



Universidad Nacional  
de La Matanza



# A rational mechanics course where everything is made with Python code

Bettachini, Víctor A.; Real, Mariano A.; Palazzo, Edgardo

New Media Pedagogy 23



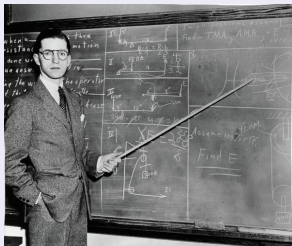
## Value students and professors time

Licklider (1957): 85 % of “thinking” are actually mundane task (calculations, drawing, etc.)



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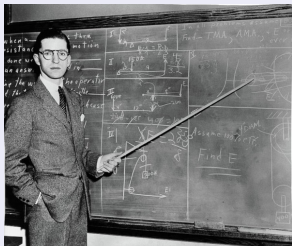
Classroom and practice: an exercise on transcription

- Professor: lessons  $\xrightarrow{\text{by heart}}$  blackboard/slides



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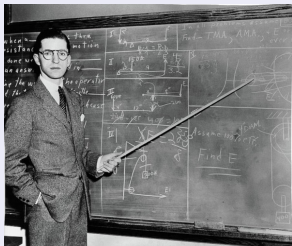
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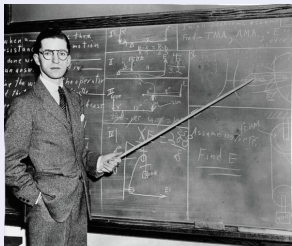
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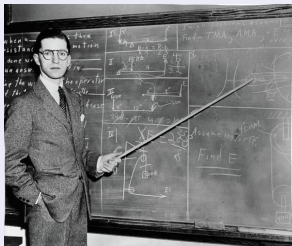
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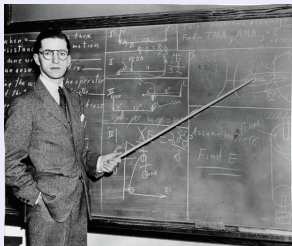
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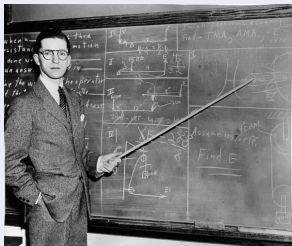
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# Value students and professors time

Licklider (1957): 85 % of “thinking” are actually mundane task (calculations, drawing, etc.)



Classroom and practice: an exercise on transcription

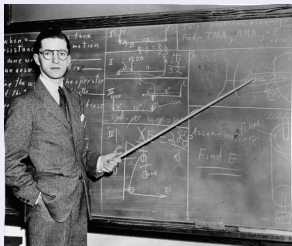
- Professor: lessons  $\xrightarrow{\text{by heart}}$  blackboard/slides
- Student: blackboard/slides  $\xrightarrow{\text{copies}}$  notebooks
- Práctica **reiterate** diagrames, calculations, etc.
- Boredom  $\implies \downarrow$  concentration on the subject

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# Value students and professors time

Licklider (1957): 85 % of “thinking” are actually mundane task (calculations, drawing, etc.)



Classroom and practice: an exercise on transcription

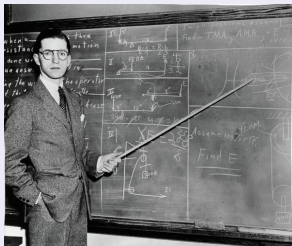
- Professor: lessons  $\xrightarrow{\text{by heart}}$  blackboard/slides
- Student: blackboard/slides  $\xrightarrow{\text{copies}}$  notebooks
- Práctica **reiterate** diagrammes, calculations, etc.
- Boredom  $\implies \downarrow$  concentration on the subject

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- Professor: ideas  $\rightarrow$  new code/notes in repository
- Student: course repository  $\rightarrow$  its own modifiable one
- Use code to solve problems = **recycle** professor's code

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- Use code to solve problems = **recycle** professor's code
- Modifying it solves different problems

Engineering students must take advantage of code at every single lecture



# Engineering students must take advantage of code at every single lecture

- Currently they use a pocket calculator **after they learnt** learning arithmetics at school



# Engineering students must take advantage of code at every single lecture

- Currently they use a pocket calculator **after they learnt** learning arithmetics at school
- They'll employ computational algebra **after they learnt** algebra and calculus

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[14]: sistemaEcuaciones = [  
    x_EL,  
    phi_EL,  
]  
variablesDespeje = [x.diff(t,2), phi.diff(t,2)] # despejar aceleraciones generalizadas  
variablesDespeje_sol = sym.nonlinsolve(sistemaEcuaciones, variablesDespeje ).args[0]  
  
