

Title: Follow up session on Toughest Student Questions on Modern Physics: 'Official' answers from PI researchers.

Date: Jul 14, 2006 02:17 PM

URL: <http://pirsa.org/06070031>

Abstract:

Q: What is the difference between "spin up" and "spin down"?

⊕ What is the difference between "half" and ~~integer~~ "full" integer spin?

Q: What is the main difference between Special and General Relativity?

Q: What is the difference between "spin up" and "spin down"?

Q: What is the difference between "half" and ~~integer~~ "Full" integer spin?

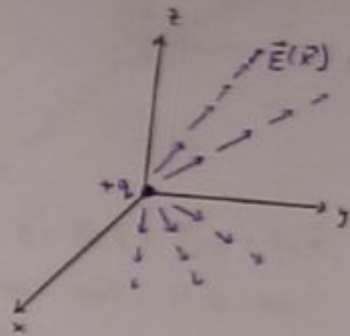
Q: What is the main difference between Special and General Relativity?

①

Example:

Vector:

Electric Field: $(\vec{E}(r))$

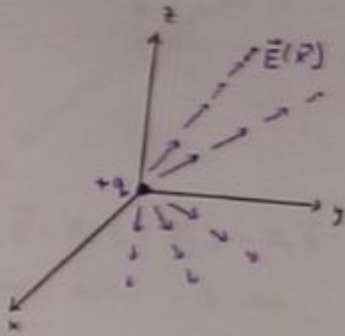


①

Example:

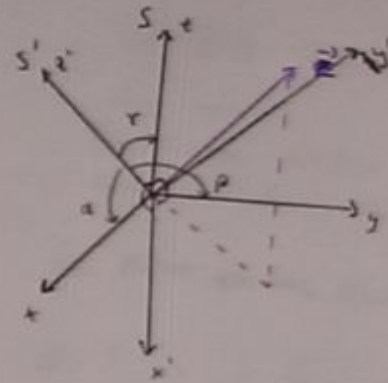
Vector:

Electric Field: ($\vec{E}(r)$)



②

Symmetry:

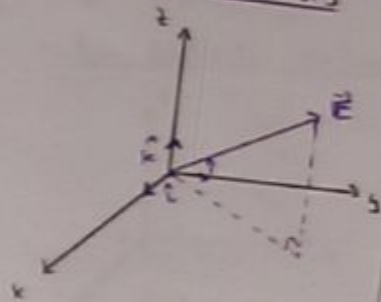


→ The vector \vec{E} is unchanged after a rotation

Vector:

③

Basis Vectors



$$\therefore \vec{E} = E_x \hat{i} + E_y \hat{j} + E_z \hat{k}$$

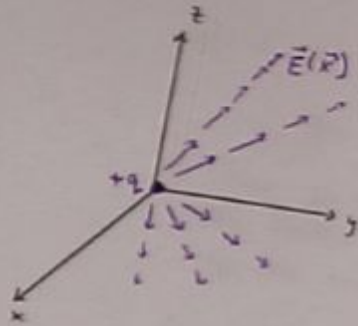
3 basis vectors = 3-Dim

①

Example:

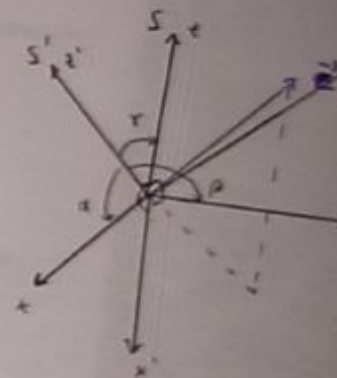
Vector:

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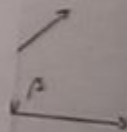


②

Symmetry:



is unchanged as
 $|\vec{E}| = \text{const.}$
The vector is unaffected

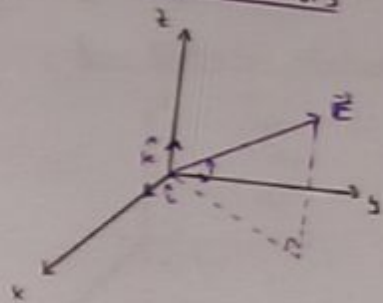


unchanged under

Vector:

③

Basis Vectors



$$\therefore \vec{E} = E_x \hat{i} + E_y \hat{j} + E_z \hat{k}$$

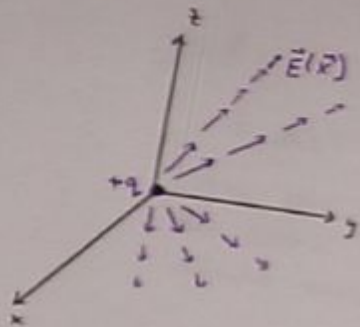
3 basis vectors = 3-Dim

①

Example:

Vector:

Electric Field: $(\vec{E}(r))$



②

Symmetry



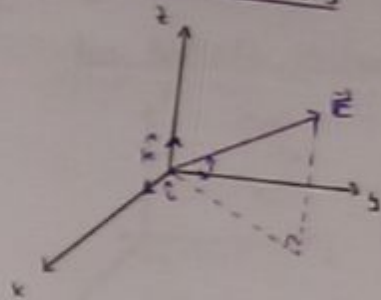
\vec{E} is unchanged
 $|\vec{E}| = \text{const.}$
The vector is unaltered



is unchanged under

Vector: ③

Basis Vectors



$$\therefore \vec{E} = E_x \hat{i} + E_y \hat{j} + E_z \hat{k}$$

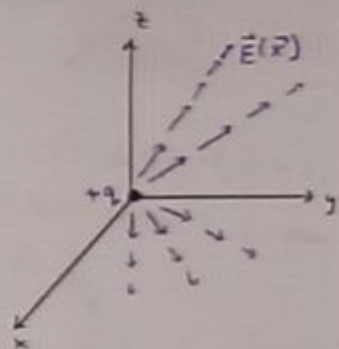
3 basis vectors = 3-Dim.

Vector: ③ Basis Vectors

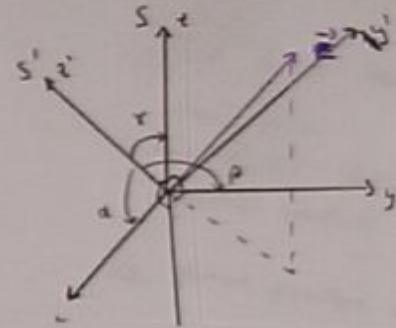
① Example:

Electric Field: $(\vec{E}(\vec{r}))$

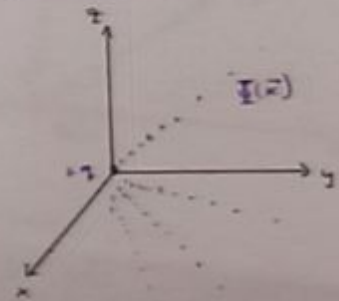
Vector:



② Symmetry:

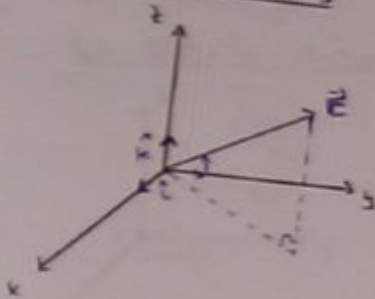


Scalar: ④ Electric Potential: $\Phi(\vec{r})$



Vector: ③

Basis Vectors



$$\therefore \vec{E} = E_x \hat{i} + E_y \hat{j} + E_z \hat{k}$$

3 basis vectors = 3-Dim.

Scalar: ④

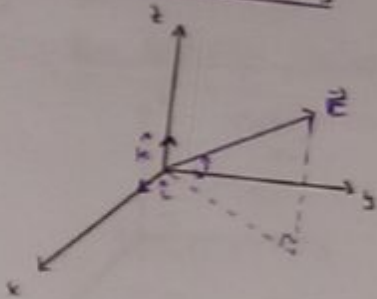


$$\therefore \underline{\phi} = \phi \hat{\phi}$$

1 basis vector = 1-Dim.

Vector: ③

Basis Vectors



$$\therefore \vec{E} = E_x \hat{i} + E_y \hat{j} + E_z \hat{k}$$

3 basis vectors = 3-dim.

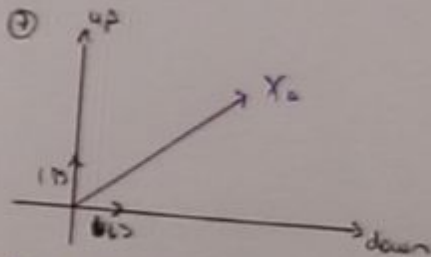
Scalar: ④



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1 basis vector = 1-dim.

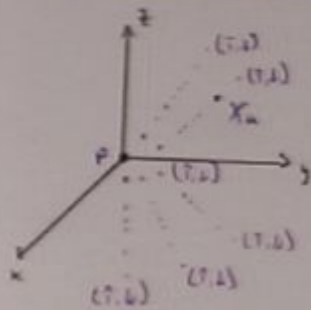
Spine:
(way)



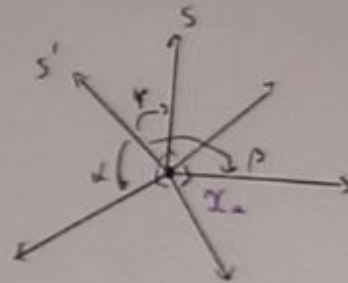
$$\therefore X = A \hat{u} + B \hat{d}$$

2 basis vectors = 2-dim.

Spinor: (cont.)
 ⑨ Example:
Non-Relativistic electron:



⑩ Symmetry:



The "magnitude" of the spin components is unchanged.

Group Theory / Quantum Statistics:

$$d = 2j + 1 \quad ; \quad j = \text{group theory parameter}$$

$$\therefore \text{if } d=3 \text{ then } j=1$$

- \therefore integer spin
- \therefore Bose-Einstein statistics \Rightarrow Boson
- \therefore symmetric wavefunction (No Pauli-Exclusion Principle)

Eg: photons, gravitons, gluons.

$$d=1 \quad \therefore \quad j=0$$

- \therefore integer spin
- \therefore Bose-Einstein statistics \Rightarrow Bosons

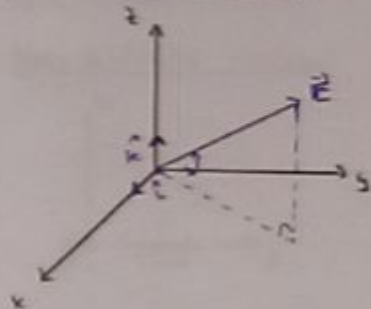
Eg: Higgs, Inflaton, etc.

$$d=2 \quad \therefore \quad j=\frac{1}{2}$$

- \therefore half integer spin
- \therefore Fermi-Dirac statistics \Rightarrow Fermions
- \therefore anti-symmetric wavefunction (Pauli-Exclusion)

Eg: electrons, positrons, quarks, etc.

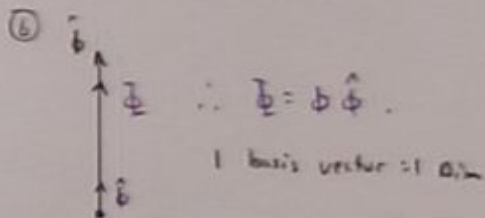
③ Vector: Basis Vectors



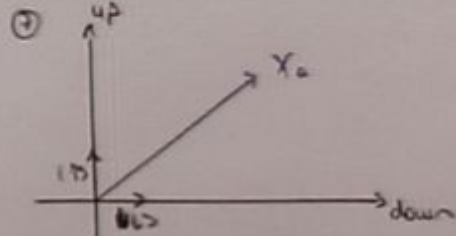
$$\therefore \vec{E} = E_x \hat{i} + E_y \hat{j} + E_z \hat{k}$$

3 basis vectors = 3-dim.

Scalar:



Spinor:
(Weyl)



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Eg: electrons, positrons, quarks, etc.

Q: What is the difference between "spin up" and "spin down"?

② What is the difference between "half" and ~~integer~~ "full" integer spin?

