P208 LEC 5:

Flos not 25

HW2 is up-sorry for abloy

THIS LEC: WEINBERS, CHEME, CAPPOLL

1. NEWTON

(BALLWAY BERTILS),

2. TIME DILATION

3. GEODESICS

Now do we fell)

4. PARQUEL TRANSPORT

next time: whather

what is arm?

9x/9f (5) · LOW VELOCITY

> " write this as dx & dt

STATIONARY FIELD / STATIC

time derivative

WEAK FIEW UMIT: SW = NW + hrv (x)

components & 1

FREE FALL OF TEST MASS IN DICE frame gove ear, of motion in any other frame  $\frac{q_{\zeta_{x}}}{q_{s}} + L_{\mu} \frac{g_{\zeta_{y}}}{g_{x_{b}}} \frac{g_{\zeta_{y}}}{g_{x_{b}}} = 0$ ed 8404, out of grav field. AFFINE CONNECTION  $= \frac{92}{95} + \frac{92}{4} + \frac{92}{4} = \frac{92}{3}$ + 2 T Di (3E) (3E) ? SUBDOM BY UMIT.  $+ \frac{1!}{h} \left( \frac{3c}{3x_i} \right) \left( \frac{3c}{3x_j} \right)$ The = = = 29th (2090v + 20900 - 20900) 7.9. =0 by static field 1 Los = 0; only non-sero for Los

TO LEADING ORDER IN WEAK FIELD LIMIT

$$\frac{1}{20} \frac{3^2 E}{372} = 0 \Rightarrow \frac{3t}{372} = const.$$

$$\frac{\partial^{2} x^{i}}{\partial \tau^{2}} + \frac{1}{2} \eta^{ij} \partial_{j} h_{oo}(x) \int_{\partial \tau}^{2t} \frac{\partial t}{\partial \tau} = 0$$

$$+ \frac{1}{2} \nabla_{i} h_{od}(x)$$

$$\frac{\partial}{\partial \tau} \frac{\partial x^{i}}{\partial \tau} = \frac{\partial}{\partial \tau} \left( \frac{\partial t}{\partial \tau} \frac{\partial x^{i}}{\partial \tau} \right)$$

JEYS DEVX6 ZEV & ESAV DEMANDE

$$\frac{3^2 \times i}{37^2} = \frac{3t}{37} = \frac{3}{37} =$$

CANCEL 
$$(3t/3t)^2$$

$$\frac{3^2 \times}{3t^2} = \frac{1}{2} \nabla h_{00} \qquad -\nabla \Phi$$

C shifts in \$ not phys

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Tax, wtangs in der growe

then: (ST) = gtw dxt dx

velocity of about

80: time paroun ticks to Xx frame is

DT DT = JON dx 7 dt dx Ydt

NOW SPECIALIZE TO THE CASE OF A

CLOCK @ REST IN X FRAME: dxi/dt = 0

dt =  $\sqrt{g_{00}}$  =  $\sqrt{1+24}$ newtonion limit

of ourse: could have simply derived this from (DT) = 9m dx dx

EXPERIMENT: Your wearning gence is also affected;  [ MEBBUTE Clock @ D & S
Better! TRANSITIONS HERE
Phobos propagate
DO ATOMIC TRANSITION  EXPERIMENT HERE -> fixed freg.  of light  emitted
crests are troks
TIME TO PROPABATE FROM @ > D
WE CALCULATED THIS IN LEE 8:  USED: $d8^2 = 0 = 9m dx^2 dx^2 38000000000000000000000000000000000000$
GoT: dt = gio [- giodxi + (giogio - giigo)dxidxi]
integrate this over trajectory (GTRAGHT UND) to get time to traverse
BUT: ldt is wer some consider pop EAQH CREST
-> time separation between crests unchanged

@ FLOOR: dt2 = BT/Ngoocke)
@ top: dt1 = BT/Ngoocke)

COMPARE OBS FREA!