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x_pp, phi_pp  
  
[15]: 
$$\ddot{x} = \frac{-\ell g m_2 \sin(\phi) + \frac{\ell m_2 (\ell m_2 \cos(\phi) \dot{\phi}^2 + g m_1 + g m_2) \sin(\phi)}{m_1 + m_2 \sin^2(\phi)}}{\ell m_2 \cos(\phi)}, \quad \ddot{\phi} = -\frac{(\ell m_2 \cos(\phi) \dot{\phi}^2 + g m_1 + g m_2) \sin(\phi)}{\ell (m_1 + m_2 \sin^2(\phi))}$$

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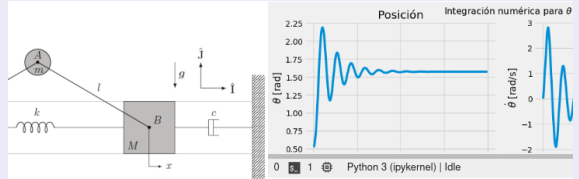


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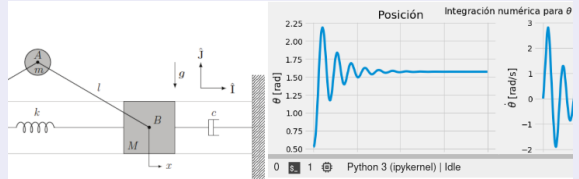


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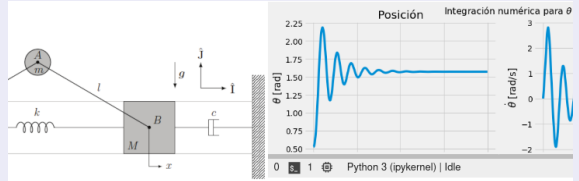


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```



Papert (1980) “...the best learning takes place when the learner takes charge”

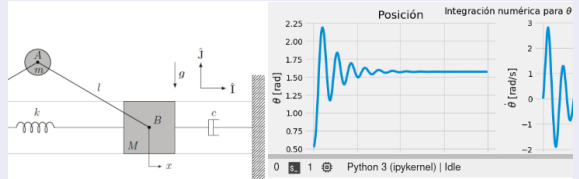
- An example problem is solved by the professor provided code

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    phi_EL,  
]  
variablesDespeje = [x.diff(t,2), phi.diff(t,2)] # despejar aceleraciones generalizadas  
variablesDespeje_sol = sym.nonlinsolve(sistemaEcuaciones, variablesDespeje).args[0]  
  
[15]: x_pp = sym.Eq(variablesDespeje[0], variablesDespeje_sol.args[0]) # [m s-2]  
phi_pp = sym.Eq(variablesDespeje[1], variablesDespeje_sol.args[1]) # [m s-2]  
x_pp, phi_pp  
  
[15]: 
$$\ddot{x} = \frac{-\ell g m_2 \sin(\phi) + \frac{\ell m_2 (\ell m_2 \cos(\phi) \dot{\phi}^2 + g m_1 + g m_2) \sin(\phi)}{m_1 + m_2 \sin^2(\phi)}}{\ell m_2 \cos(\phi)}, \quad \ddot{\phi} = -\frac{(\ell m_2 \cos(\phi) \dot{\phi}^2 + g m_1 + g m_2) \sin(\phi)}{\ell (m_1 + m_2 \sin^2(\phi))}$$

```



Papert (1980) “...the best learning takes place when the learner takes charge”

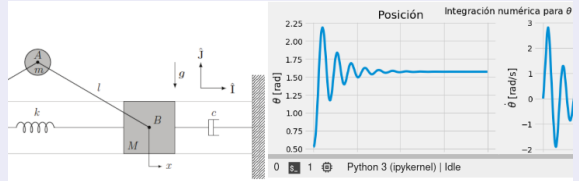
- An example problem is solved by the professor provided code
- The student modifies it to solve other related problems

# Engineering students must take advantage of code at every single lecture

- Currently they use a pocket calculator **after they learnt** learning arithmetics at school
- They'll employ computational algebra **after they learnt** algebra and calculus
  - ▶ Focus on new skills, not in automatable calculations
  - ▶ Employing numerical calculus they solve what is impossible in a blackboard/paper

```
[14]: sistemaEcuaciones = [  
    x_EL,  
    phi_EL,  
]  
variablesDespeje = [x.diff(t,2), phi.diff(t,2)] # despejar aceleraciones generalizadas  
variablesDespeje_sol = sym.nonlinsolve(sistemaEcuaciones, variablesDespeje).args[0]  
  
[15]: x_pp = sym.Eq(variablesDespeje[0], variablesDespeje_sol.args[0]) # [m s-2]  
phi_pp = sym.Eq(variablesDespeje[1], variablesDespeje_sol.args[1]) # [m s-2]  
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```