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Physics 1

SR



Physics 1

SR

GR



Physical

SR:

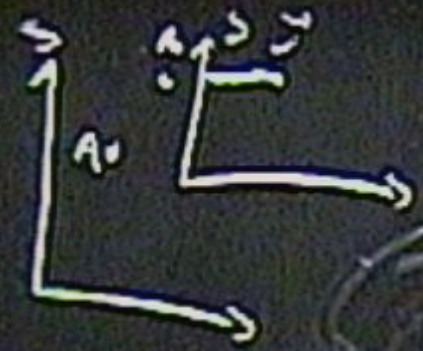


GR:



Physical

SR:

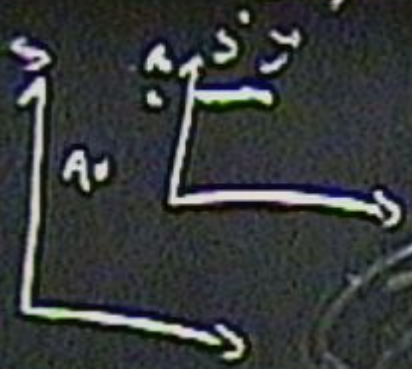


GR:



Physical

SR:



GR:

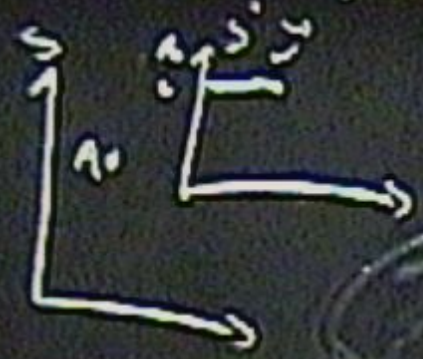
forces:

- Gravity
- EM
- Weak
- Strong



Physical

SR:



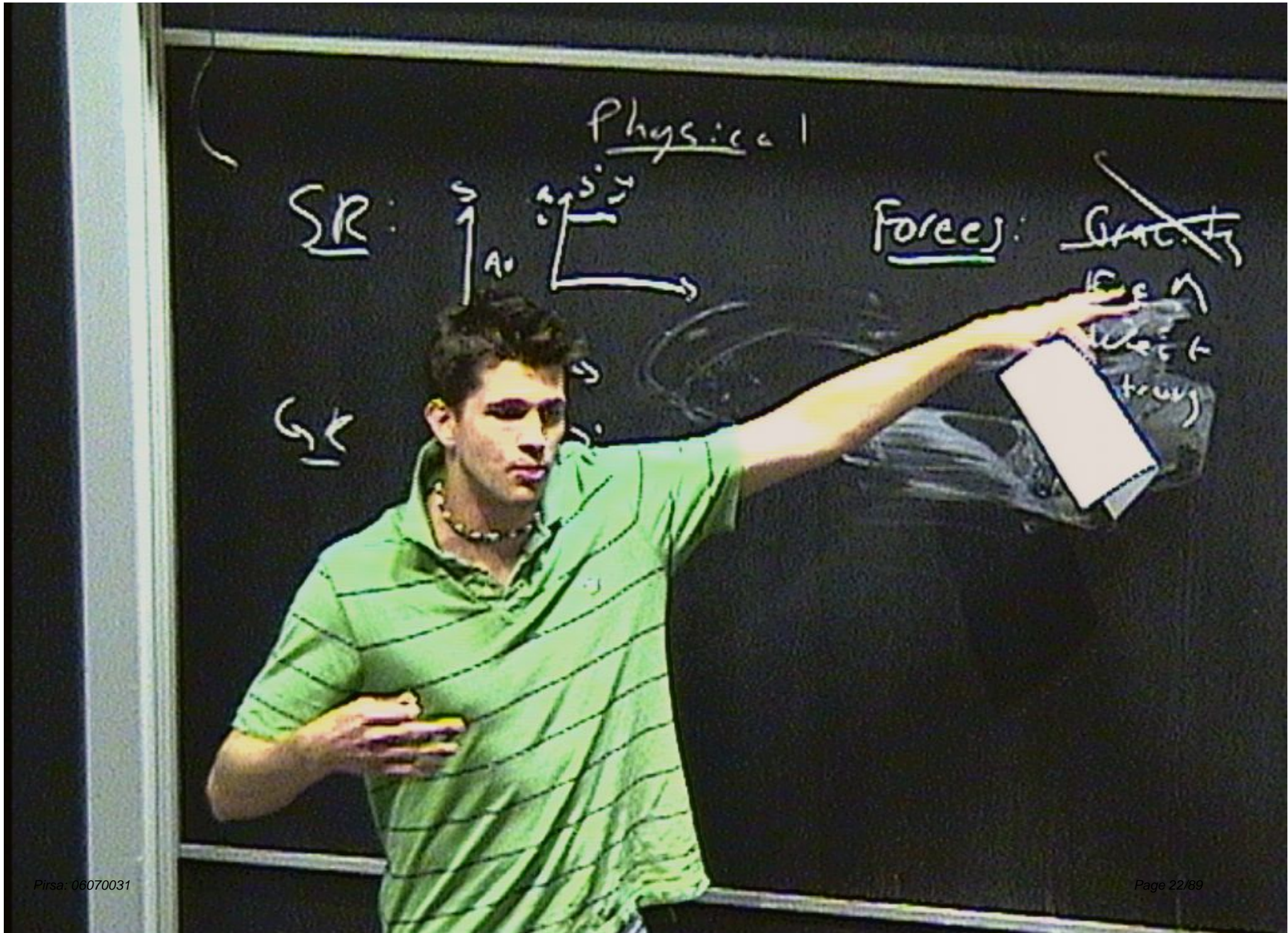
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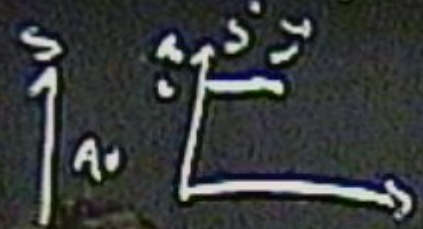
GR:





Physical

SR:



Force:

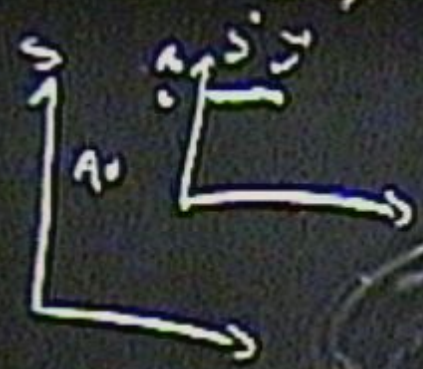
~~Gravity~~

Gravity
Gravity
Gravity

G

Physical

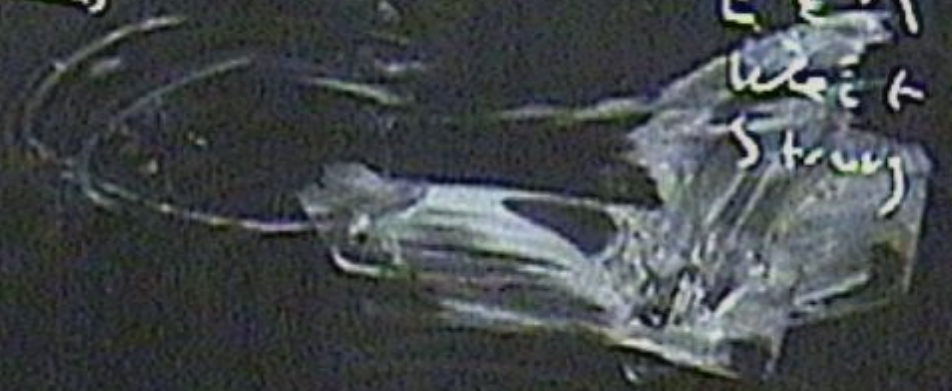
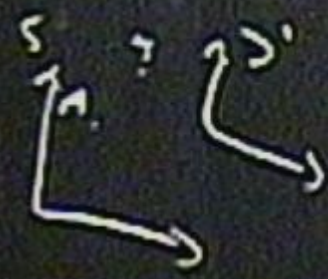
SR:



Force:

~~Gravity~~
EEM
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Physical

SR



GR



Math:

Force:

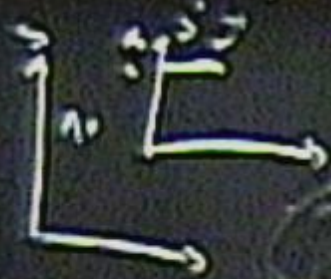
~~Gravity~~
EEM
Weak
Strong

Math

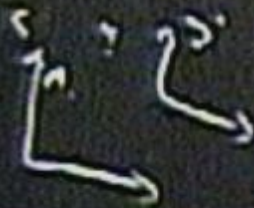
$$\Delta L^2 = c^2 \Delta t^2 + \Delta x^2 + \Delta y^2 + \Delta z^2$$

Physical

SR



GR



Math:

Force

~~Gravity~~

EEM
Weak
Strong

Math

$$\Delta L^2 = -c^2 \Delta t^2 + \Delta x^2 + \Delta y^2 + \Delta z^2$$

$$\begin{pmatrix} -c \Delta t \\ \Delta x \\ \Delta y \\ \Delta z \end{pmatrix}$$



Physical

Math

SR



Force

~~Gravity~~

$$\Delta L^2 = -c^2 \Delta t^2 + \Delta x^2 + \Delta y^2 + \Delta z^2$$

$$\begin{pmatrix} -1 & 0 & 0 & 0 \\ 0 & +1 & 0 & 0 \\ 0 & 0 & -1 & 0 \\ 0 & 0 & 0 & -1 \end{pmatrix} \begin{pmatrix} -c \Delta t \\ \Delta x \\ \Delta y \\ \Delta z \end{pmatrix}$$

GR



Math



Physical

Math

SR



Force

~~Gravity~~

$$\Delta L^2 = -c^2 \Delta t^2 + \Delta x^2 + \Delta y^2 + \Delta z^2$$

$$\begin{pmatrix} -c\Delta t & \Delta x & \Delta y & \Delta z \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{pmatrix} \begin{pmatrix} -c\Delta t \\ \Delta x \\ \Delta y \\ \Delta z \end{pmatrix}$$

Gr

Ma



Physical

Math

SR



Force: ~~Gravity~~

$$\Delta L^2 = -c^2 \Delta t^2 + \Delta x^2 + \Delta y^2 + \Delta z^2$$

$$(-c \Delta t \quad \Delta x \quad \Delta y \quad \Delta z) \begin{pmatrix} -1 & 0 & 0 & 0 \\ 0 & +1 & 0 & 0 \\ 0 & 0 & +1 & 0 \\ 0 & 0 & 0 & +1 \end{pmatrix} \begin{pmatrix} +c \Delta t \\ \Delta x \\ \Delta y \\ \Delta z \end{pmatrix}$$

$$\Delta X^\mu g_{\mu\nu} \Delta X^\nu$$

Physical

Math

SR



Force

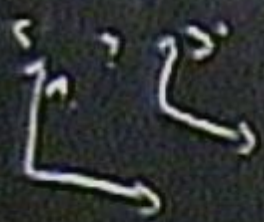
~~Gravity~~

$$\Delta L^2 = -c^2 \Delta t^2 + \Delta x^2 + \Delta y^2 + \Delta z^2$$

$$\begin{pmatrix} -c\Delta t & \Delta x & \Delta y & \Delta z \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{pmatrix} \begin{pmatrix} +c\Delta t \\ \Delta x \\ \Delta y \\ \Delta z \end{pmatrix}$$

$$\Delta x^\mu g_{\mu\nu} \Delta x^\nu$$

GR



Math:

Physical

Math

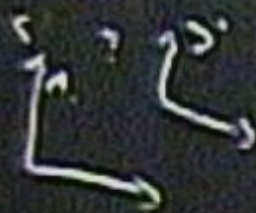
SR



Force: ~~Gravity~~

$$\Delta L^2 = -c^2 \Delta t^2 + \Delta x^2 + \Delta y^2 + \Delta z^2$$

GR



$$\begin{pmatrix} -c\Delta t & \Delta x & \Delta y & \Delta z \\ \Delta x & \dots & \dots & \dots \\ \Delta y & \dots & \dots & \dots \\ \Delta z & \dots & \dots & \dots \end{pmatrix} \begin{pmatrix} -1 & 0 & 0 & 0 \\ 0 & + & 0 & 0 \\ 0 & 0 & + & 0 \\ 0 & 0 & 0 & + \end{pmatrix} \begin{pmatrix} +c\Delta t \\ \Delta x \\ \Delta y \\ \Delta z \end{pmatrix}$$

$\Delta x^{\mu} + g_{\mu\nu} \Delta x^{\nu}$

Math:

Physical

Math

SR

Force: ~~Gravity~~

$\Delta L^2 = -c^2 \Delta t^2 + \Delta x^2 + \Delta y^2 + \Delta z^2$

GR

$$\begin{pmatrix} -c\Delta t & \Delta x & \Delta y & \Delta z \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{pmatrix} \begin{pmatrix} +c\Delta t \\ \Delta x \\ \Delta y \\ \Delta z \end{pmatrix}$$

$\Delta z^2 = \Delta x^2 + g_{\mu\nu} \Delta x^\mu \Delta x^\nu$

Math:

Physical

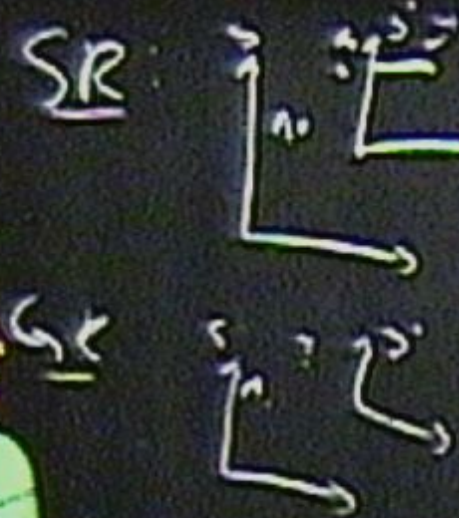
Math

SR

Force

~~Gravity~~

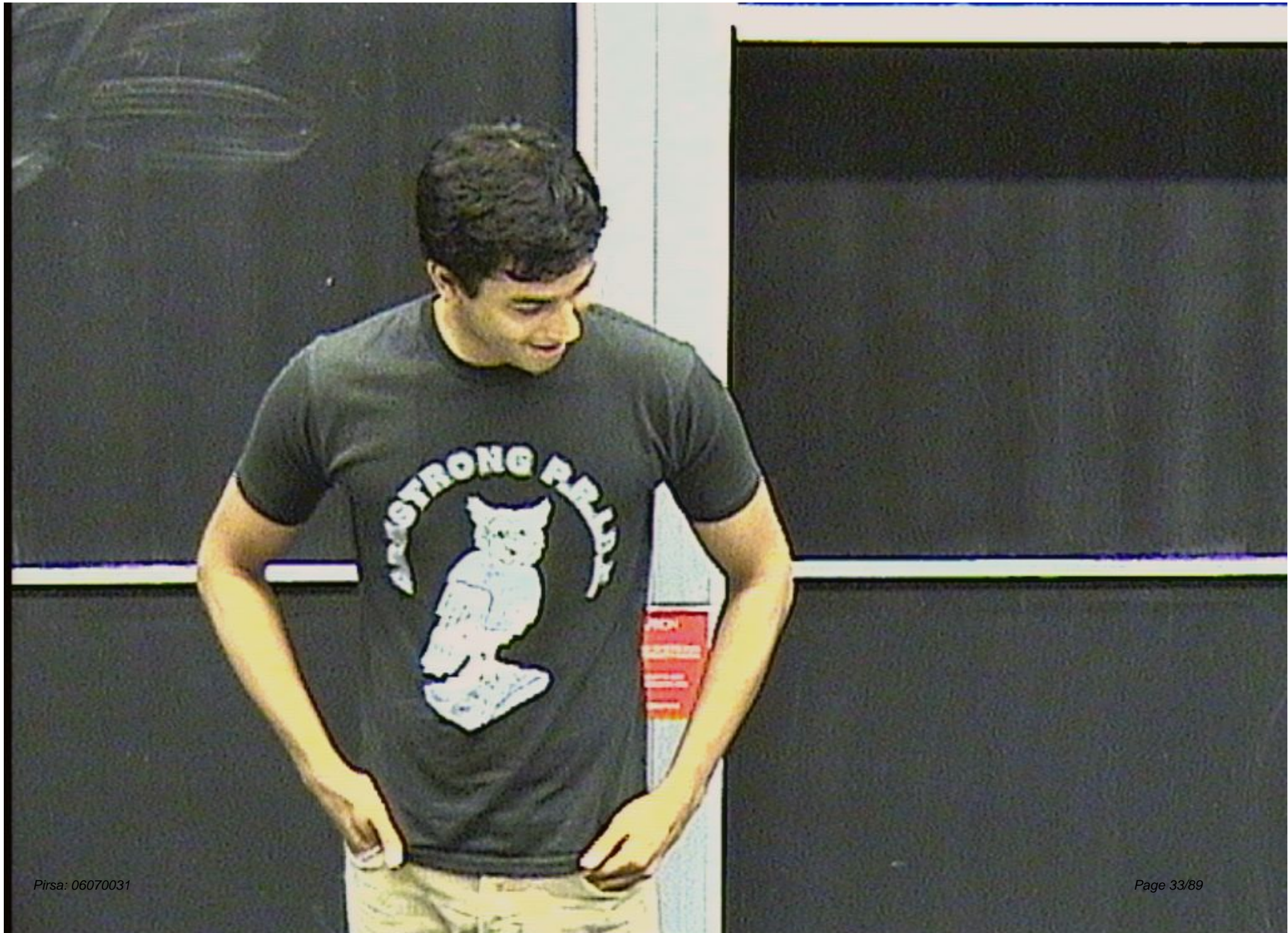
$\Delta L^2 = -c^2 \Delta t^2 + \Delta x^2 + \Delta y^2 + \Delta z^2$



$$\begin{pmatrix} -c\Delta t & \Delta x & 0 & 0 \\ 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \end{pmatrix}
 \begin{pmatrix} +c\Delta t \\ \Delta x \\ \Delta y \\ \Delta z \end{pmatrix}$$

