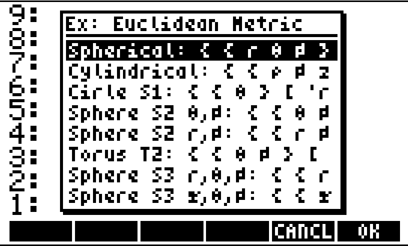
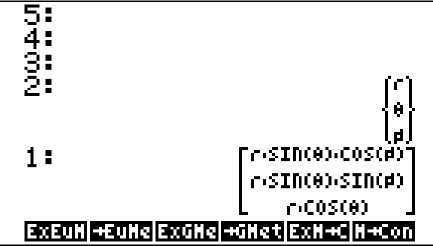
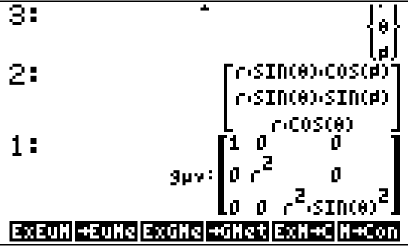
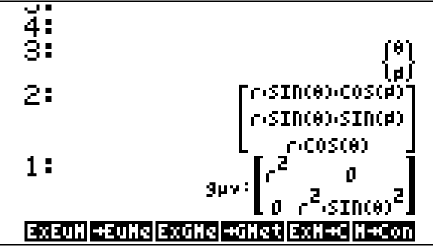
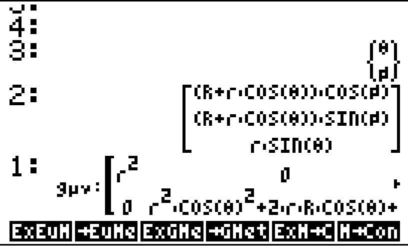
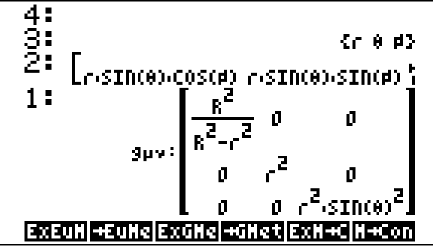
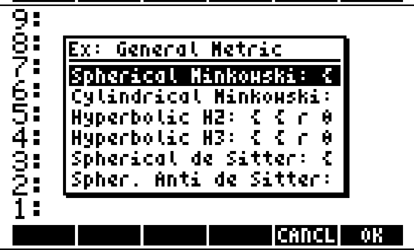
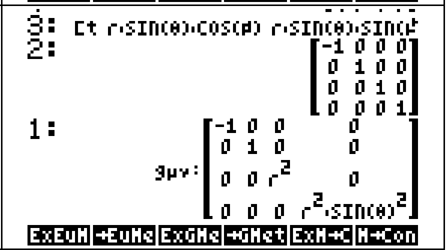
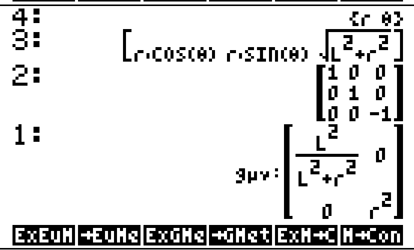
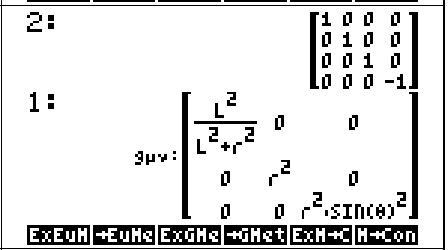
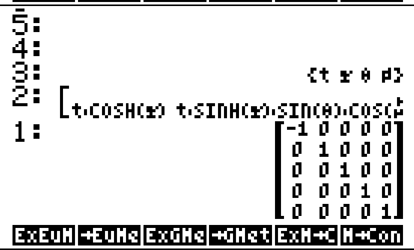
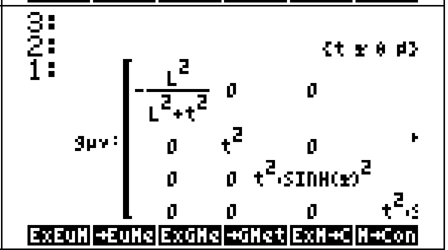
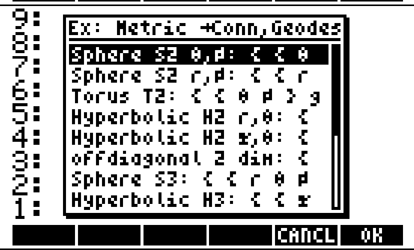
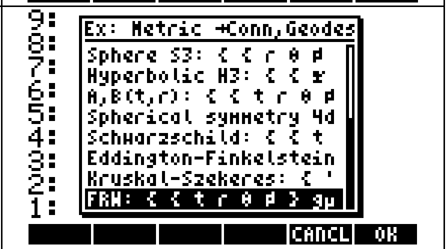
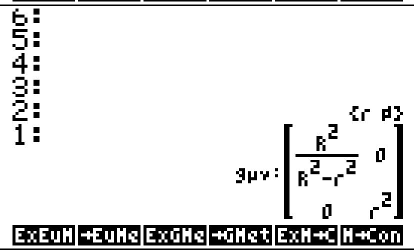
