Exercise 6.7 Schwarzschild spacetime in isotropic coordinates

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{t, r, \theta, \varphi}::Coordinate.
{a,b,c,d,e,f,g,h#}::Indices(values={t, r, \theta, \varphi}, position=independent).

\partial{#}::PartialDerivative.

g^{a b}::InverseMetric.  # essential when using complete (gab, $g^{a b}$)

Gamma := \Gamma^{a}_{f g} -> 1/2 g^{a b} (   \partial_{g}{g_{b f}}
                                          + \partial_{f}{g_{b g}}
                                          - \partial_{b}{g_{f g}} ).

Rabcd := R^{d}_{e f g} ->   \partial_{f}{\Gamma^{d}_{e g}}
                          - \partial_{g}{\Gamma^{d}_{e f}}
                          + \Gamma^{d}_{b f} \Gamma^{b}_{e g}
                          - \Gamma^{d}_{b g} \Gamma^{b}_{e f}.

Rab := R_{a b} -> R^{c}_{a c b}.

gab := { g_{t t}             = -((2*r-m)/(2*r+m))**2,
         g_{r r}             = (1+m/(2*r))**4,
         g_{\theta\theta}    = r**2 (1+m/(2*r))**4,
         g_{\varphi\varphi} = r**2 \sin(\theta)**2 (1+m/(2*r))**4}.  # cdb(ex-0607.101,gab)

complete   (gab, $g^{a b}$)                                          # cdb(ex-0607.102,gab)

substitute (Rabcd, Gamma)
substitute (Rab, Rabcd)

evaluate   (Gamma, gab, rhsonly=True)                                # cdb(ex-0607.103,Gamma)
evaluate   (Rabcd, gab, rhsonly=True)                                # cdb(ex-0607.104,Rabcd)
evaluate   (Rab,   gab, rhsonly=True)                                # cdb(ex-0607.105,Rab)
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$$\left[g_{tt}=-\left(\left(2r-m\right)\left(2r+m\right)^{-1}\right)^{2},\ g_{rr}=\left(1+\frac{1}{2}mr^{-1}\right)^{4},\ g_{\theta\theta}=r^{2}\left(1+\frac{1}{2}mr^{-1}\right)^{4},\ g_{\varphi\varphi}=r^{2}(\sin\theta)^{2}\left(1+\frac{1}{2}mr^{-1}\right)^{4}\right] \tag{ex-0607.101}$$

$$\Bigg[g_{tt}=-\left(\left(2r-m\right)\left(2r+m\right)^{-1}\right)^{2},\ g_{rr}=\left(1+\frac{1}{2}mr^{-1}\right)^{4},\ g_{\theta\theta}=r^{2}\left(1+\frac{1}{2}mr^{-1}\right)^{4},\ g_{\varphi\varphi}=r^{2}(\sin\theta)^{2}\left(1+\frac{1}{2}mr^{-1}\right)^{4},\ g^{tt}= -(m+2r)^{2}(-m+2r)^{-2},\ g^{rr}=\left(\frac{1}{2}mr^{-1}+1\right)^{-4},\ g^{\theta\theta}=\left(r^{2}\left(\frac{1}{2}mr^{-1}+1\right)^{4}\right)^{-1},\ g^{\varphi\varphi}=\left(r^{2}\left(\frac{1}{2}mr^{-1}+1\right)^{4}(\sin\theta)^{2}\right)^{-1}\Bigg] \tag{ex-0607.102}$$

$$\Gamma^{a}{}_{fg}\rightarrow\Box_{fg}{}^{a}\begin{cases}\Box_{\varphi r}{}^{\varphi}=\left(-m+2r\right)\left(r\left(m+2r\right)\right)^{-1}\\ \Box_{\varphi\theta}{}^{\varphi}=(\tan\theta)^{-1}\\ \Box_{\theta r}{}^{\theta}=\left(-m+2r\right)\left(r\left(m+2r\right)\right)^{-1}\\ \Box_{rr}{}^{r}=-2m(r\left(m+2r\right))^{-1}\\ \Box_{tr}{}^{t}=4m\left(-m^{2}+4r^{2}\right)^{-1}\\ \Box_{r\varphi}{}^{\varphi}=\left(-m+2r\right)\left(r\left(m+2r\right)\right)^{-1}\\ \Box_{\theta\varphi}{}^{\varphi}=(\tan\theta)^{-1}\\ \Box_{r\theta}{}^{\theta}=\left(-m+2r\right)\left(r\left(m+2r\right)\right)^{-1}\\ \Box_{rt}{}^{t}=4m\left(-m^{2}+4r^{2}\right)^{-1}\\ \Box_{\varphi\varphi}{}^{r}=r\left(m-2r\right)(\sin\theta)^{2}(m+2r)^{-1}\\ \Box_{\varphi\varphi}{}^{\theta}=-\frac{1}{2}\sin\left(2\theta\right)\\ \Box_{\theta\theta}{}^{r}=r\left(m-2r\right)\left(m+2r\right)^{-1}\\ \Box_{tt}{}^{r}=-64mr^{4}\left(m-2r\right)\left(m+2r\right)^{-7}\end{cases} \tag{ex-0607.103}$$