$\Delta L^2 = \Delta X^{\mu} \Delta X^{\nu}$

math



Stars

H₂He

Stars

Hydrogen
Helium



Stars

~~Hydrogen~~
H → He



Stars

~~Hydrogen~~
H → He



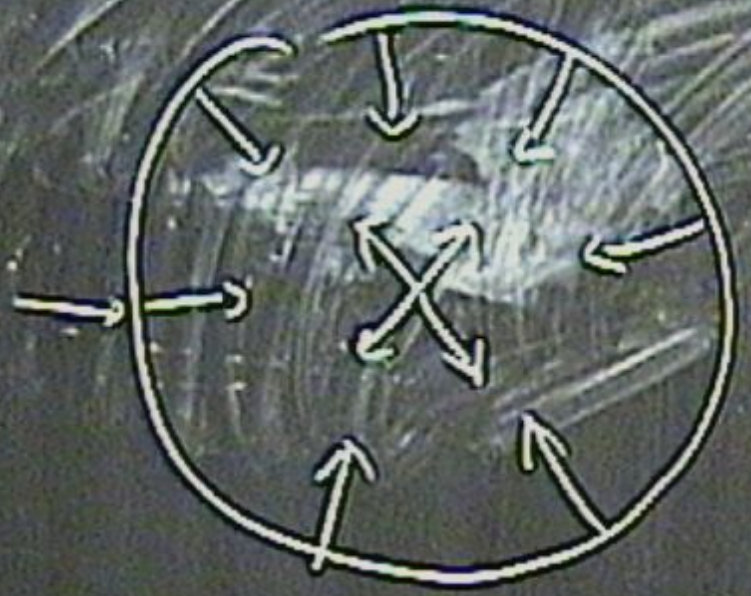
Stars

~~Hydrogen~~
H → He



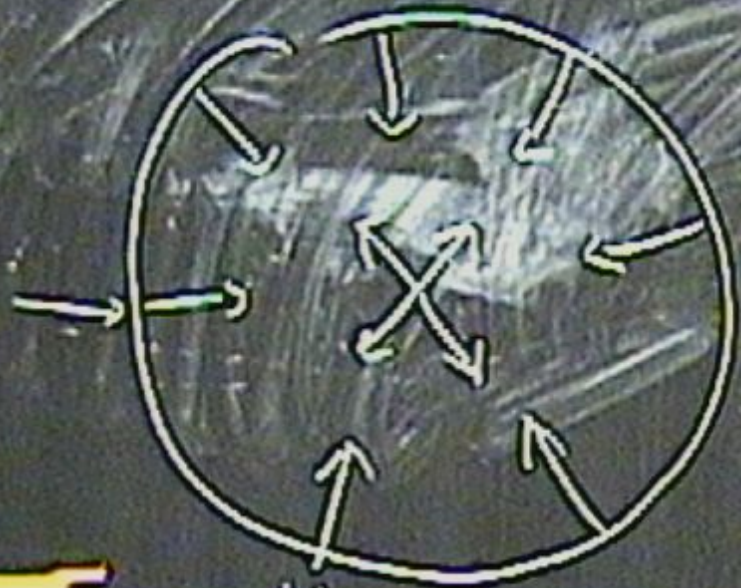
Stars

Main
H₂ He



Stars

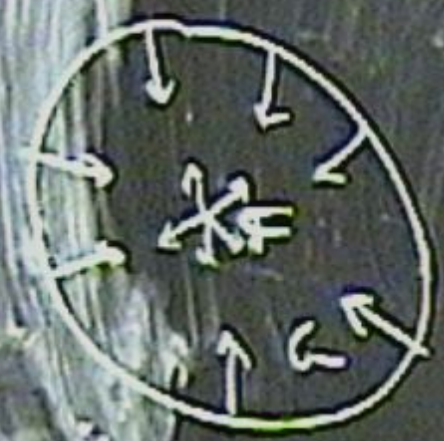
~~Hydrogen~~
H → He



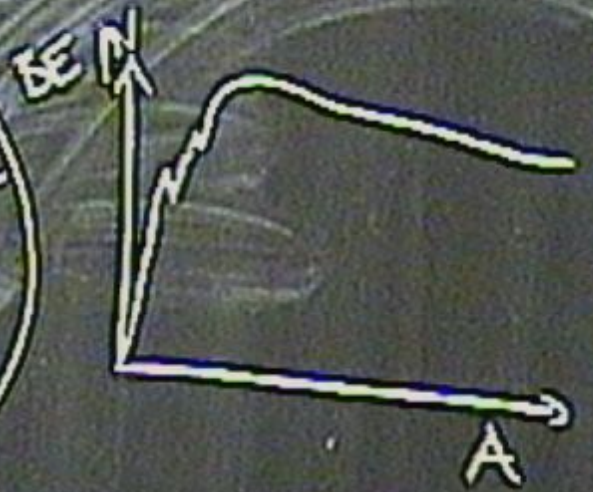
He → C, O, Si

Stars

$H \rightarrow He$

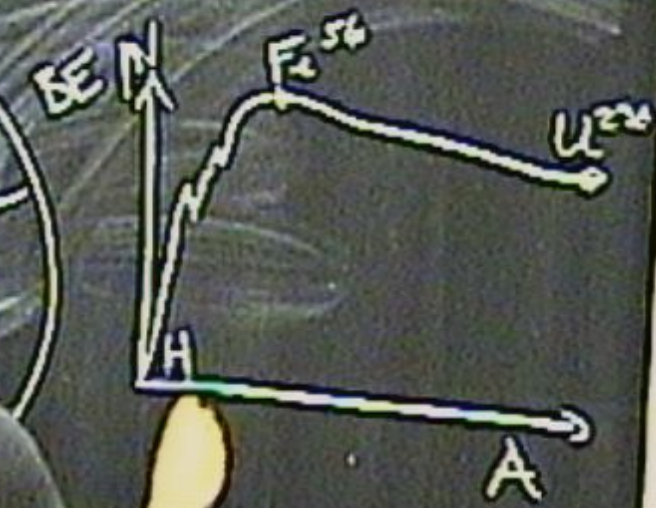


$He \rightarrow C, O, Si$



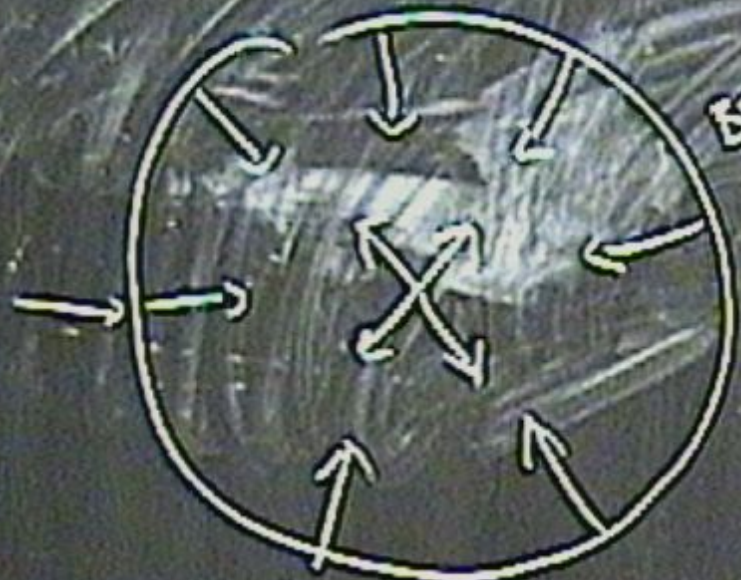
Stars

~~Handwritten scribbles~~

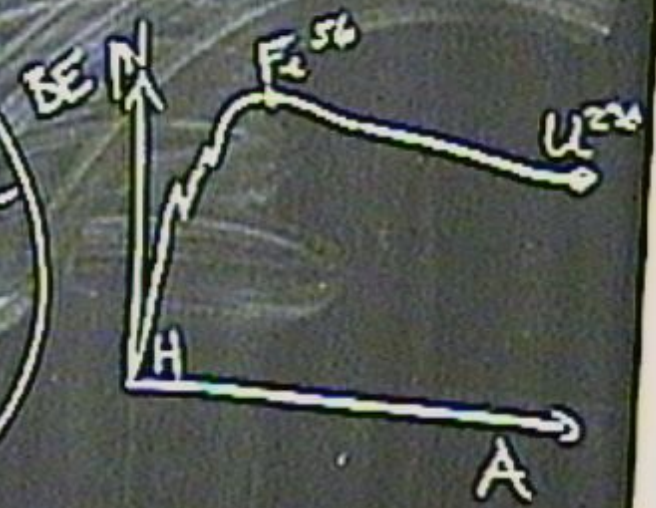


Stars

$H \rightarrow He$



$He \rightarrow C, O, Si$

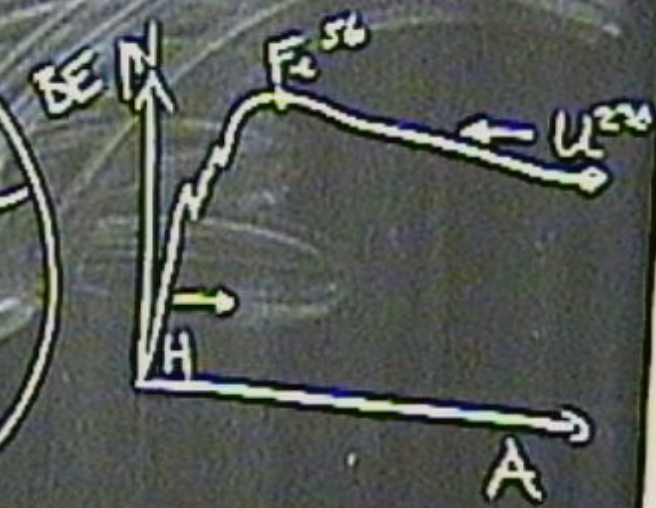


Stars

Main
 $H \rightarrow He$



$He \rightarrow C, O, Si$



MEMBRANE PARADIGM

MEMBRANE PARADIGM



MEMBRANE PARADIGM



MEMBRANE PARADIGM

 H, R

MEMBRANE PARADIGM

\bigcirc H, R, L

MEMBRANE PARADIGM

O_{H, R, E}

MEMBRANE PARADIGM



MEMBRANE PARADIGM

Frame Dragging



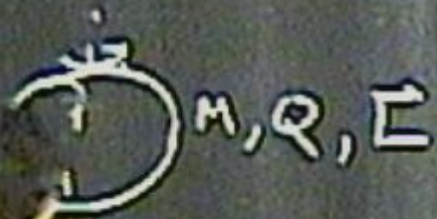
MEMBRANE PARADIGM



Frame Dragging



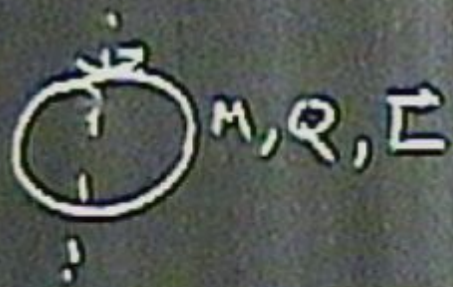
MEMBRANE PARADIGM



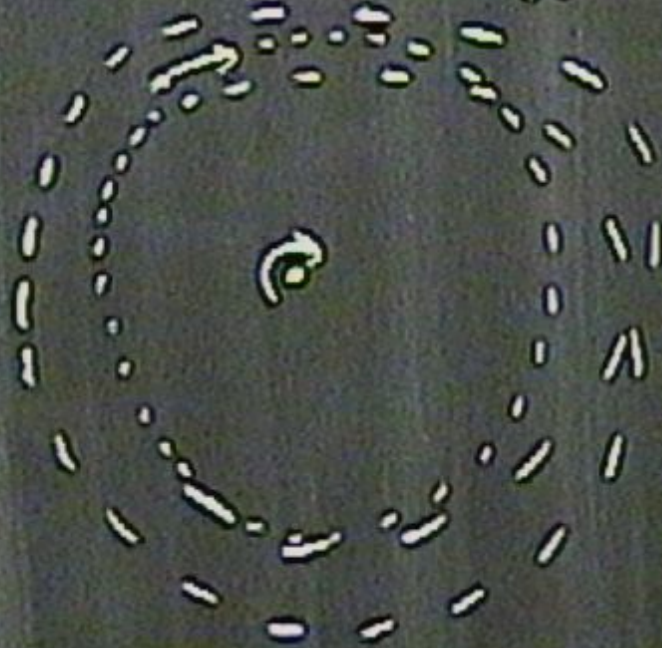
Frame Dragging



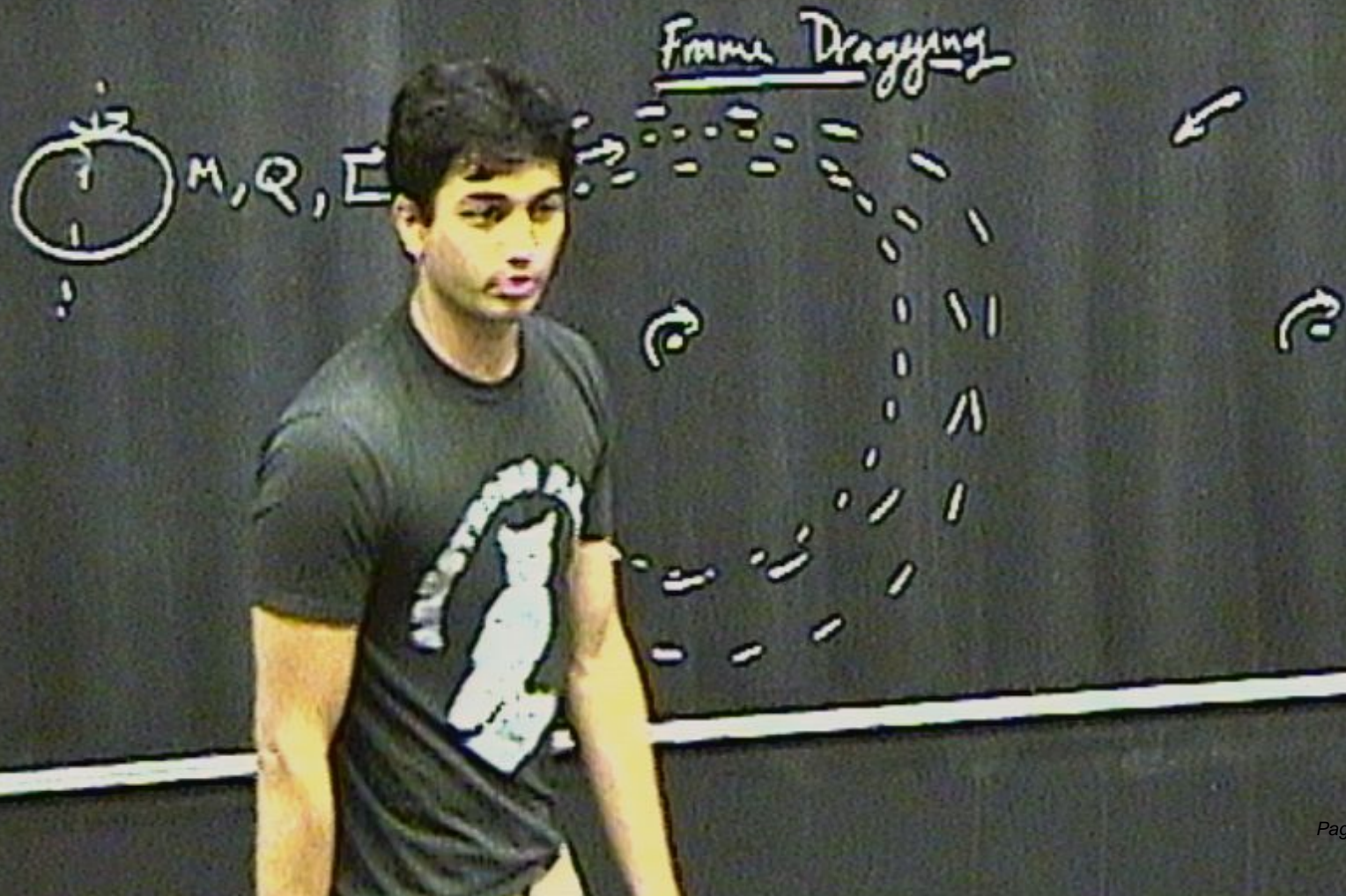
MEMBRANE PARADIGM