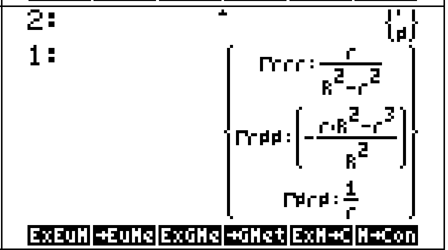
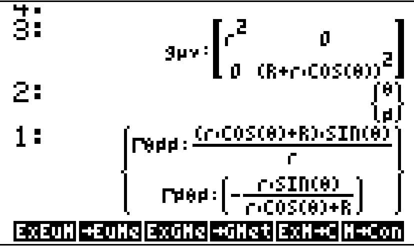
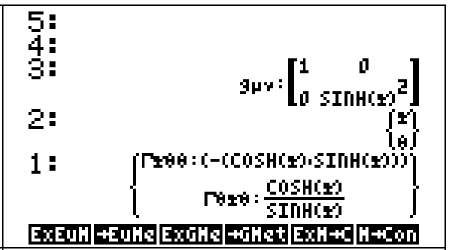
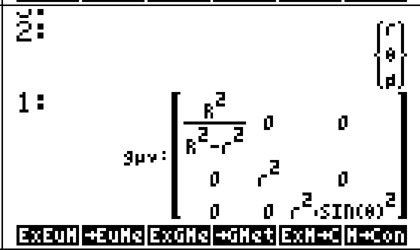
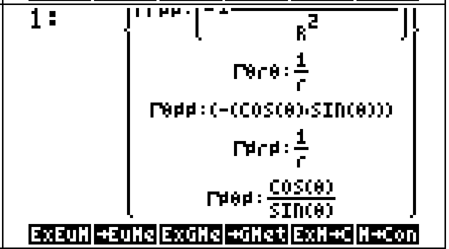
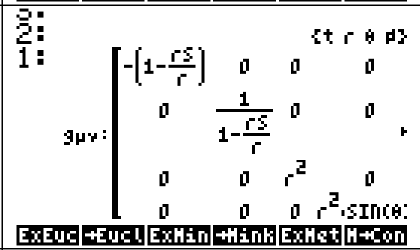
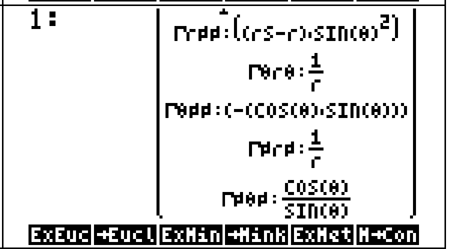
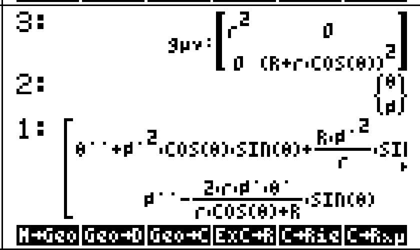
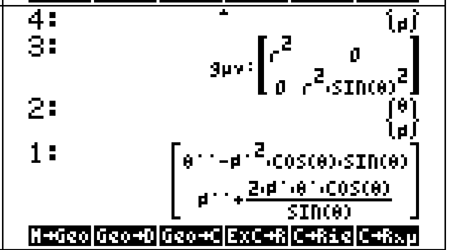
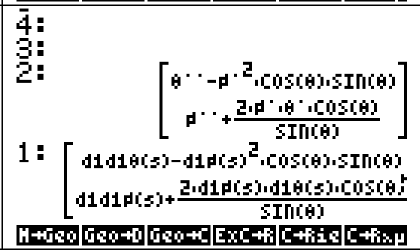
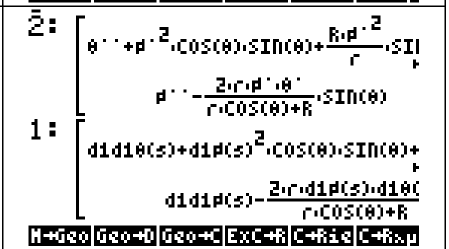
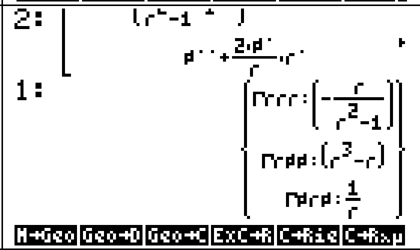
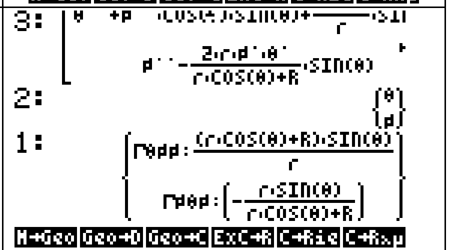
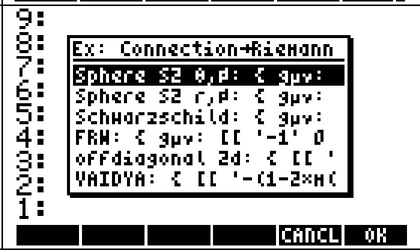