[ 900 ≈ 1+2\$

$$\frac{NU}{V} = \frac{V_2 - V_1}{\frac{1}{2}(V_2 + V_1)} \approx \sqrt{\frac{2(\varphi_2 - \varphi_1)}{1 + \varphi_1 + \varphi_2}} \approx \sqrt{\frac{\varphi_2 - \varphi_1}{1 + \varphi_1 + \varphi_2}}$$

Grav. REDSHIFT

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	VEIMA	1 <i>50</i> 00	Janeita	600	ygss

tion from	Geodesics versus 7 "PATH-OF USHT"					
	1 Whu?					
* ALL PERSON PROCESSOR PERSON PROCESSOR AND	WRUES OF EXTREMAL LEMBER					
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a 'n 7 A Girl de aan 1800 aan de aan 1800 an 1	measure distances  SPACETIME ARCHENECH:					
	8. Jds: J((dx))2 dx					
	FOR SOME TRAJECTORY PARAMETER, >					
و المعارض المع	COULD USE, SAY, PROPER TIME, X=T					
	(dack of someone draversing that path)					
	dx" dx"					
د د د د د د د د د د د د د د د د د د د	JNJM dx dx dx					
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er in 1919 en mensen in 1914 en 1914 en 1914 en 1915 en	1					
	$\dot{x} = \frac{4}{4}$					
us To substitute de Miller de Miller au Stefan Sprage papar par de marco de proposación de propo						

Segue to EINStein EQ. LAPER

HOW TO FIND MEXTREMAL ARCHENGTH? VARIATIONAL PRINCIPLE

EULER-LAGRANGE EAN (recall Mechanics!)

C RECORN: 
$$SL = \frac{\partial L}{\partial x} 8x + \frac{\partial L}{\partial x} 8x$$

Miteg by parts

$$= \frac{\partial L}{\partial x} 8x$$

$$= \frac{\partial L}{\partial x} 8x$$

then EVIEL-LAGE:

$$\frac{d}{d\lambda} \frac{\partial \hat{L}}{\partial \dot{x}^r} - \frac{\partial \hat{L}}{\partial x^r} = \frac{d}{d\lambda} \left( 2L \frac{\partial L}{\partial \dot{x}^r} \right) - 2L \frac{\partial L}{\partial x^r}$$

Nan suppose $\lambda$ chosen $s.4$ .
ds _ 1's constant
i.e. (dL/dx =0) - then
$2L \left[ \frac{\partial \lambda}{\partial t} \frac{\partial \dot{x}}{\partial x} - \frac{\partial \dot{x}}{\partial \dot{x}} \right] = 0$
ORIG. E-L
(ED): GEODESICS OF L = GEODESICS OF L
(extrema of squared archerath also
extremize orderath) orden.
orden. $ \sqrt{\frac{1}{2}} = \frac{1}{2} $ $ \sqrt{\frac{1}{2}} = \frac{1}{2} $
me are moving a speed of light
T is an example of an "APPINE PARAMOTOR"
for now: "nice" way to parameterize a trajectory.

My out star.

to tred (32m/3xe)

and a summary of military of fighting it grant against a section and a security of laurence and	MASSABING DEAMS: MULT BY 2 2 2 2
	$\frac{d\ddot{x}}{dx} + \frac{1}{2} \frac{3h}{3h} \left[ \frac{38h}{38h} + \frac{38h}{38h} \right] \frac{38h}{38h} = 0$
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	WE HAVE REDISCOVERED OUR "FREE FAIL" BRUATION
	FREE FALLING INTERTIAL FRAMES FALL ALONG OBJECT GEODESICS.
	OUR "FREE FOR EA" IS GRUED THE GEODESIC DON.
	Now: given give to get trajectories
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049ML 3.3 PARALLEL TRANSPORT

geodesics give us special

tajectories. Now vers male sture

ALONG THOSE TRANSFERDRIES

Vectors.

PECKL: UF y -> any home X(y),

W/ gm (x) = = y/2x = y/2x 7

, deoqesicz

Dr covariant derivatives

"nice" derivatives -> (4w)

act nicely on objects wil indices

COVER A PATH XM(X), CAN DEFINE DIRECTIONAL COVARIANT DERIVATIVE

 $\frac{dx}{p} = \frac{dx}{dx} \Delta^{k}$ 

	THEN PARAUEL TRANSPORT OF A
	VECTOR IS DEFINED BY
more processes at the work of a little work of the contract of	
	dx + Lab gx Ab = 0
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	IN PARTICULAR: CONSIDER THE TANGENT VECTOR
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anne de la company de la c	PARALLEL TRANSPORT OF TANGENT UTCER:
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	Nb. PAROMETERIZATION MATTERS
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