Frame Dragging



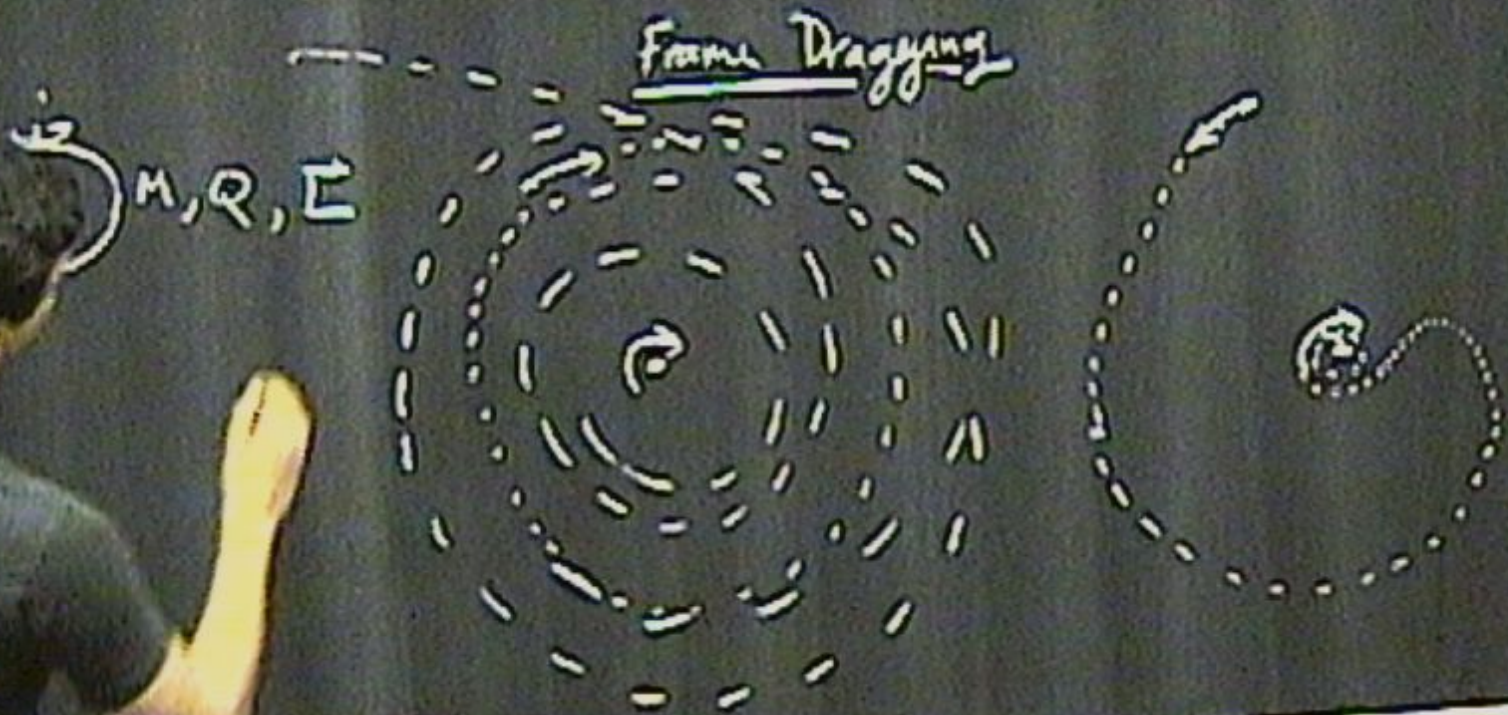
MEMBRANE PARADIGM



MEMBRANE PARADIGM



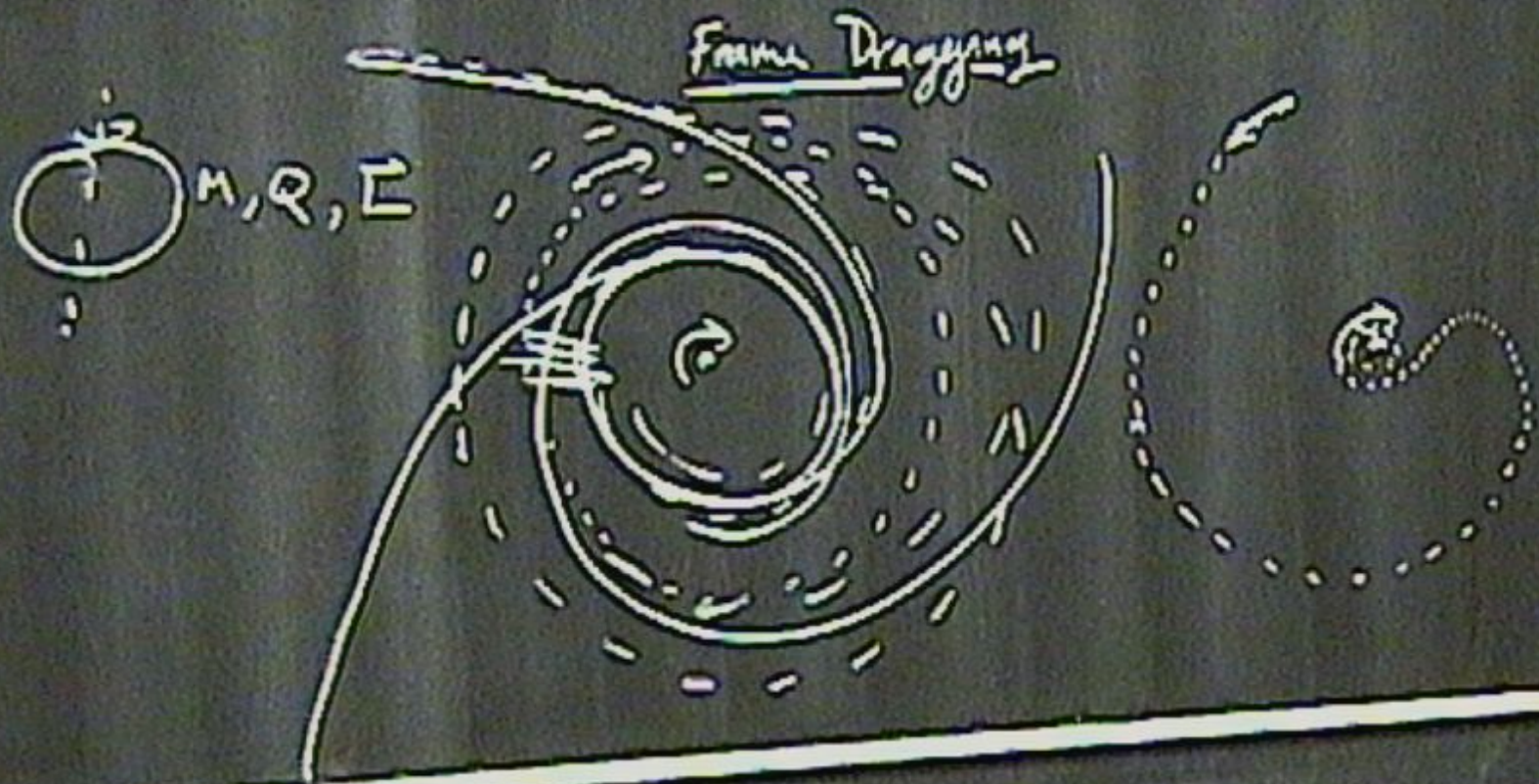
MEMBRANE PARADIGM



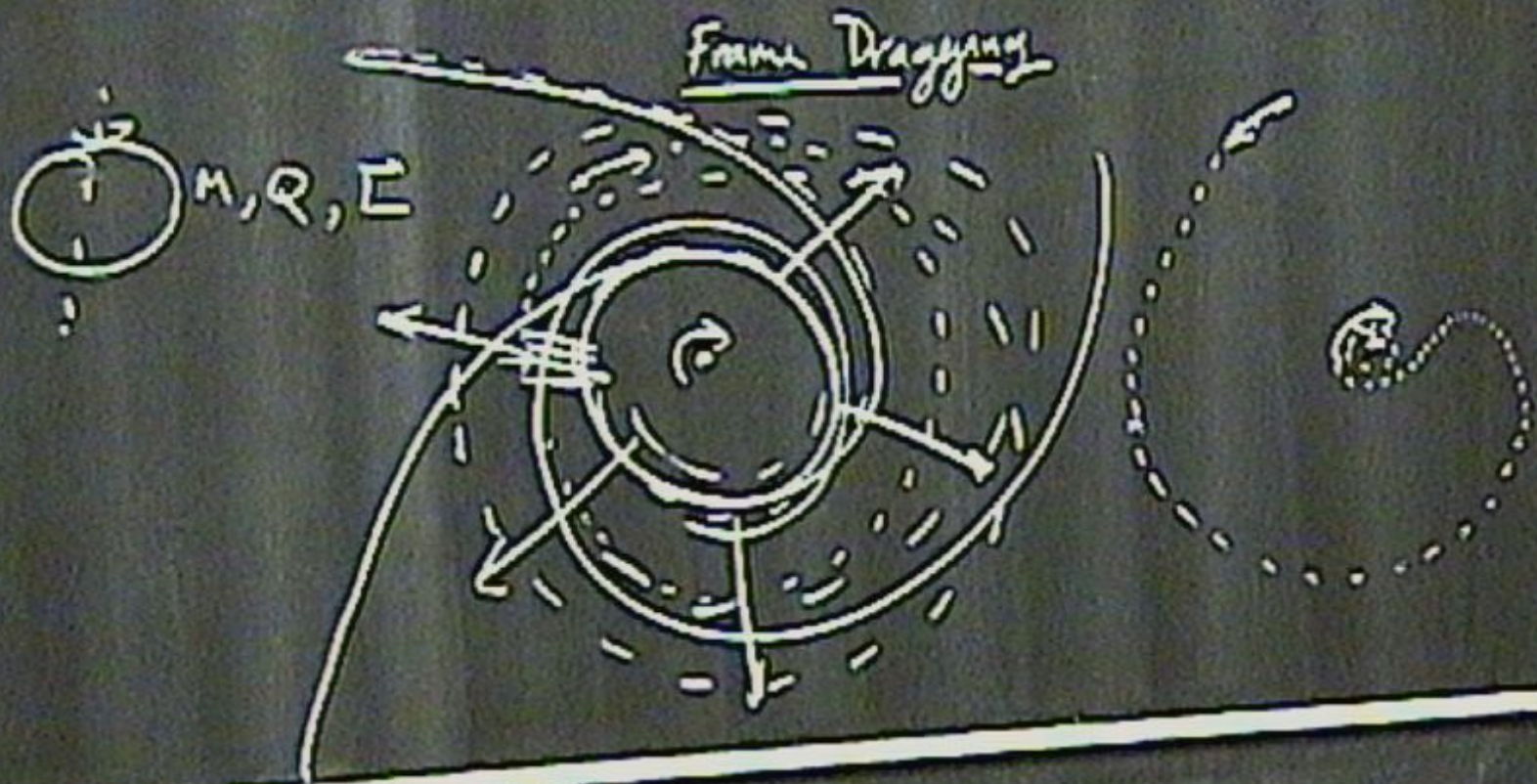
MEMBRANE PARADIGM



MEMBRANE PARADIGM



MEMBRANE PARADIGM

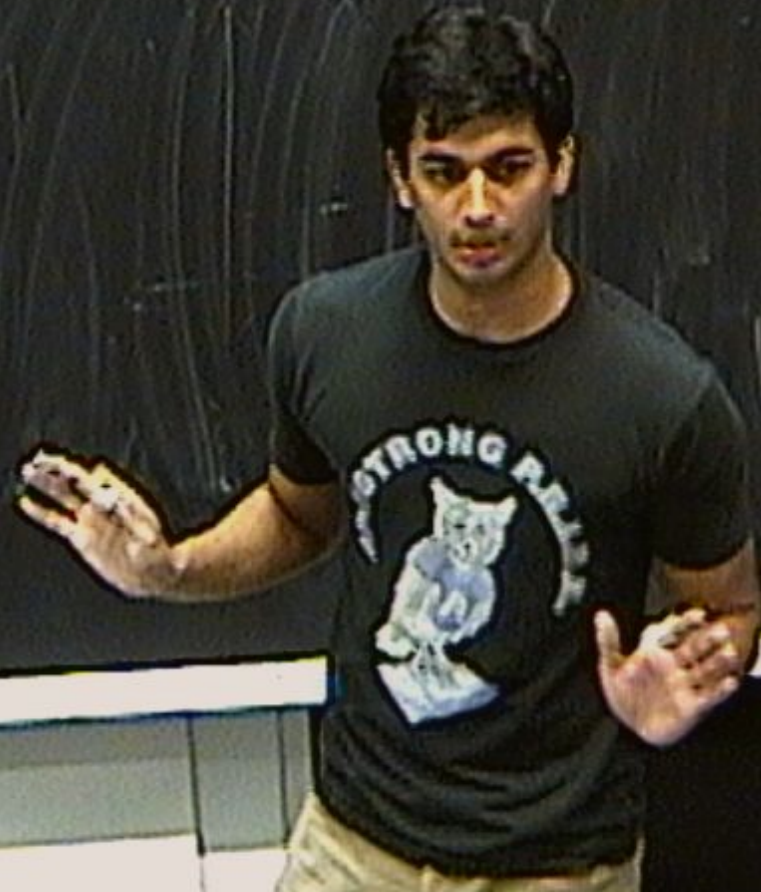


$$T = 2\pi \sqrt{\frac{l}{g}}$$



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$$\frac{l}{m} \quad \downarrow$$



$$T = 2\pi \sqrt{\frac{l}{g}}$$

$$\frac{l}{m} \quad \downarrow \downarrow$$

$$T = 2\pi \sqrt{\frac{l}{g}}$$

$$\frac{l}{g} \quad 2.2$$

$$T = 2\pi \sqrt{\frac{l}{g}} \quad ; \quad T \propto \sqrt{l}$$

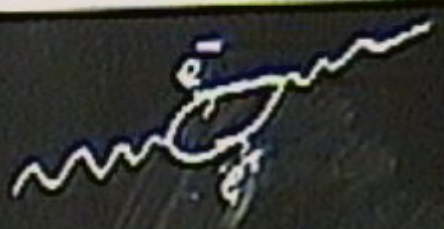
$$\frac{l}{g} \rightarrow$$



$$T = 2\pi \sqrt{\frac{l}{g}} \quad ; \quad T \propto \sqrt{\frac{l}{g}}$$

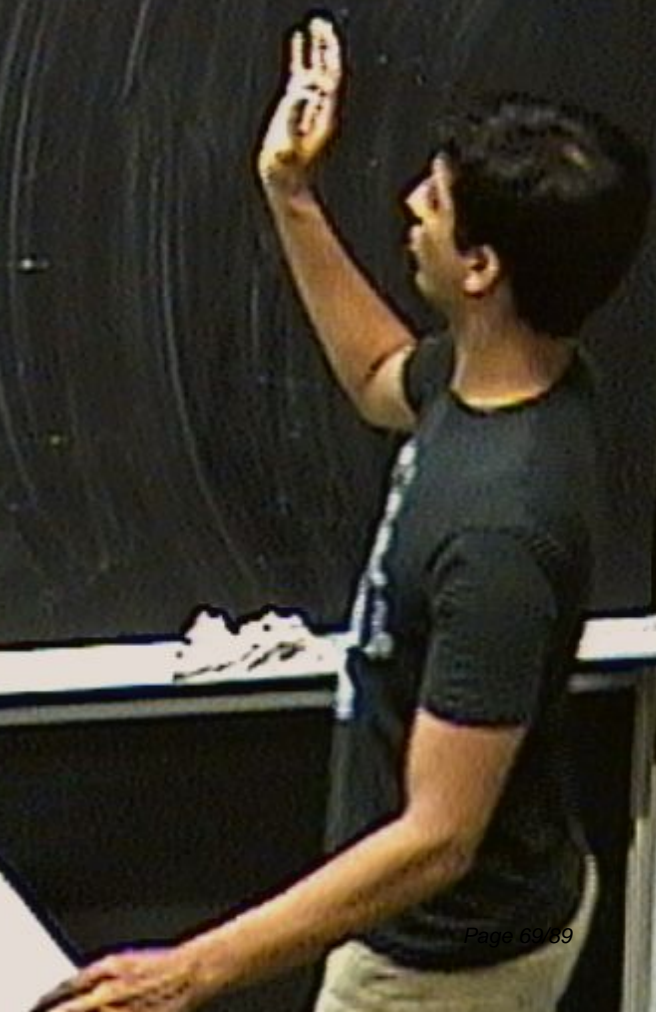
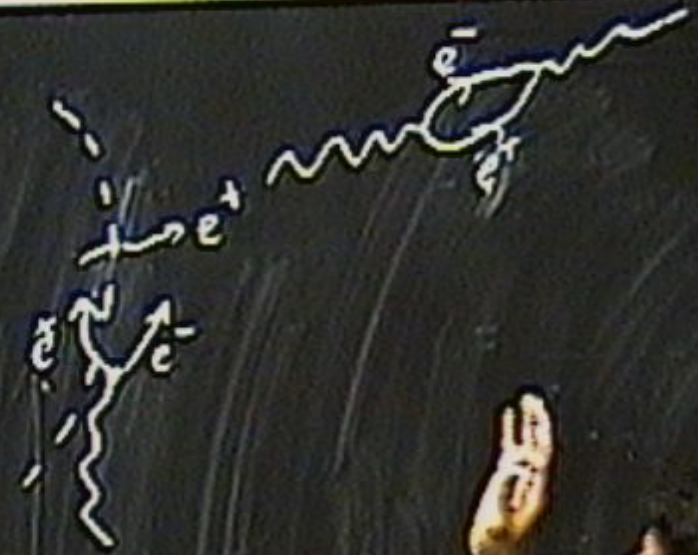
$\frac{l}{g}$ \downarrow
 $\frac{l}{g}$

$$T = 2\pi \sqrt{\frac{l}{g}} \quad ; \quad T \propto \sqrt{\frac{l}{g}}$$



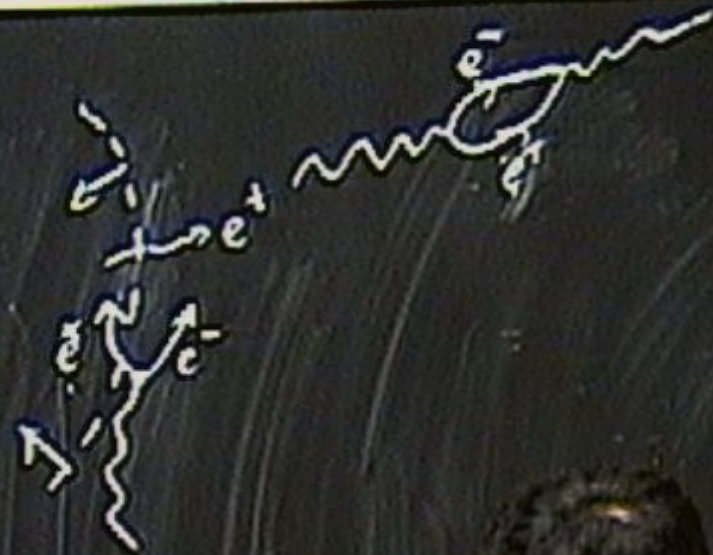
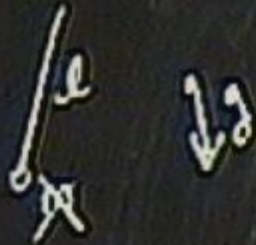
$$T = 2\pi \sqrt{\frac{l}{g}}$$

$$; T \propto \sqrt{\frac{l}{g}}$$



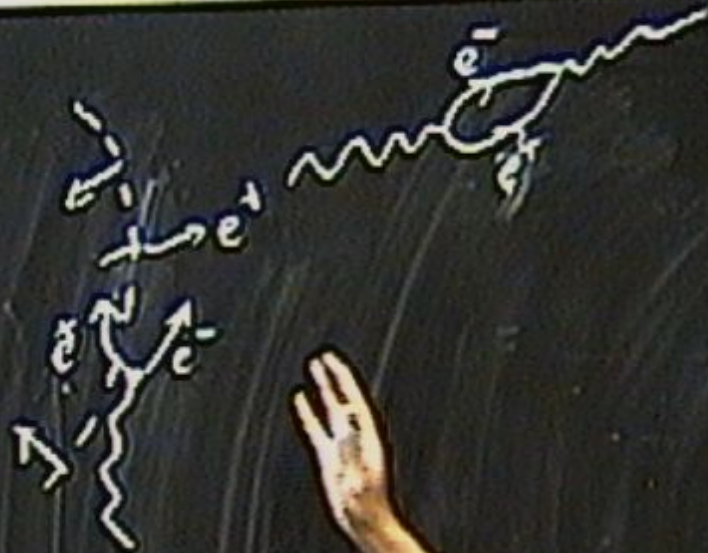
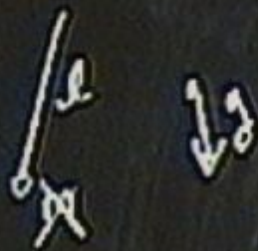
$$T = 2\pi \sqrt{\frac{l}{g}}$$