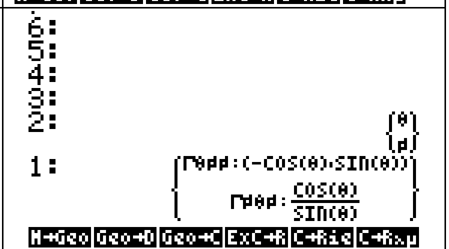
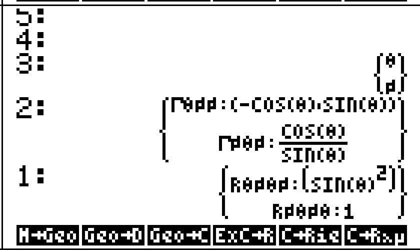
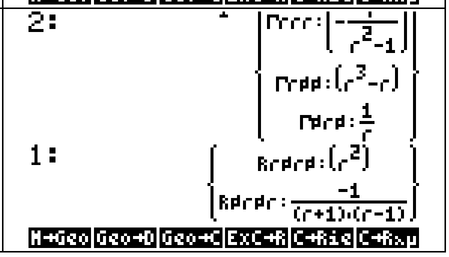
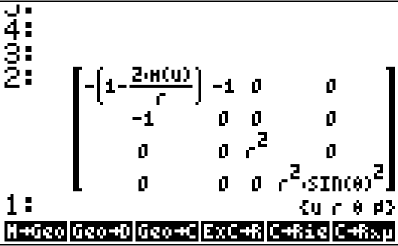
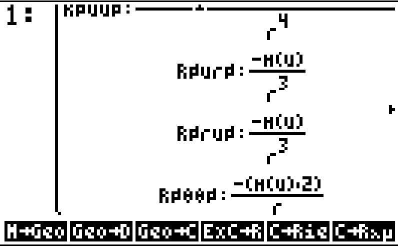
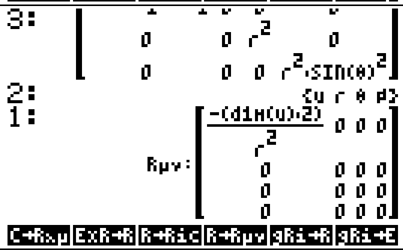
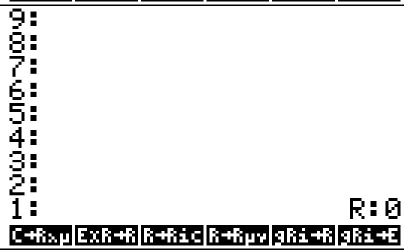
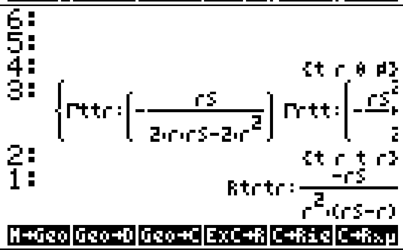
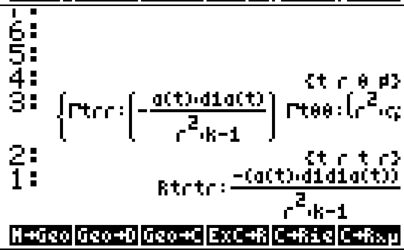
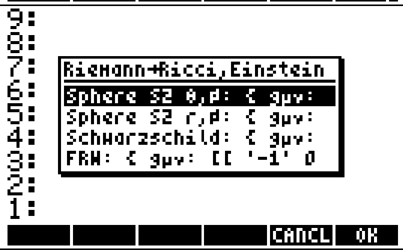
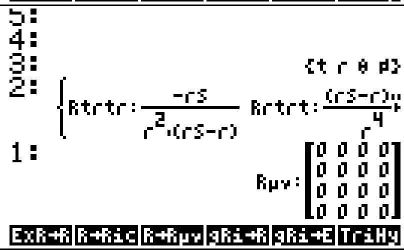
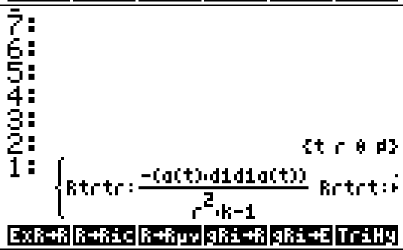
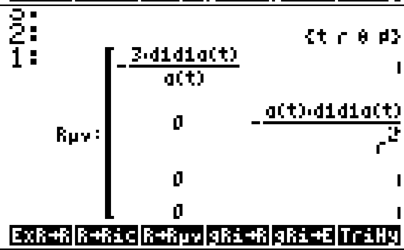
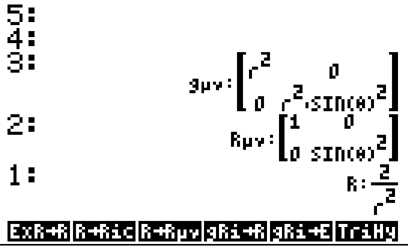
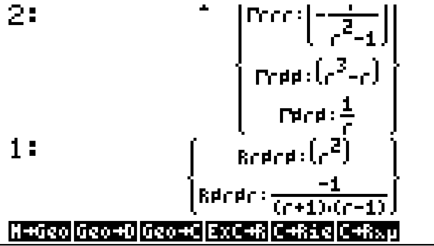