Papert (1980) “...the best learning takes place when the learner takes charge”

- An example problem is solved by the professor provided code
- The student modifies it to solve other related problems
- Gradually he becomes autonomous by reusing not the provided but his own code

All course material can be edited on-line



# All course material can be edited on-line

## On-line programmable notebook: text + equations + code

File Edit View Run Kernel Tabs Settings Help

PÉNDULO ENHEBRADO SOLVED.IPYNB

Launcher cursoJupyter.ipynb pénduloEnhebradoSolved.ipynb Python 3

3. Obtenga una expresión para la tensión que ejerce la barra

$$Q_d = \lambda_1 \frac{\partial f_1}{\partial d} = \lambda_1$$

Por tanto hay que resolver el sistema con las 3 ecuaciones de Euler-Lagrange y la única de ligadura para determinar  $\lambda_1$ . Esta última hay que resolverla para su caso homogéneo y expresar su derivada segunda para que esté en el mismo orden que las de Euler-Lagrange, a fin de cuentas estamos resolviendo sistemas diferenciales de 2.º orden.

```
[14]: f_1
```

```
[14]: f_1 = -l + d
```

Determinamos también  $\ddot{\theta}_1$  y  $\ddot{\theta}_2$  pues serán necesarias para los cálculos numéricos posteriores.

```
[15]: sistema = [theta1_EL.expand(),
               theta2_EL.expand(),
               d_EL.expand(),
               sym.Eq(f_1.rhs.diff(t,2), 0), # esto es igual a d punto punto = 0
               ]
variables = [theta1.diff(t,2), theta2.diff(t,2), lambda_1]
variables_sol = sym.nonlinsolve(sistema, variables).args[0]
```

```
[16]: lambda_1_sol = sym.Eq(lambda_1, variables_sol.args[2])
      lambda_1_sol.simplify()
```

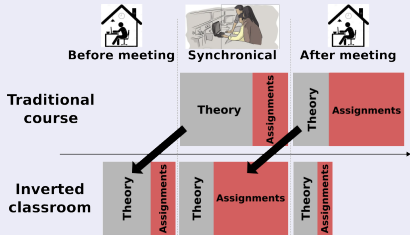
```
[16]: m (2a cos(theta_1 - theta_2) \ddot{\theta}_1^2 + g cos(2\theta_1 - \theta_2) + g cos(\theta_2) + 2d \ddot{\theta}_2^2 - 2\ddot{d})
```

# Synchronical and asynchronical work on the code

## New theory alongisde its worked examples in programmable notebooks

- On-line 24/7 **asynchronical** consultations that are **public** for others to see

### Inverted classroom



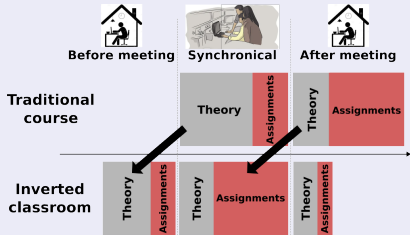
Synchronical	Theory	Assignments
Before	Read and apply	Start them
During	Consultations	Complete them
After	Additional consultations	TA's corrections

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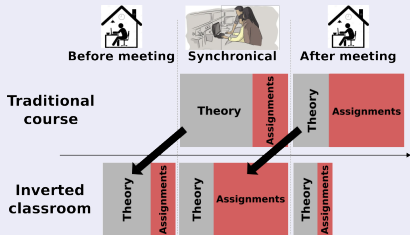


# Synchronical and asynchronical work on the code

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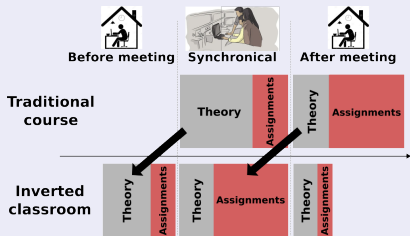
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- Weekly meetings to **synchronically** unfinished assignments with TA's assistance
- On a weekly basis these **must** be turned-in for scoring


## Inverted classroom



Synchronical	Theory	Assignments
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# Asynchronous corrections and remote assistance

## Student's work can be commented and edited in Google Colaboratory

 07 No conservativas | ej4 ☆

Archivo Editar Ver Insertar Entorno de ejecución Herramientas Ayuda [Se editó por última vez: 3 de junio](#)

Comentar Compartir Configuración Perfil

+ Código + Texto

Cómodo Editando

```
[ ] # Energía potencial
m1_V = - (m1* g* (- N.y)).dot(m1_r)
# pot_k1 = unMedio* ( -k1* ((l10 + x1)* (sym.cos(theta) - sym.sin(theta)) )**2 ) # mal
pot_k1 = unMedio* k1* (l10 + x1)**2 # Lo escribí yo
# pot_k2 = unMedio* -k2* (l20 + x)**2
pot_k2 = unMedio* k2* (l20 + x)**2
V = sym.Eq(sym.Symbol('V'), m1_V + pot_k1 + pot_k2 ) #agrega el potencial elastico k en la ecuacion
V
```