$$; T \propto \sqrt{\frac{l}{g}}$$



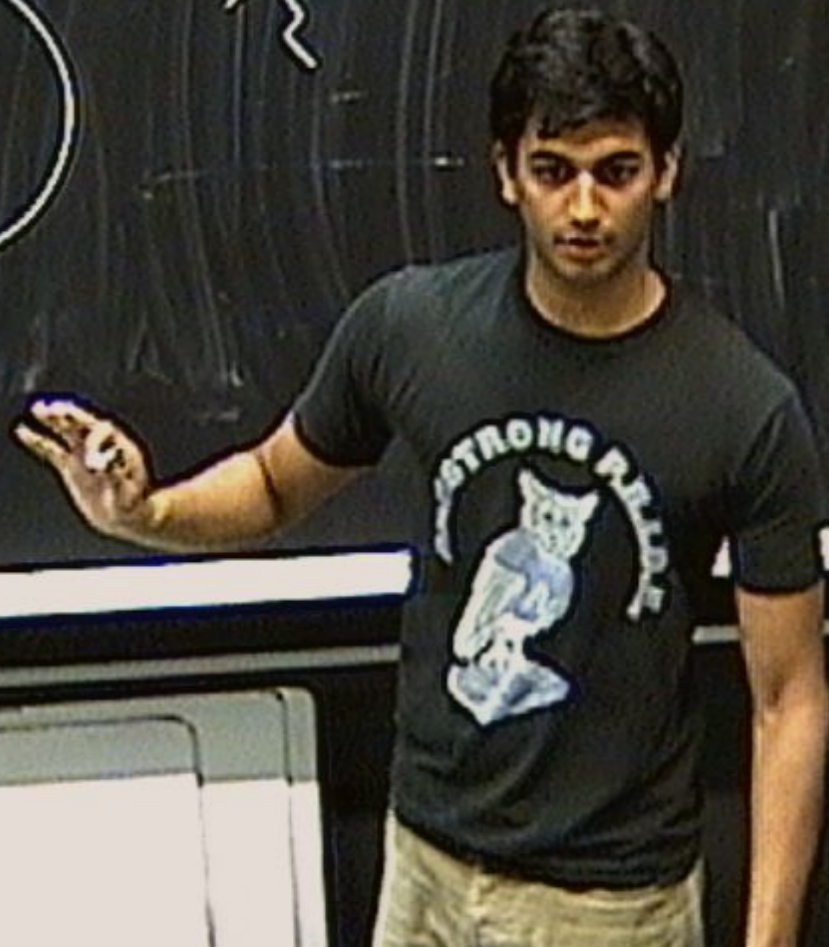
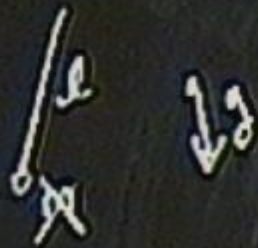
$$T = 2\pi \sqrt{\frac{l}{g}}$$

$$; T \propto \sqrt{\frac{l}{g}}$$



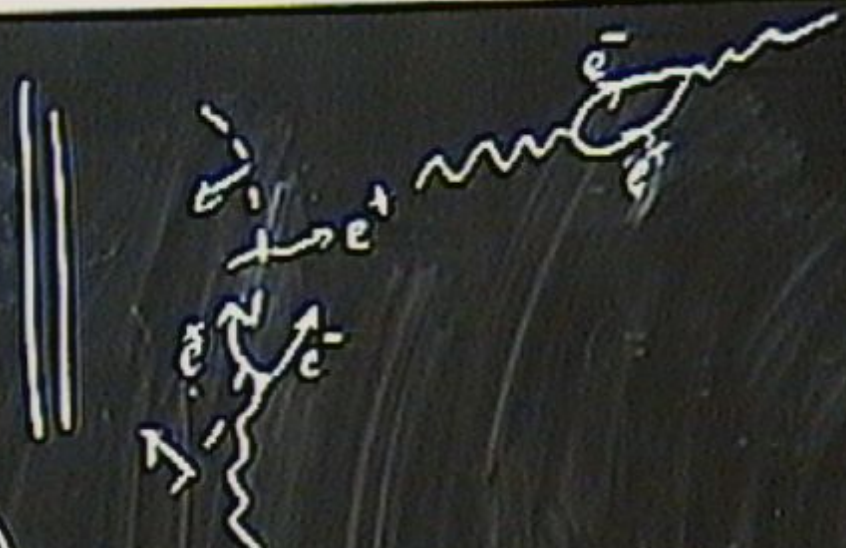
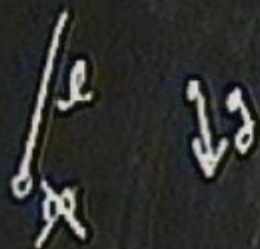
$$T = 2\pi \sqrt{\frac{l}{g}}$$

$$; T \propto \sqrt{\frac{l}{g}}$$



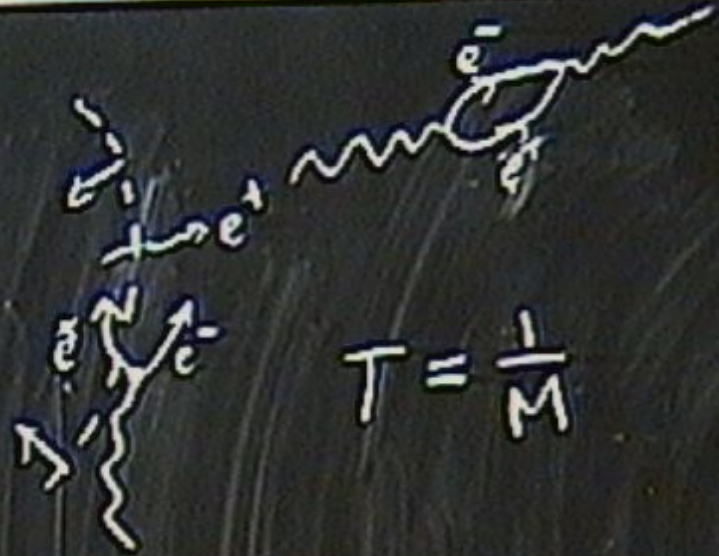
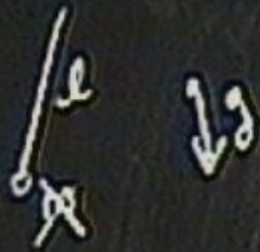
$$T = 2\pi \sqrt{\frac{l}{g}}$$

$$; T \propto \sqrt{\frac{l}{g}}$$



$$T = 2\pi \sqrt{\frac{l}{g}}$$

$$; T \propto \sqrt{\frac{l}{g}}$$

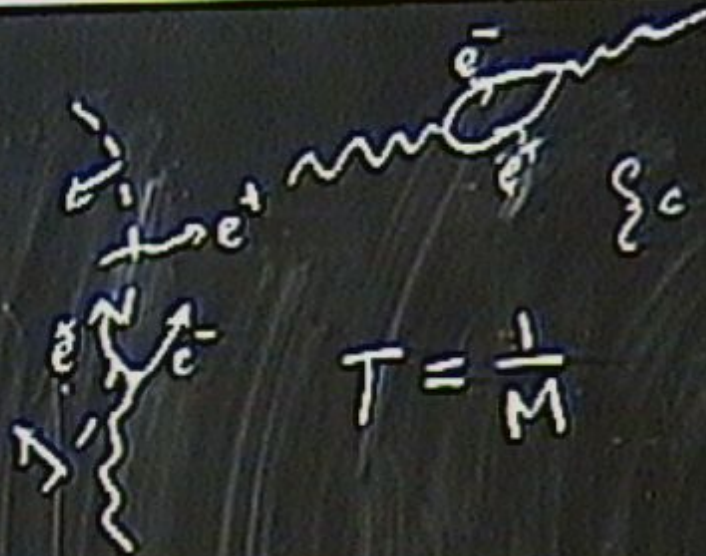
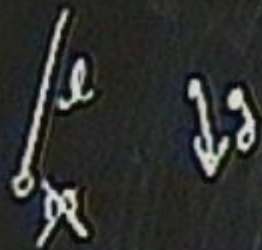


$$T = \frac{1}{M}$$



$$T = 2\pi \sqrt{\frac{l}{g}}$$

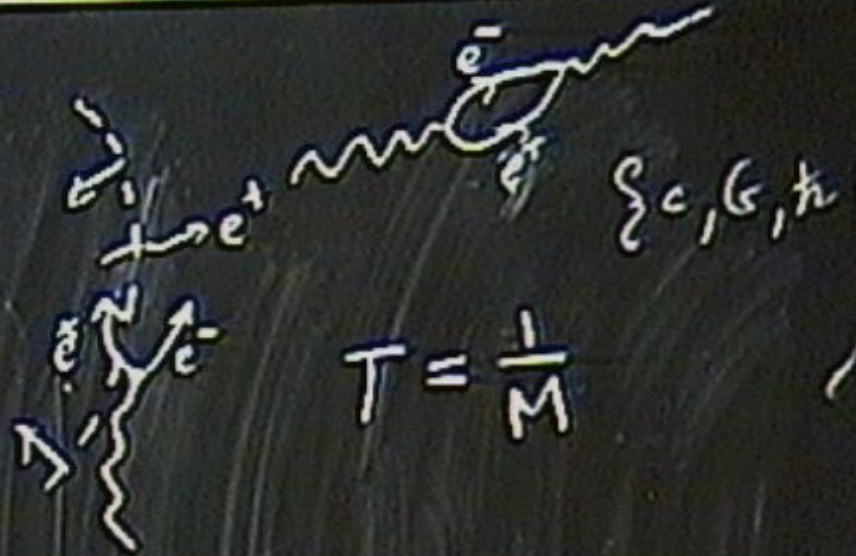
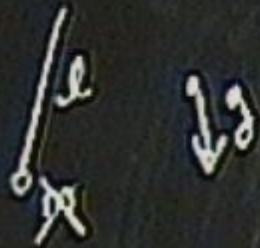
$$; T \propto \sqrt{\frac{l}{g}}$$



$$T = \frac{1}{M}$$

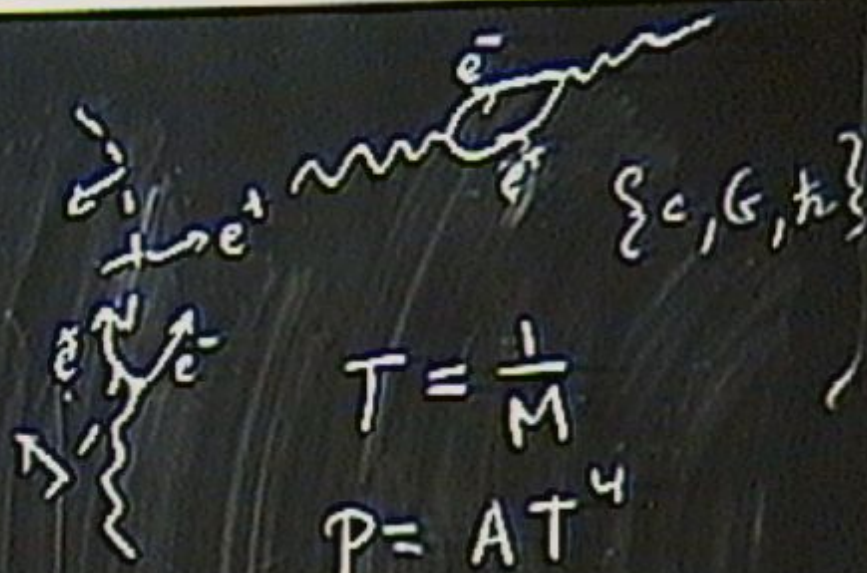
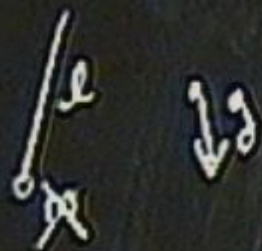
$$T = 2\pi \sqrt{\frac{l}{g}}$$

$$; T \propto \sqrt{\frac{l}{g}}$$



$$T = \frac{1}{M}$$

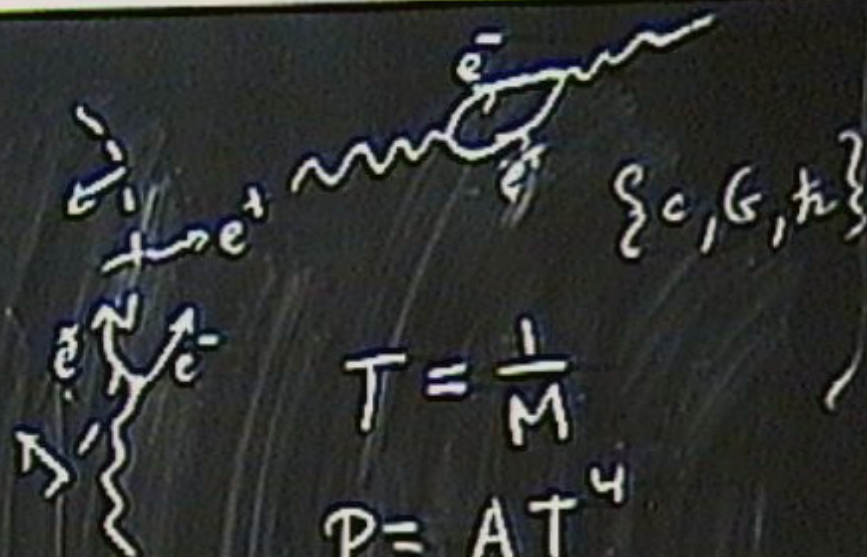
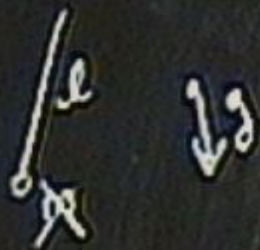
$$T = 2\pi \sqrt{\frac{l}{g}} \quad ; \quad T \propto \sqrt{\frac{l}{g}}$$



