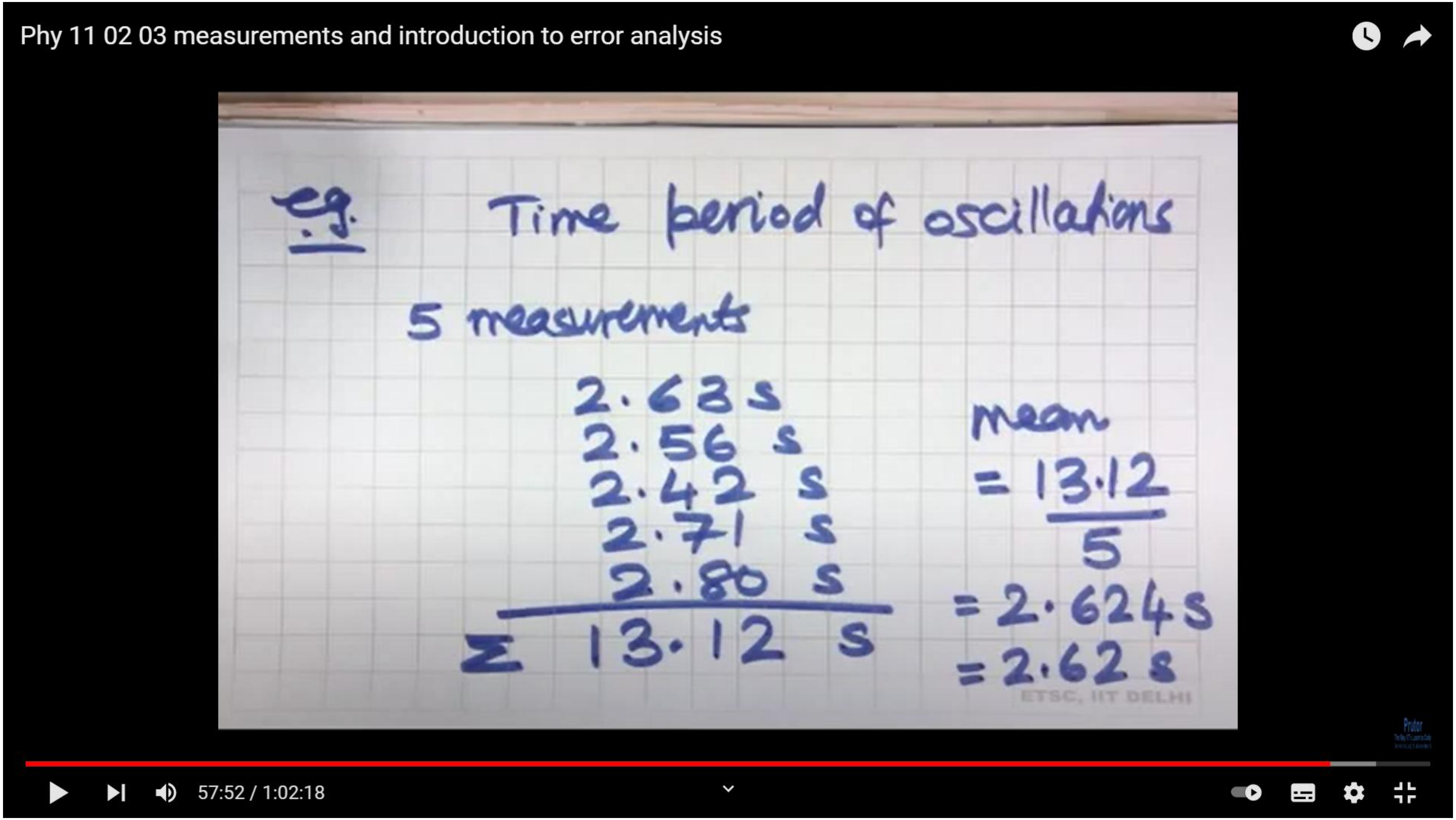
$$a_{mean} \pm \Delta a_{mean}$$

