The EMGB solution that will be employed as a thin-shell solution with a normal matter [6] is given by (with $\Lambda = 0$)

$$f(r) = 1 + \frac{r^2}{4\alpha}\left(1 - \sqrt{1 + \frac{8\alpha}{r^4}\left(\frac{2M}{\pi} - \frac{Q^2}{3r^2}\right)}\right) \tag{14}$$

with constants, M =mass and Q =charge. For a black hole solution the inner (r_-) and event horizons ($r_+ = r_h$) are

$$r_\pm = \sqrt{\frac{M}{\pi} - \alpha \pm \left[\left(\frac{M}{\pi} - \alpha\right)^2 - \frac{Q^2}{3}\right]^{1/2}}. \tag{15}$$

By employing the solution (14) we determine the surface energy-momentum on the thin-shell, which will play the major role in the perturbation. We shall address this problem in the next section.

III. RADIAL, LINEAR PERTURBATION OF THE THIN-SHELL WORMHOLE WITH NORMAL MATTER

In order to study the radial perturbations of the wormhole we take the throat radius as a function of the proper time, i.e., $a = a(\tau)$. Based on the generalized Birkhoff theorem, for $r > a(\tau)$ the geometry will be given still by (6). For the metric function $f(r)$ given in (14) one finds the energy density and pressures as [6]

$$\sigma = -S_\tau^\tau = -\frac{\Delta}{4\pi}\left[\frac{3}{a} - \frac{4\alpha}{a^3}\left(\Delta^2 - 3\left(1 + \dot{a}^2\right)\right)\right], \tag{16}$$

$$S_\theta^\theta = S_\phi^\phi = S_\psi^\psi = p = \frac{1}{4\pi}\left[\frac{2\Delta}{a} + \frac{\ell}{\Delta} - \frac{4\alpha}{a^2}\left(\ell\Delta - \frac{\ell}{\Delta}\left(1 + \dot{a}^2\right) - 2\ddot{a}\Delta\right)\right], \tag{17}$$

where $\ell = \ddot{a} + f'(a)/2$ and $\Delta = \sqrt{f(a) + \dot{a}^2}$ in which

$$f(a) = 1 + \frac{a^2}{4\alpha}\left(1 - \sqrt{1 + \frac{8\alpha}{a^4}\left(\frac{2M}{\pi} - \frac{Q^2}{3a^2}\right)}\right). \tag{18}$$

We note that in our notation a 'dot' denotes derivative with respect to the proper time τ and a 'prime' implies differentiation with respect to the argument of the function. By a simple substitution one can show that, the conservation equation

$$\frac{d}{d\tau}\left(\sigma a^3\right) + p\frac{d}{d\tau}\left(a^3\right) = 0. \tag{19}$$