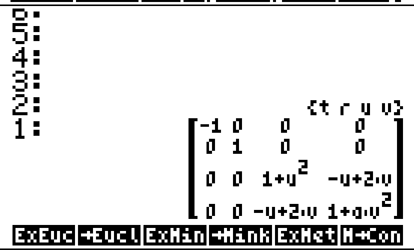
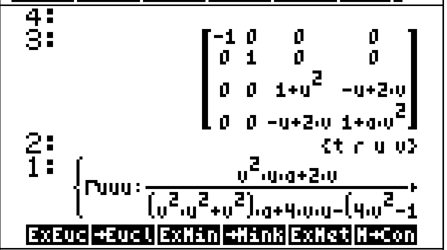
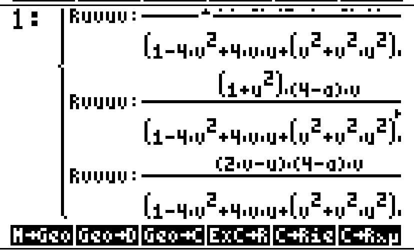
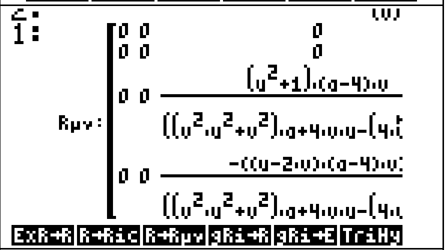
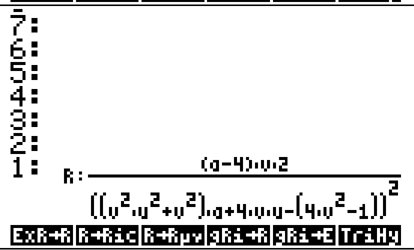
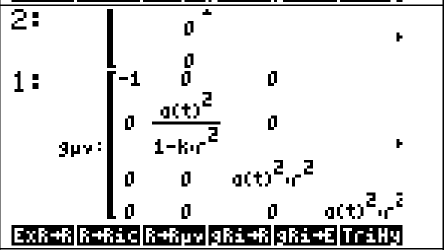
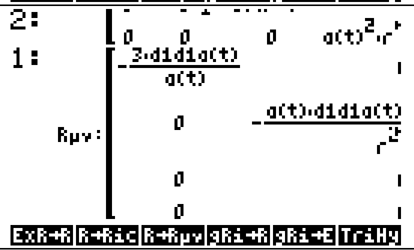
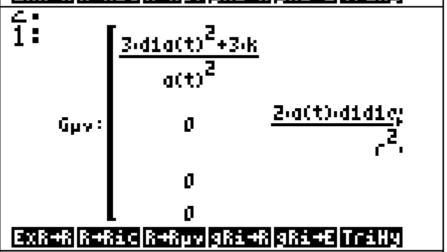
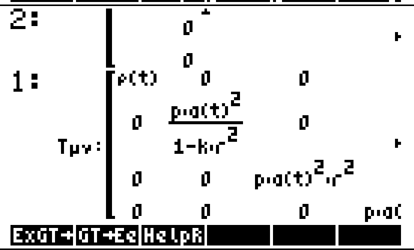
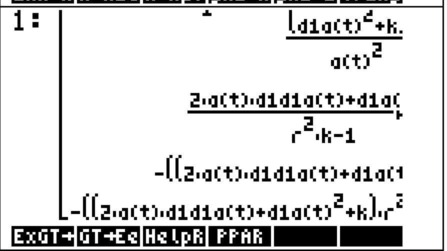
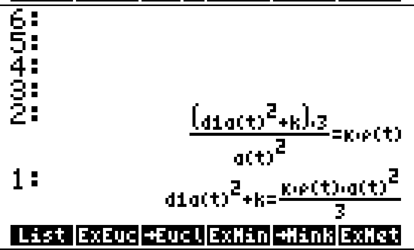
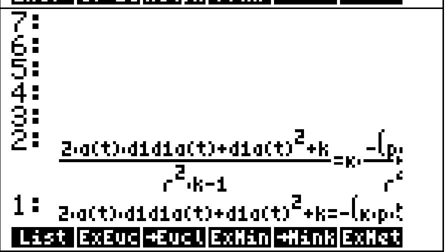
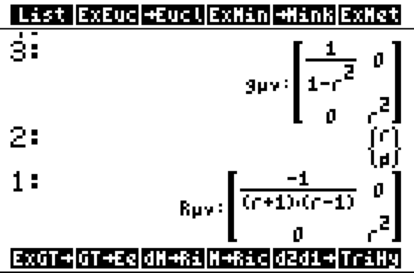
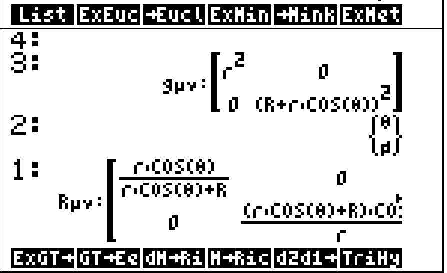
RIEMANN