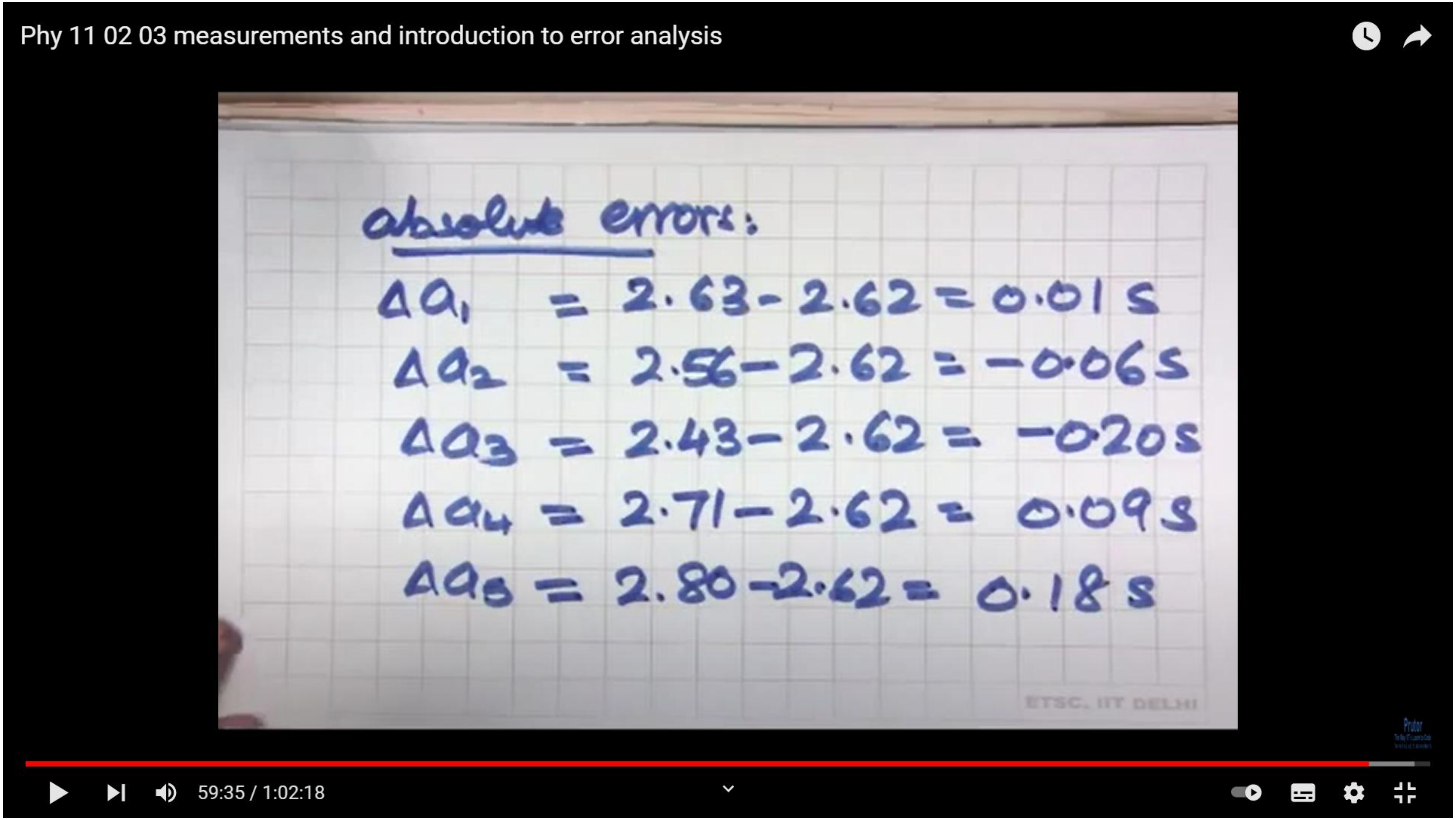
$$a_{mean} - \Delta a_{mean} \leq a \leq a_{mean} + \Delta a_{mean}$$

