

GRAVITATION

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W. H. FREEMAN AND COMPANY San Francisco

Library of Congress Cataloging in Publication Data

Misner, Charles W. 1932-

Gravitation.

Bibliography: p.

I. Gravitation. 2. Astrophysics. 3. General relativity (Physics) I. Thorne, Kip S., 1940- joint author.
II. Wheeler, John Archibald, 1911- joint author.
III. Title.

QC178.M57 531'.14 78-156043

ISBN 0-7167-0334-3

ISBN 0-7167-0344-0 (pbk)

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Kip S. Thorne, and John Archibald Wheeler.

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Printed in the United States of America

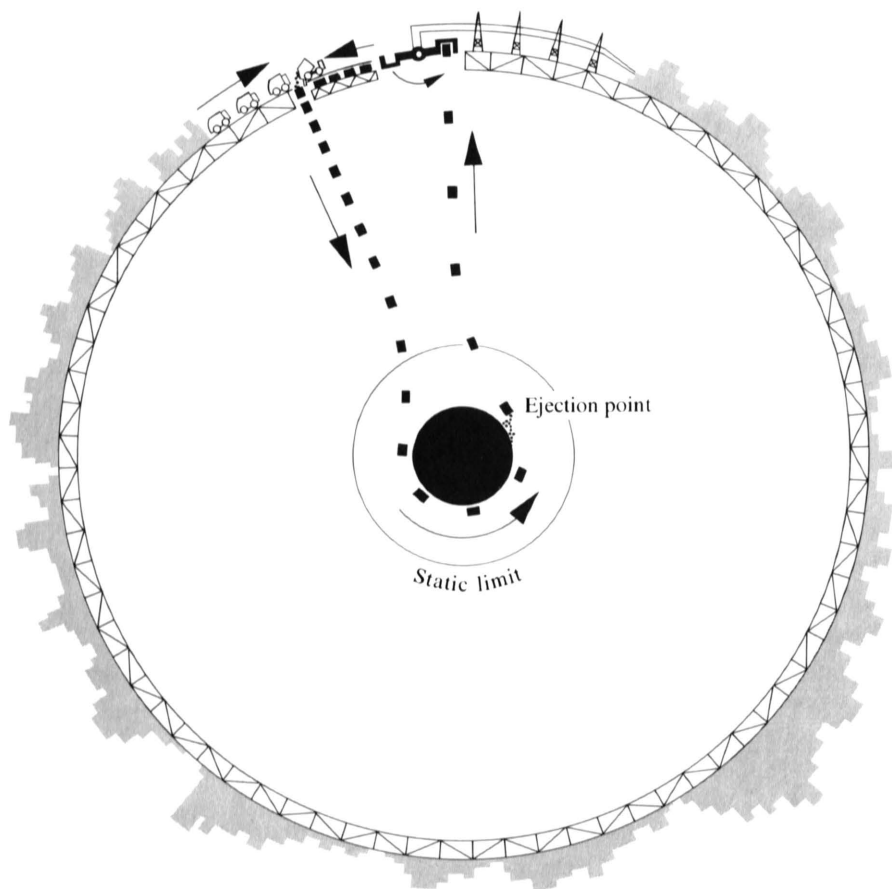


Figure 33.2.

An advanced civilization has constructed a rigid framework around a black hole, and has built a huge city on that framework. Each day trucks carry one million tons of garbage out of the city to the garbage dump. At the dump the garbage is shoveled into shuttle vehicles which are then, one after another, dropped toward the center of the black hole. Dragging of inertial frames whips each shuttle vehicle into a circling, inward-spiraling orbit near the horizon. When it reaches a certain “ejection point,” the vehicle ejects its load of garbage into an orbit of negative energy-at-infinity, $E_{\text{garbage}} < 0$. As the garbage flies down the hole, changing the hole’s total mass-energy by $\Delta M = E_{\text{garbage ejected}} < 0$, the shuttle vehicle recoils from the ejection and goes flying back out with more energy-at-infinity than it took down

$$E_{\text{vehicle out}} = E_{\text{vehicle + garbage down}} - E_{\text{garbage ejected}}$$

$$> E_{\text{vehicle + garbage down}}$$

The vehicle deposits its huge kinetic energy in a giant flywheel adjacent to the garbage dump; and the flywheel turns a generator, producing electricity for the city, while the shuttle vehicle goes back for another load of garbage. The total electrical energy generated with each round trip of the shuttle vehicle is

$$\begin{aligned} \text{(Energy per trip)} &= E_{\text{vehicle out}} - (\text{rest mass of vehicle}) \\ &= (E_{\text{vehicle + garbage down}} - E_{\text{garbage ejected}}) - (\text{rest mass of vehicle}) \\ &= (\text{rest mass of vehicle} + \text{rest mass of garbage} - \Delta M) - (\text{rest mass of vehicle}) \\ &= (\text{rest mass of garbage}) + (\text{amount, } -\Delta M, \text{ by which hole's mass decreases}). \end{aligned}$$

Thus, not only can the inhabitants of the city use the black hole to convert the entire rest mass of their garbage into kinetic energy of the vehicle, and thence into electrical power, but they can also convert some of the mass of the black hole into electrical power!