ExEuMetr: examples for →EuclM, Euclidean metric [OK] gives example		
→EuMetr: Euclidean metric of coordinates or manifold, ex: spher. coordinates (0.5s) (HP50Emulator) sphere S2 θ φ (0.2s)		
→EuMetr: torus T2 (0.2s) sphere S3(0.5s)		
ExGMetr: examples for →GMetr, general metric spherical Minkowski (0.5s)		
→GMetr: ex. hyperbolic H2 (0.1s) hyperbolic H3 (0.6s)		
→GMetr: spherical de Sitter (3.5s)		
ExMetric: examples coordinates, metric		
M→Conn: metric to connection, (nonvanishing Christoffel symbols, note that $\Gamma\lambda\nu\mu=\Gamma\lambda\mu\nu$ is not shown and $\Gamma\lambda\mu\nu:=\Gamma^{\lambda}{}_{\mu\nu}$) sphere S2 r φ (0.6s)		

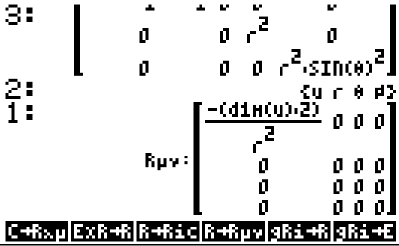
M→Conn: torus T2 (0.6s) M→Conn: hyperbolic H2 (0.4s)		
M→Conn: sphere S3 (1.3s)		
M→Conn: Schwarzschild (150s/3s)		
M→Geodes: metric to geodesic ex: torus (0.5s) ex. sphere S2 (12s/0.4s)		
Geo→DEQ: geodesic to differential equation sphere S2 (0s) torus T2 (0s)		
Geo→Conn: geodesic to connection ex: sphere S2 (0s) ex: torus T2 (0s)		
ExC→R: examples for connection to Riemann tensor [OK] gives example		
C→Riemann: calculates components $R^{\mu}{}_{\nu\mu\nu}$, ($\mu\neq\nu$) of Riemanntensor for diagonal metric ex: S2 θ φ (0.7s) ex S2 r φ (0.5s)		