$$R^{d}{}_{efg} \rightarrow \Box_{eg}{}^{d}{}_{f} \begin{cases} \Box_{tt}{}^{r}{}_{r} = -128m^3r^3(m+2r)^{-8} + 512m^2r^4(m+2r)^{-8} - 512mr^5(m+2r)^{-8} \\ \Box_{\theta\theta}{}^{r}{}_{r} = -4mr\left(m^2+4mr+4r^2\right)^{-1} \\ \Box_{\varphi\varphi}{}^{\theta}{}_{\theta} = 8mr(\sin\theta)^2(m+2r)^{-2} \\ \Box_{\varphi\varphi}{}^{r}{}_{r} = -4mr(\sin\theta)^2\left(m^2+4mr+4r^2\right)^{-1} \\ \Box_{rt}{}^{t}{}_{r} = -8m\left(r\left(m^2+4mr+4r^2\right)\right)^{-1} \\ \Box_{r\theta}{}^{\theta}{}_{r} = 4m\left(r\left(m^2+4mr+4r^2\right)\right)^{-1} \\ \Box_{\theta\varphi}{}^{\varphi}{}_{\theta} = (m-2r)^2(m+2r)^{-2} - 1 \\ \Box_{r\varphi}{}^{\varphi}{}_{r} = 4m\left(r\left(m^2+4mr+4r^2\right)\right)^{-1} \\ \Box_{tr}{}^{r}{}_{t} = 128m^3r^3(m+2r)^{-8} - 512m^2r^4(m+2r)^{-8} + 512mr^5(m+2r)^{-8} \\ \Box_{\theta r}{}^{r}{}_{\theta} = 4mr\left(m^2+4mr+4r^2\right)^{-1} \\ \Box_{\varphi\theta}{}^{\theta}{}_{\varphi} = (m-2r)^2(\sin\theta)^2(m+2r)^{-2} - (\sin\theta)^2 \\ \Box_{\varphi r}{}^{r}{}_{\varphi} = 4mr(\sin\theta)^2\left(m^2+4mr+4r^2\right)^{-1} \\ \Box_{rr}{}^{t}{}_{t} = 8m\left(r\left(m^2+4mr+4r^2\right)\right)^{-1} \\ \Box_{rr}{}^{\theta}{}_{\theta} = -4m\left(r\left(m^2+4mr+4r^2\right)\right)^{-1} \\ \Box_{\theta\theta}{}^{\varphi}{}_{\varphi} = 8mr(m+2r)^{-2} \\ \Box_{rr}{}^{\varphi}{}_{\varphi} = -4m\left(r\left(m^2+4mr+4r^2\right)\right)^{-1} \\ \Box_{\varphi\varphi}{}^{t}{}_{t} = -4mr(\sin\theta)^2(m+2r)^{-2} \\ \Box_{\theta\theta}{}^{t}{}_{t} = -4mr(m+2r)^{-2} \\ \Box_{tt}{}^{\varphi}{}_{\varphi} = 64mr^3(m-2r)^2(m+2r)^{-8} \\ \Box_{tt}{}^{\theta}{}_{\theta} = 64mr^3(m-2r)^2(m+2r)^{-8} \\ \Box_{\varphi t}{}^{t}{}_{\varphi} = 4mr(\sin\theta)^2(m+2r)^{-2} \\ \Box_{\theta t}{}^{t}{}_{\theta} = 4mr(m+2r)^{-2} \\ \Box_{t\varphi}{}^{\varphi}{}_{t} = -64mr^3(m-2r)^2(m+2r)^{-8} \\ \Box_{t\theta}{}^{\theta}{}_{t} = -64mr^3(m-2r)^2(m+2r)^{-8} \end{cases} \tag{ex-0607.104}$$

$$R_{ab} \rightarrow 0 \tag{ex-0607.105}$$