1.9.3 Tunnels to UK (5600 miles as an earthworm crawls) are shown below. One high-road is a direct route. A low-road turns at the Earth center. (Travel and turn-around are assumed frictionless and survivable.) (a) What is the time for each trip? Discuss using geometry or algebra arguments.

(a) Hi-road & low-road

(b) Lots of roads

(b) Assume cars in subway tunnels depart Ark. at time $t=0$ as indicated above. Describe curve (thru dots shown) locating car positions at a later time $t$ before arrival and at arrival. (Thales geometry helps here and in 1.9.4 below.)

1.9.4. Ex. 1.9.3 compares high-road or direct-route to low-road or Earth-center-and-back-routes. Here we compare Short-roads, Middle-road routes in Fig (a) of fixed longitudinal angle $\phi_{AOB}$ and various road-bend angle $\phi_{AMB}$, and “V-shaped” or “U-shaped” Slow-Roads in Fig. (b) below. Believe-it-or-not, (a3) is elegantly solvable by geometry. (a1) First consider a frictionless 2km L-subway $ACB$ that is laser-straight and ‘level’ (normal to Earth radius at $C$). A mag-lev car riding on it has a non-zero oscillation frequency? Discuss.

(a2) Next consider a frictionless L-subway $AMB$ that is much faster. Derive the angle $\phi_{AMB}$ that gives maximum oscillation frequency, that is, shortest A to B travel time.

(a3) Now for generally long trips find the fastest two-straight-section middle road $A$-to-$B$ in Fig (a). Derive optimal angle $\phi_{AMB}$ for $\phi_{AOB} = 90^\circ$ (UK trips) and a general $\phi_{AMB}$ ($\phi_{AOB}$) formula. (Check formula for low $\phi_{AOB}$ case.) Compare optimal 1-way UK trip travel time to that for straight-thru road $AHB$.

(b) Give $A$-to-$B$ 1-way Slow-road travel time on the “V-shaped” tunnel and on the “U-shaped” tunnel in Fig. (b).

(c) Xtra credit Later we will discuss the very-very-quickest A-to-B roads. You’re free to comment or speculate on what these results might be.