C→Riemann: Schwarzschild connection (23s)		
C→Riemann: FLRW connection (30s)		
C→Riemann: connection to Riemann tensor for offdiagonal metric. Ex: Vaidya metric		
C→Riemann: connection to Riemann tensor for offdiagonal metric. Ex: Vaidya metric (25s)		
R→Ricci: Riemann to Ricci tensor, ex: Vaidya metric (2s) MRi→R: metric and Ricci to Ricciscalar(0.1)		
C→$R^{\lambda}{}_{\mu\nu\rho}$: calculate one component $R^{\lambda}{}_{\mu\nu\rho}$ of the Riemann tensor Schwarzschild (0.3s) FLRW (0.7s) FriedmannRobertsonWalker		
ExR→RE: examples for Riemann to Ricci, Einstein tensor R→Ricci: Riemann to Ricci Ex: Schwarzschild (1.5s)		
R→Ricci: Ex: FLRW(2.1s)		

MRi→R: metric and Ricci tensor to Ricci scalar ex: sphere S2 (0s)		
M→Conn: offdiagonal Minkowski (2.6s)		
C→Riemann: offdiagonal Minkowski (3.5s) R→Ricci: (1.5s)		
MRi→R: metric and Ricci tensor to Ricci scalar (2s). For a=4 R=0. FLRW metric		
FLRW Ricci tensor MRi→$G_{\mu\nu}$: metric and Ricci tensor to Einstein tensor Ex: FRW (3.5s)		
ExGT→Eeq: example Einstein G and energy mom. tensor T to Einstein equations ex: FLRW GT→Eeq (0.5s)		
1. equation (before and after simplifying) 2. equation (3. and 4. eq are identical)		
M→Ricci: diagonal metric to Ricci tensor ex: sphere S2 (3s) ex: torus T2 (4s)		

