

Physics 341
Old Final
Two Problems Removed

1. (a) Is it reasonable to suggest that all of the dust we wipe off our furniture comes from tires wearing down? (Make an estimate for the city of Austin only; don't try to do the whole US.) (5 points)
(b) Could all the dust come from the particulate matter produced when our cars burn gasoline? (5 points)
2. A mass m is thrown vertically into the air at speed v . Using dimensional analysis, show that the maximum height to which it rises does not depend on m . (7 points) How does this illustrate the equivalence principle? (3 points)
3. You are flying around in a rocket near a black hole with mass $M = 2$ in units such that $G = c = 1$.
 - (a) Where is the closest point you can get to the center and still come back out? (2 points)
 - (b) You maneuver your rocket so as to stay at a radial coordinate 20% greater than the one in part (a). Is your clock running faster or slower than a clock infinitely far away, and by what factor? (4 points)
 - (c) You decide to build a rod extending from your current position to the event horizon. How much building material do you need? (4 points)
4. Gaston flies away from the earth at $\frac{3}{5}c$ and Alphonse flies away in the opposite direction at $\frac{4}{5}c$. When Gaston is 3 light years away and Alphonse is 4 light years away (as measured from the earth), both instantaneously reverse their directions of travel and return to earth at the same speeds at which they left. Harry and Sally stay home the whole time. How much time has passed for Harry and Sally? (3 points) For Gaston? (3 points) For Alphonse? (2 points) Who aged the most? (1 point) The least? (1 point)
5. Recall the motion of a quartet of test masses suspended above the earth and allowed to fall freely. We will now consider the motion of test masses allowed to fall *inside* the earth (yes, I know there's stuff in the way; imagine they're falling through small tunnels or something). The curvature of spacetime in every plane inside the earth is positive.
 - (a) If we arrange our four masses as before, what happens to the two masses arranged one directly above the other? (5 points)
 - (b) What happens to the two masses beside one another? (5 points)
6. How would your life be different if (a) c were much smaller, (5 points) (b) G were much larger, (5 points) and (c) h were much larger? (5 points)
7. A really, really, really massive paddle travelling at speed v hits a teeny little ball at rest. What is the subsequent velocity of the ball? (Hint: This is a Galilean invariance problem. It is best analyzed in the inertial reference frame in which the paddle is at rest.) (10 points)
8. A manhole cover with a diameter of half a meter (at rest) is zooming over a manhole of the same diameter at speed v . When the front of the manhole cover reaches the front of the manhole, where is the back of the manhole cover (a) according to the manhole (5 points) and (b) according to the manhole cover? (5 points)