$$T = \frac{1}{M}$$

$$P = AT^4$$

$$T = 2\pi \sqrt{\frac{L}{g}} \quad ; \quad T \propto \sqrt{\frac{L}{g}}$$

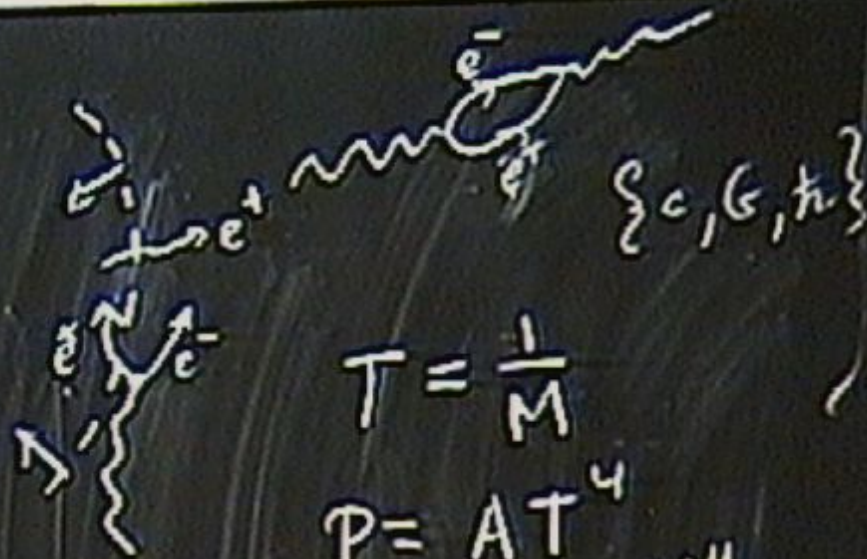
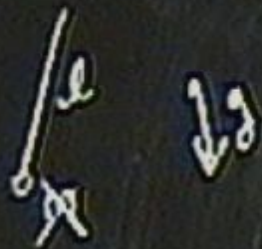


$$T = \frac{1}{M}$$

$$P = AT^4$$

$$= |$$

$$T = 2\pi \sqrt{\frac{l}{g}} \quad ; \quad T \propto \sqrt{\frac{l}{g}}$$



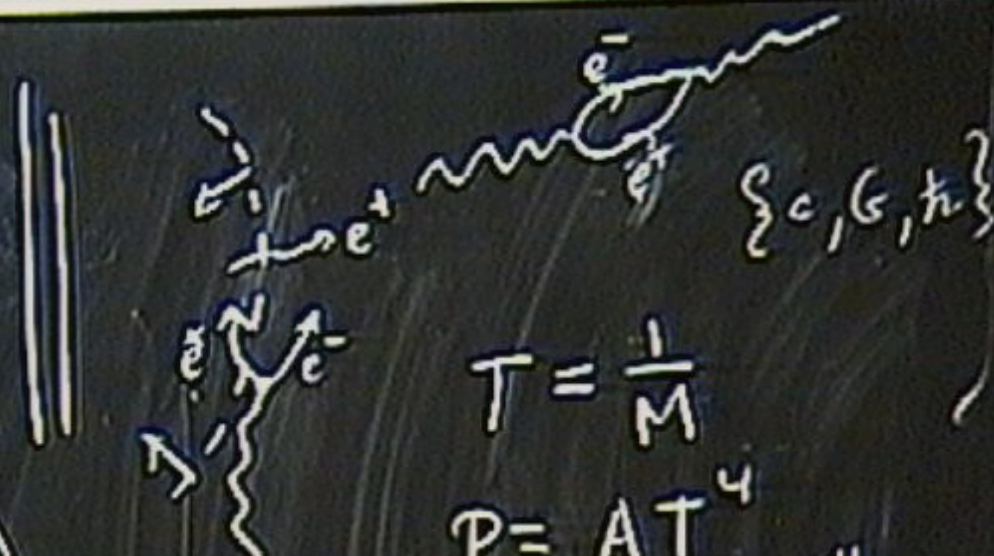
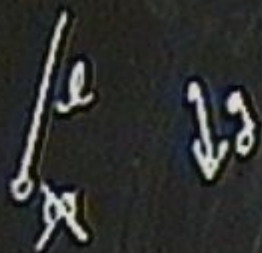
$$T = \frac{1}{M}$$

$$P = AT^4$$

$$= (M^2) \left(\frac{1}{M}\right)^4$$

M

$$T = 2\pi \sqrt{\frac{e}{g}} \quad ; \quad T \propto \sqrt{\frac{e}{g}}$$



$$T = \frac{1}{M}$$

$$P = AT^4$$

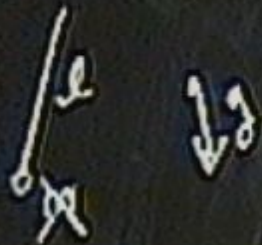
$$= (M^2) \left(\frac{1}{M}\right)^4$$

$$\frac{dM}{dt} = -\frac{1}{M^2}$$

{c, G, h}

$$T = 2\pi \sqrt{\frac{l}{g}}$$

$$; T \propto \sqrt{\frac{l}{g}}$$



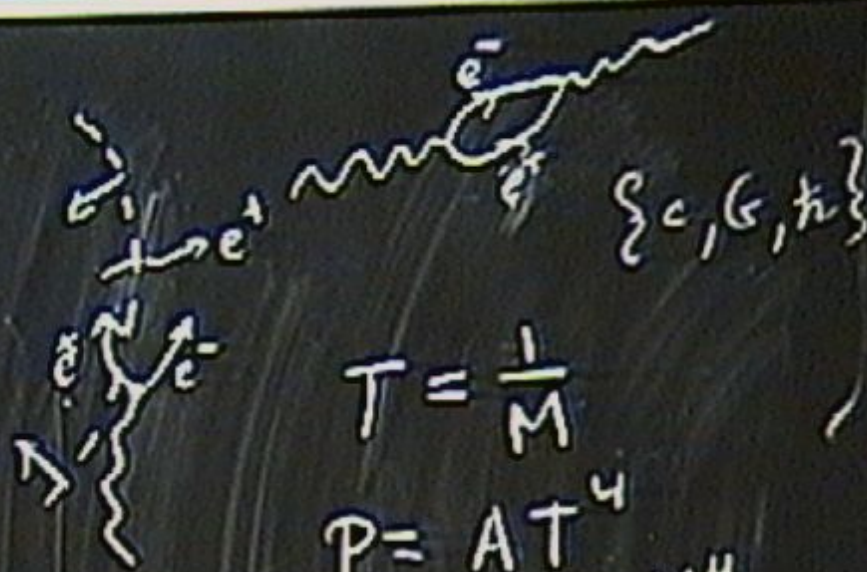
$$M(t) = M_0 + \frac{dM}{dt}$$

$$\frac{dM}{dt} = -\frac{1}{M^2}; \checkmark$$

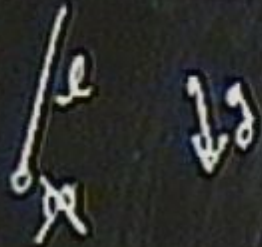
$$T = \frac{1}{M}$$

$$P = AT^4$$

$$= (M^2) \left(\frac{1}{M}\right)^4$$

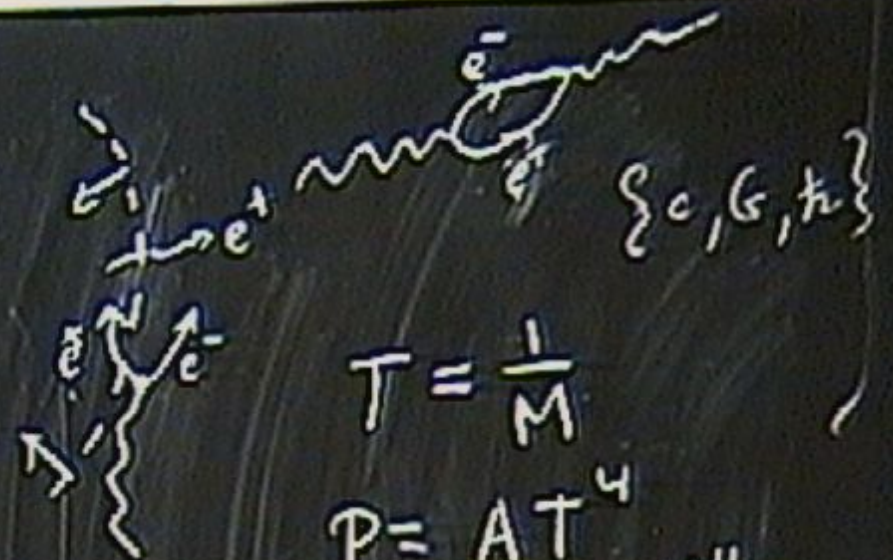


$$T = 2\pi \sqrt{\frac{L}{g}} \quad ; \quad T \propto \sqrt{\frac{L}{g}}$$



$$M(t) = M_0 + \frac{dM}{dt} \quad \frac{dM}{dt} = -\frac{1}{M^2} ;$$

$$\text{Life}(M) \propto M^3$$

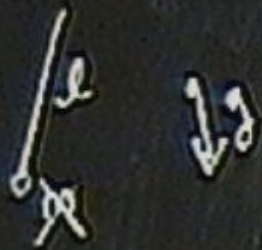


$$T = \frac{1}{M}$$

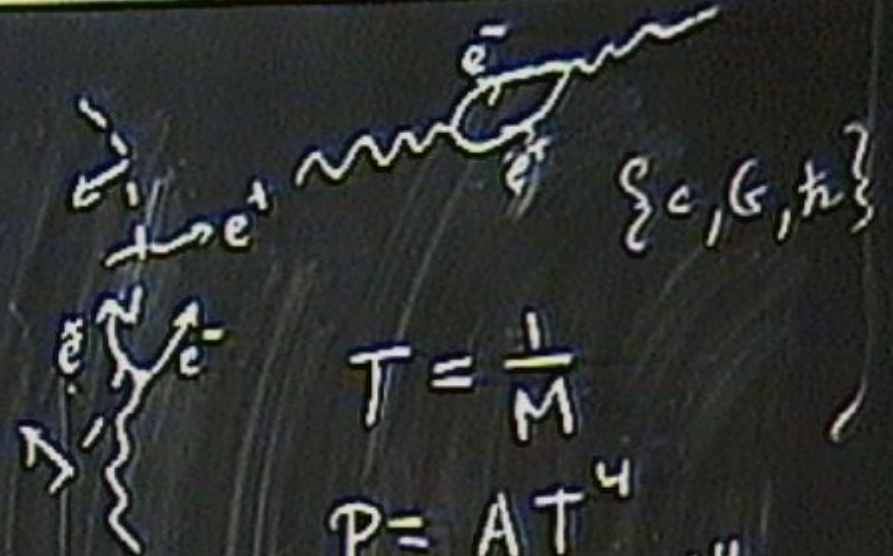
$$P = AT^4$$

$$= (M^2) \left(\frac{1}{M}\right)^4$$

$$T = 2\pi \sqrt{\frac{e}{g}} \quad ; \quad T \propto \sqrt{\frac{e}{g}}$$



	M	T	L
Sun:			
Moon:			



$$T = \frac{1}{M}$$

$$P = AT^4$$

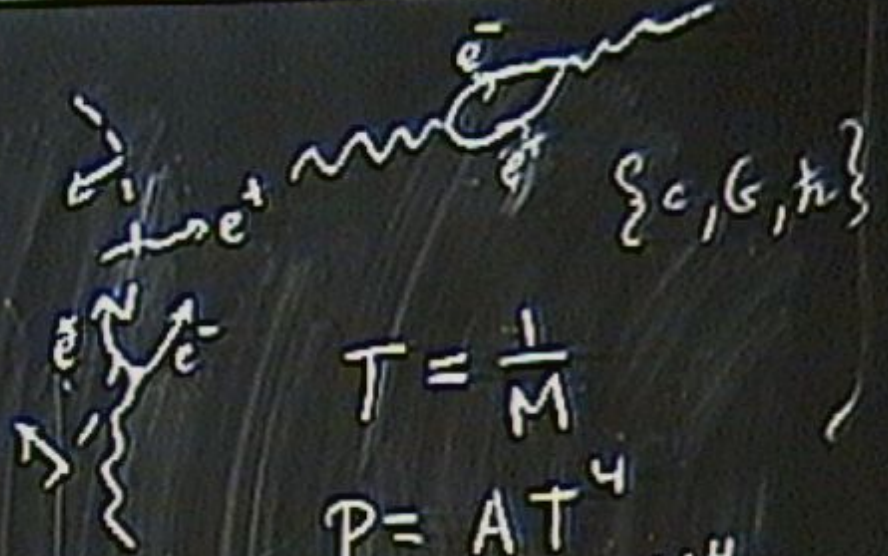
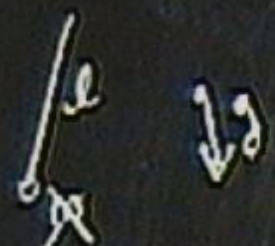
$$= (M^2) \left(\frac{1}{M}\right)^4$$

$$M(t) = M_0 + \frac{dM}{dt}$$

$$\frac{dM}{dt} = -\frac{1}{M^2} ; \checkmark$$

$Life(M) \propto M^3$

$$T = 2\pi \sqrt{\frac{e}{g}} \quad ; \quad T \propto \sqrt{\frac{e}{g}}$$



$$T = \frac{1}{M}$$

$$P = AT^4$$

$$= (M^2) \left(\frac{1}{M}\right)^4$$

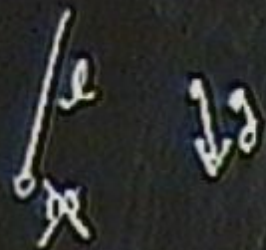
	M (kg)	T	L
Sun:	2×10^{30}		
Moon:			