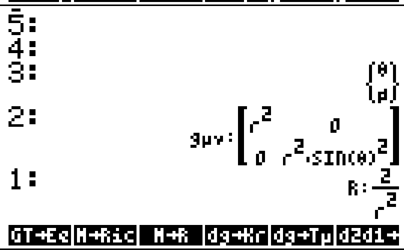
M→Ricci: (off-) diagonal metric to Ricci tensor
ex: Vaidya metric
(30s)

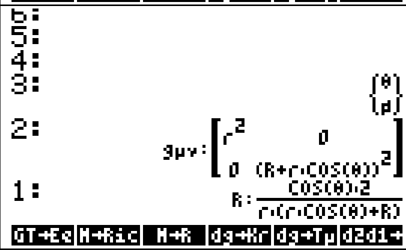
d2d1→d1d2:



M→R: metric to Ricci scalar, ex: sphere S2
(2s)

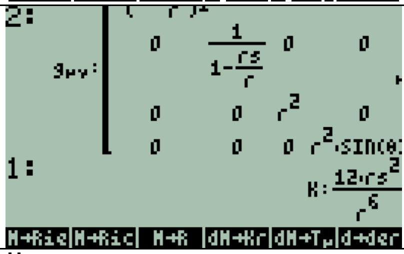
ex: torus (4s)

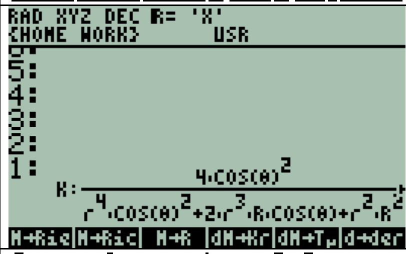




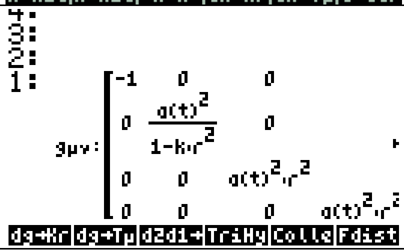
dM→Kret: diagonal metric to Kretschmann scalar K= $R_{\lambda\mu\nu\rho}R^{\lambda\mu\nu\rho}$ ex: Schwarzschild
(35s)

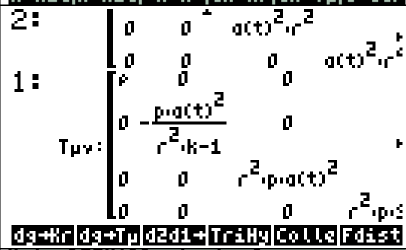
ex: torus (1s)





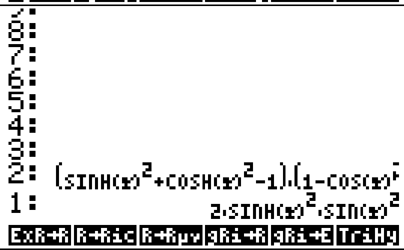
dM→Tμν: diagonal metric to energy momentum tensor comoving coordinates
(0s)

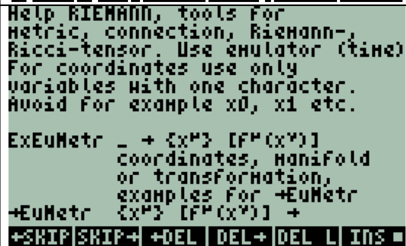




TriHyp: simplify terms with SINH,COSH,SIN,COS
(0s)