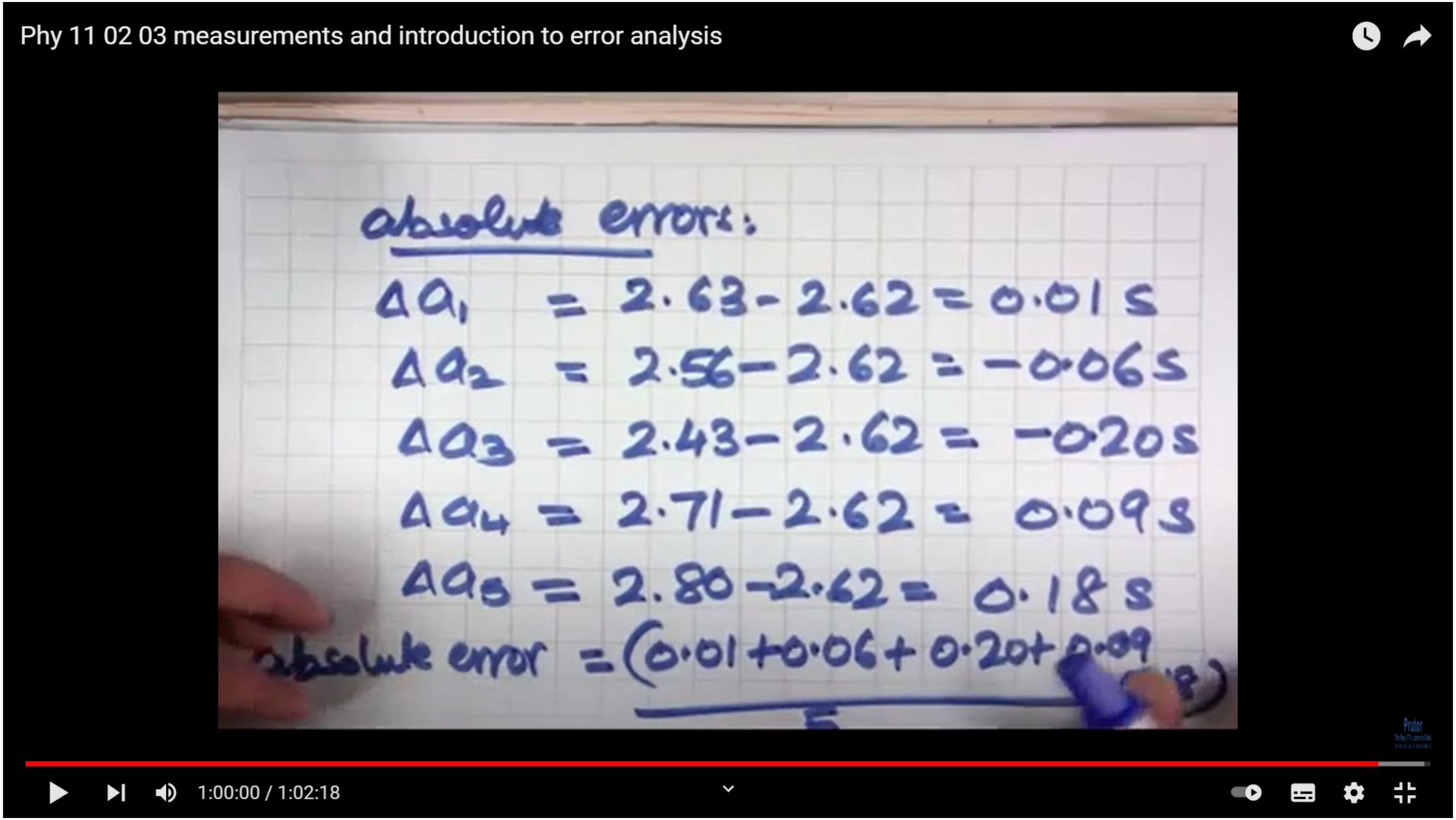

Phy 11 02 03 measurements and introduction to error analysis
relative or percentage error
relative error = $\frac{\Delta a_{mean}}{a_{mean}}$
fraction
% error : $\delta a = \frac{\Delta a_{mean}}{a_{mean}} \times 100\%$
ETSC, IIT DELHI
55:35 / 1:02:18