$$M(t) = M_0 + \frac{dM}{dt}$$

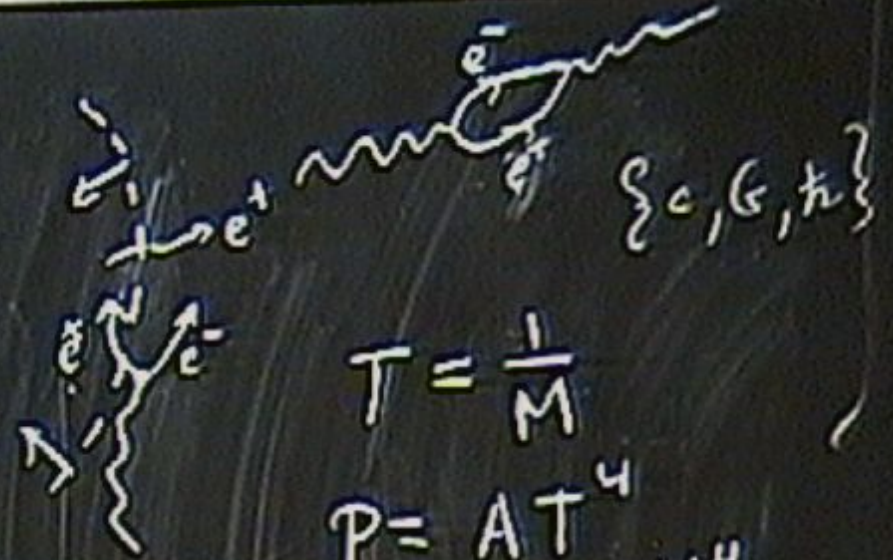
$$\frac{dM}{dt} = -\frac{1}{M^2}$$

$$\boxed{\text{Life}(M) \propto M^3}$$

$$T = 2\pi \sqrt{\frac{L}{g}} \quad ; \quad T \propto \sqrt{\frac{L}{g}}$$



	$M(kg)$	$T(s)$
Sun:	2×10^{30}	60×10^3
Moon:		



$$T = \frac{1}{M}$$

$$P = AT^4$$

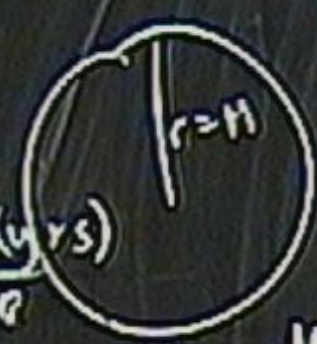
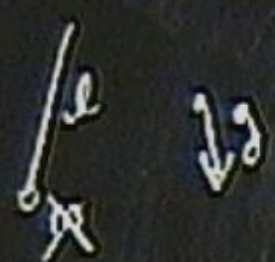
$$= (M^2) \left(\frac{1}{M}\right)^4$$

$$M(t) = M_0 + \frac{dM}{dt}$$

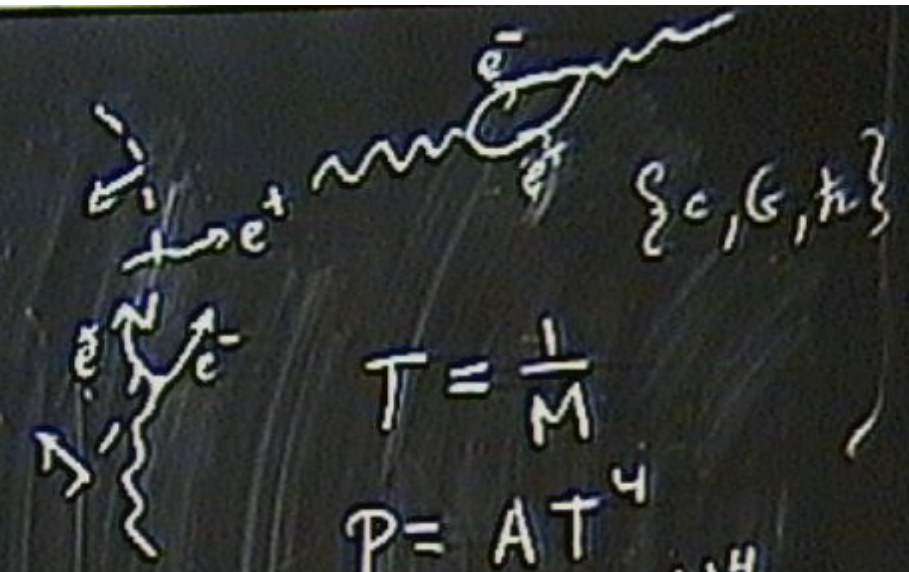
$$\frac{dM}{dt} = -\frac{1}{M^2}$$

$$\boxed{\text{Life}(M) \propto M^3}$$

$$T = 2\pi \sqrt{\frac{e}{g}} \quad ; \quad T \propto \sqrt{\frac{e}{g}}$$



	$M(kg)$	$T(r)$	$L(yrs)$
Sun:	2×10^{30}	60×10^9	10^{10}
Moon:			



$$T = \frac{1}{M}$$

$$P = AT^4$$

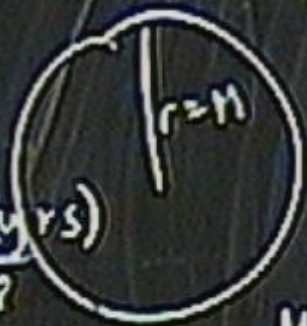
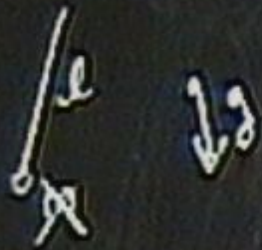
$$= (M^2) \left(\frac{1}{M}\right)^4$$

$$M(t) = M_0 + \frac{dM}{dt}$$

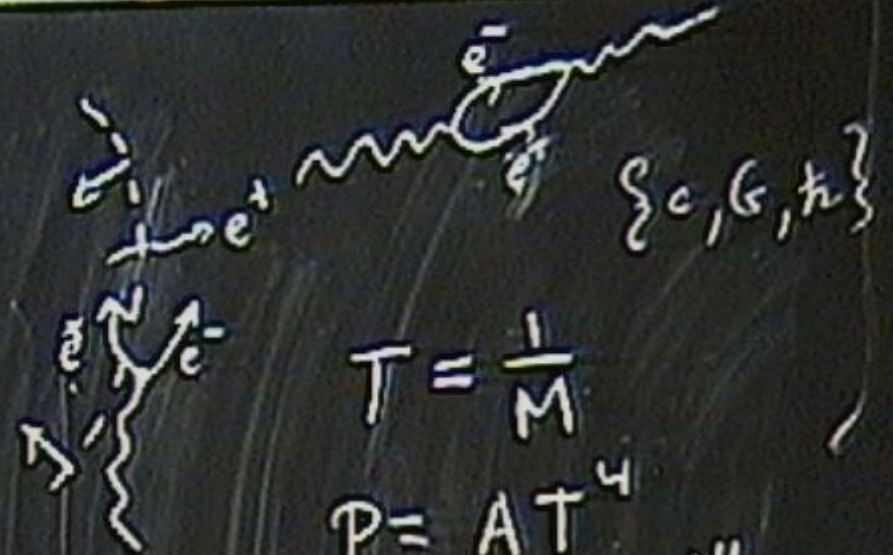
$$\frac{dM}{dt} = -\frac{1}{M^2} ;$$

$Life(M) \propto M^3$

$$T = 2\pi \sqrt{\frac{r}{g}} \quad ; \quad T \propto \sqrt{\frac{r}{g}}$$



	M(kg)	T(r)	L(yrs)
Sun:	2×10^{30}	60×10^9	10^{10}
Moon:	4×10^{22}		



$$T = \frac{1}{M}$$

$$P = AT^4$$

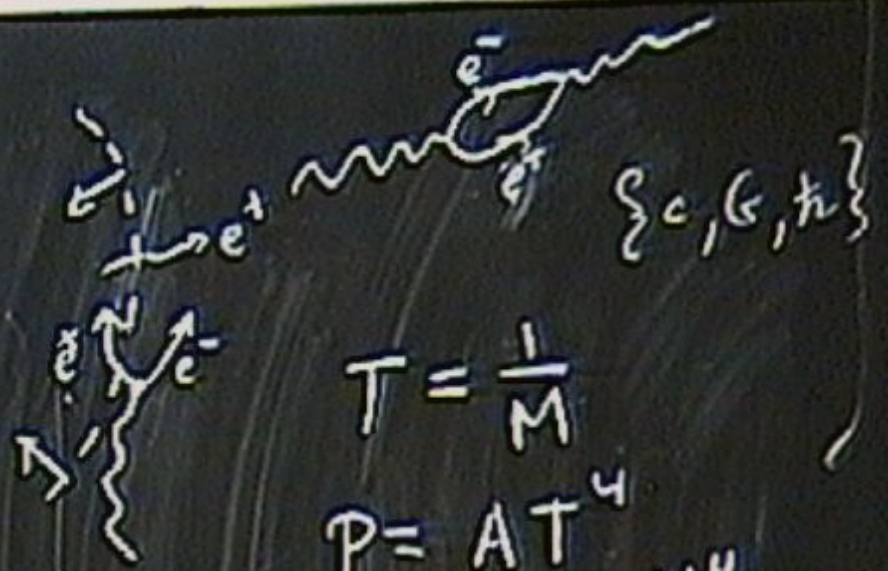
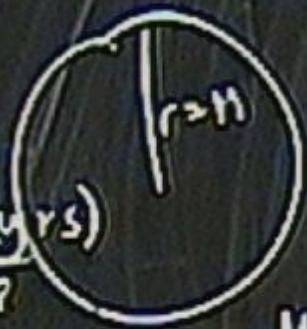
$$= (M^2) \left(\frac{1}{M}\right)^4$$

$$M(t) = M_0 + \frac{dM}{dt}$$

$$\frac{dM}{dt} = -\frac{1}{M^2} ;$$

$Life(M) \propto M^3$

$$T = 2\pi \sqrt{\frac{R}{g}} \quad ; \quad T \propto \sqrt{\frac{R}{g}}$$



$$T = \frac{1}{M}$$

$$P = AT^4 = (M^2) \left(\frac{1}{M}\right)^4$$

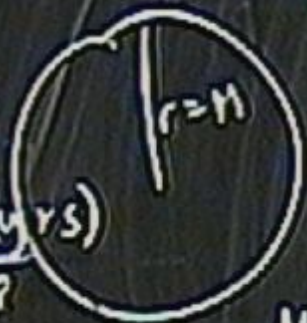
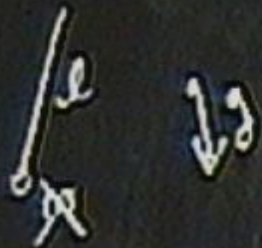
	M (kg)	T (K)	L (yrs)
Sun:	2×10^{30}	60×10^3	10^{10}
Moon:	4×10^{22}	2.7	

$$M(t) = M_0 + \frac{dM}{dt}$$

$$\frac{dM}{dt} = -\frac{1}{M^2}$$

$$\boxed{\text{Life}(M) \propto M^3}$$

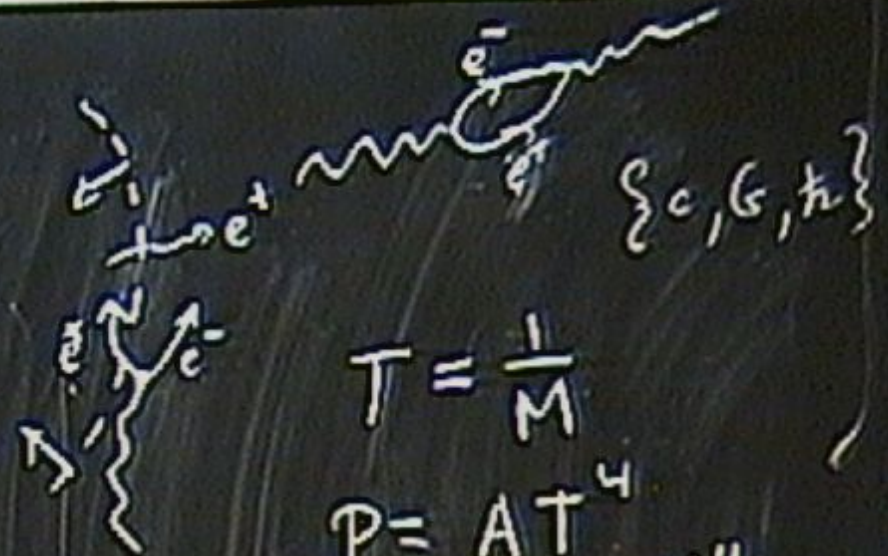
$$T = 2\pi \sqrt{\frac{e}{g}} \quad ; \quad T \propto \sqrt{\frac{e}{g}}$$



	$M(M_\odot)$	$T(r)$	$L(\text{yrs})$
Sun:	2×10^{30}	60×10^6	10^{10}
Moon:	4×10^{22}	2.7	3×10^7

$$M(t) = M_0 + \frac{dM}{dt} \quad \frac{dM}{dt} = -\frac{1}{M^2} ;$$

$$\boxed{\text{Life}(M) \propto M^3}$$



$$T = \frac{1}{M}$$

$$P = AT^4 = (M^{-2}) \left(\frac{1}{M}\right)^4$$