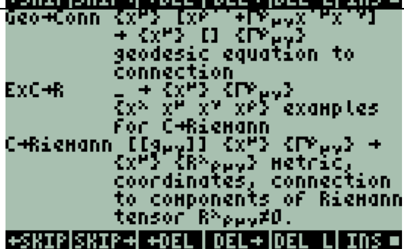
HelpRIEMANN: help to programs

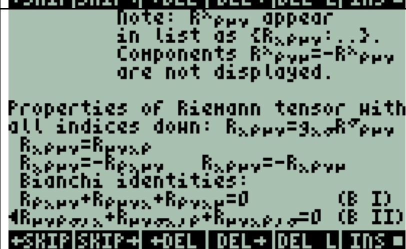




HelpRIEMANN: help to programs

HelpRIEMANN: help to programs





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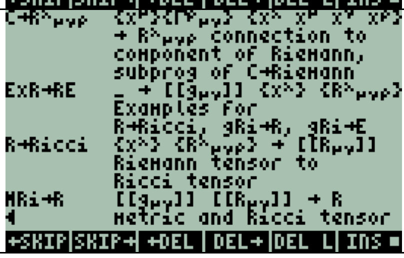
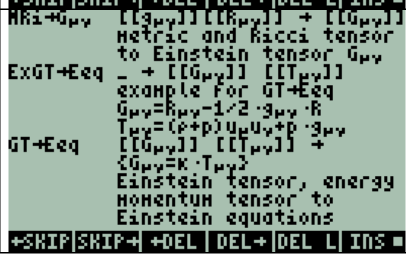
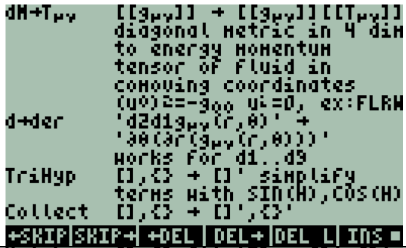
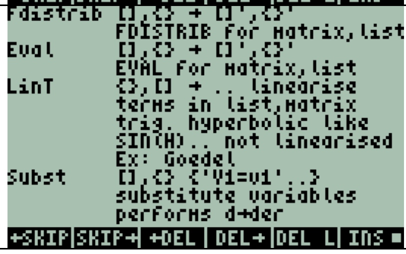




HelpRIEMANN: help to programs		
HelpRIEMANN: help to programs		

The software RIEMANN provides tools for calculating metric, connection, geodesic equations, Riemann and Ricci tensor and Einstein equations. The programs should be used on the HP50 emulator on a computer, smart phone or tablet. The software requires the MPC font for correct display of tensor indices.

How do the programs work?
M→Conn: The direct variation of $ds^2 = g_{\mu\nu} dx^\mu dx^\nu$ yields the geodesic equations $\frac{d^2 x^\lambda}{ds^2} + \Gamma^\lambda_{\mu\nu} \frac{dx^\mu}{ds}\frac{dx^\nu}{ds} = 0$ with M→Geodes, from which the non vanishing Christoffel symbols of second kind $\Gamma^\lambda_{\mu\nu}$ are obtained as a list with Geo→Conn.
(Ex: FLRW M→Conn 12s/3.5s on a slow/fast smart phone)

C→Riemann: calculates all components of the Riemann tensor via brute force with $C \to Riemann$ and $C \to R^\rho_{\lambda\mu\nu}$ from the non vanishing Christoffel symbols. Only non zero components are given (Ex: FLRW 30s/9.5s). For more complicated metrics as Kerr one should use one of the many computer programs like GRtensor, which employ Cartan's calculus.

Several algebraic tools help to simplify terms in lists or matrices: TriHyp, Collect, Fdistrib, Eval, LinT. With Subst and Match you can substitute functions or perform matches.
Check all examples in RIEMANN and the over 30 metrics in RIEM2 with the programs.

Some important books on the subject are (among many others):

A. Zee, Einstein Gravity in a Nutshell
L. Ryder, Introduction to General Relativity
M. Nakahara, Geometry, Topology and Physics