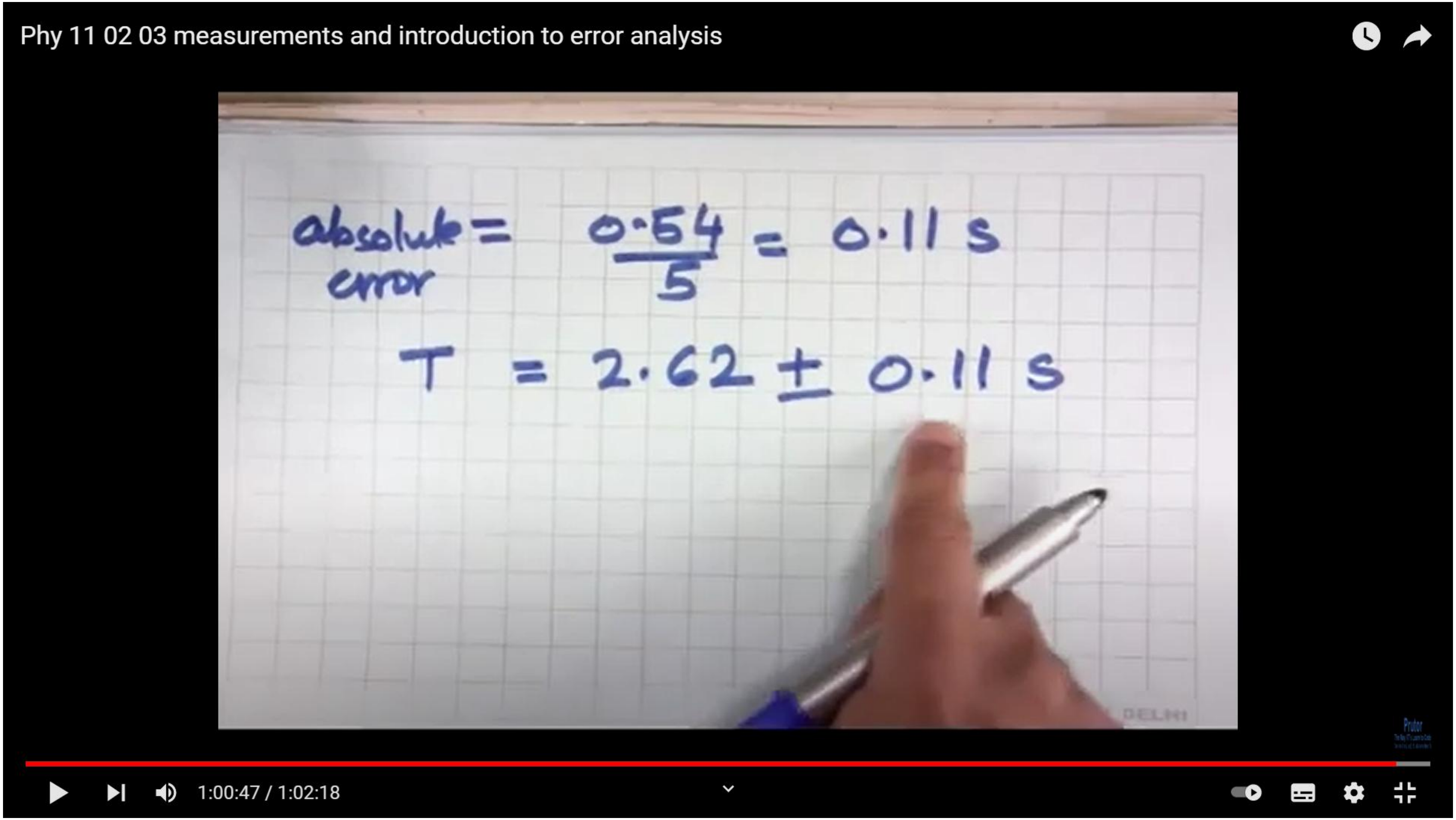

Phy 11 02 03 measurements and introduction to error analysis
eg. Time period of oscillations
5 measurements
2.63 s
2.56 s
2.42 s
2.71 s
2.80 s
ETSC, IIT DELHI
56:26 / 1:02:18


Phy 11 02 03 measurements and introduction to error analysis
e.g.
Time period of oscillations
5 measurements
2.63 s
2.56 s
2.42 s
2.71 s
2.80 s
Σ 13.12 s
mean
= 13.12 / 5
= 2.624 s
ETSC, IIT DELHI
57:26 / 1:02:18


Phy 11 02 03 measurements and introduction to error analysis
e.g.
Time period of oscillations
5 measurements
2.63 s
2.56 s
2.42 s
2.71 s
2.80 s
Σ 13.12 s
mean
= 13.12 / 5
= 2.624 s
= 2.62 s
ETSC, IIT DELHI
57:52 / 1:02:18


Phy 11 02 03 measurements and introduction to error analysis
absolute errors:
Δa1 = 2.63 − 2.62 = 0.01 s
Δa2 = 2.56 − 2.62 = −0.06 s
Δa3 = 2.43 − 2.62 = −0.20 s
Δa4 = 2.71 − 2.62 = 0.09 s
Δa5 = 2.80 − 2.62 = 0.18 s
ETSC, IIT DELHI
59:35 / 1:02:18


Phy 11 02 03 measurements and introduction to error analysis
absolute errors:
Δa1 = 2.63 - 2.62 = 0.01 s
Δa2 = 2.56 - 2.62 = -0.06 s
Δa3 = 2.43 - 2.62 = -0.20 s
Δa4 = 2.71 - 2.62 = 0.09 s
Δa5 = 2.80 - 2.62 = 0.18 s
absolute error = (0.01 + 0.06 + 0.20 + 0.09
5
1:00:00 / 1:02:18


Phy 11 02 03 measurements and introduction to error analysis
absolute error = 0·54 / 5 = 0·11 s
T = 2·62 ± 0·11 s
1:00:47 / 1:02:18

Phy 11 02 03 measurements and introduction to error analysis

$$\text{absolute error} = \frac{0.54}{5} = 0.11\ s$$

$$T = 2.62 \pm 0.11\ s$$

$$\text{error} > 0.1\ s$$

$$T = 2.6 \pm 0.1\ s$$

$$\text{relative error \%} = \frac{0.1}{2.6} \times 100 = 4\%$$

ETSC, IIT DELHI

1:01:41 / 1:02:18