Victor Alexis Bettachini [Resolver](#)

31 de may. de 2021  
(editado el 31 de may. de 2021)

- El estiramiento del resorte de k\_1 es colineal con x1. No tienen sentido pensar en proyecciones (si es lo que hiciste, que realmente no entiendo).  
- ¿Porque negativos los k?

$$V = gm_1(-l_{10} - x_1)\sin(\theta) + \frac{k_1(l_{10} + x_1)^2}{2} + \frac{k_2(l_{20} + x)^2}{2}$$

▼ Lagrangiano

```
[ ] L = sym.Eq(sym.Symbol('\mathcal{L}'), (T.rhs - V.rhs))
L
```

$$\mathcal{L} = -gm_1(-l_{10} - x_1)\sin(\theta) - \frac{k_1(l_{10} + x_1)^2}{2} - \frac{k_2(l_{20} + x)^2}{2} + \frac{(m_0 + m_1)(2\cos(\theta)\dot{x}_1 + \dot{x}^2 + \dot{x}_1^2)}{2}$$

ECUACIONES DE EULER

## Individualized student follow-up at Microsoft Teams

A record of the weekly turn-up of assignments

Calificaciones							
Vencimiento el 28 sept	<div> <div>Exportar a Excel</div> <div></div> </div>						
g06e03	g06e04	g06e05	g05e01a	g05e01c	g05e02	g05e03	
28 sept	28 sept	28 sept	14 sept	14 sept	14 sept	14 sept	
<b>Promedio de clase</b>							
[Avatar] [Nombre]	Visto		Visto	Devuelto	Entregado	Entregado	Entregado
[Avatar] [Nombre]				Devuelto	Entregado	Entregado	Entregado
[Avatar] [Nombre]				Entregado	Entregado	Entregado	Entregado
[Avatar] [Nombre]	Visto	Visto	Visto	Entregado	Entregado	Entregado	Entregado
[Avatar] [Nombre]				Entregado	Entregado		Entregado
[Avatar] [Nombre]	Visto	Visto	Visto	Entregado	Entregado	Visto	Entregado

# Summary

## A course centred on code

- Theory: text + equations + executable code in digital notebooks.

## Inverted classroom



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- Theory: emphasis on student's autonomous reading



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- Consultations: mostly on-line asynchronous and of public access



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- Theory: emphasis on student's autonomous reading
- Consultations: mostly on-line asynchronous and of public access
- TA personal assistance when completing assignments in synchronous meetings



# Current developments



# Current developments

2023 Students feedback improved:





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- Theory notes and code at repository



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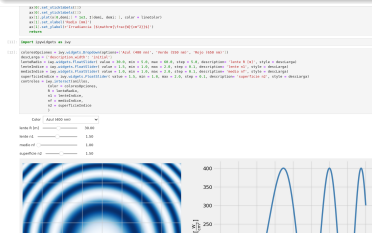
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2024

- A course on optics and waves will incorporate part of the methodology



# Current developments

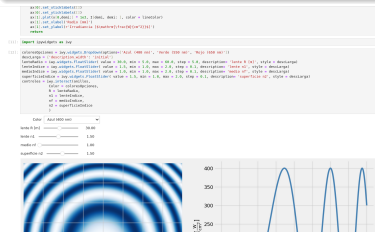
## 2023 Students feedback improved:

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- Grading of assignments methodology

Evaluating each one of them → higher student's performance

## 2024

- A course on optics and waves will incorporate part of the methodology
- AI assistance in code generation employing *GitHub Copilot*



```
lagrangiano = (T.xhs - V.ths).expand()
t = sym.Symbol('t') # como se deriva respecto al tiempo con la función diff se declara t como simbolo
return sym.Eq(
    lagrangiano.diff(coordenadaGeneralizada)
    - lagrangiano.diff(coordenadaGeneralizada).diff(t)).diff(t)
    )
simplify()
```

```
x1_EL = eulerLagrange(T, V, x1)
x1_EL
```

$$\frac{m^2 M \ddot{x}_1}{2} - g m_1 + g m_2 + m_1 \ddot{x}_1 + m_2 \ddot{x}_1 = 0$$

Esta es una ecuación diferencial lineal de segundo orden homogenea. De aquí se puede despejar  $\ddot{x}$

```
#Despejar x1PuntoPunto
x1PuntoPunto = sym.solve(x1_EL, x1.diff(t, t)).args[0]
```