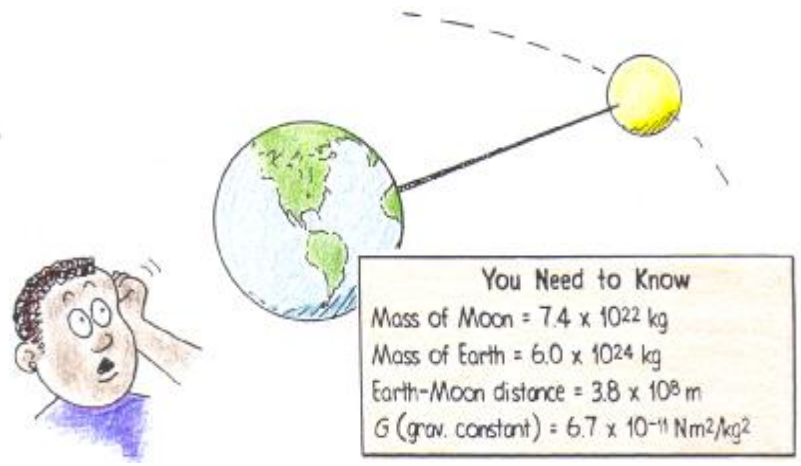
NEXT-TIME QUESTION

CONCEPTUAL Physics

Suppose the gravitational force between the Earth and Moon was turned off and the pull replaced by the tension in a steel cable joining them. Consider the tension in such a cable, and its size. The tensile strength of a steel cable is about 5.0×10^8 N/m (each square meter cross section can support a 5.0×10^8-newton force).

The cross-sectional area would be about that of

a) a bass guitar string.
b) a typical vertical cable that supports the Golden Gate Bridge.
c) Empire State Building.
d) Manhattan Island, NY.
e) an area greater than the state of New York.



You Need to Know

Mass of Moon = 7.4×10^{22} kg
Mass of Earth = 6.0×10^{24} kg
Earth-Moon distance = 3.8×10^8 m
G (grav. constant) = 6.7×10^{-11} Nm^2/kg^2

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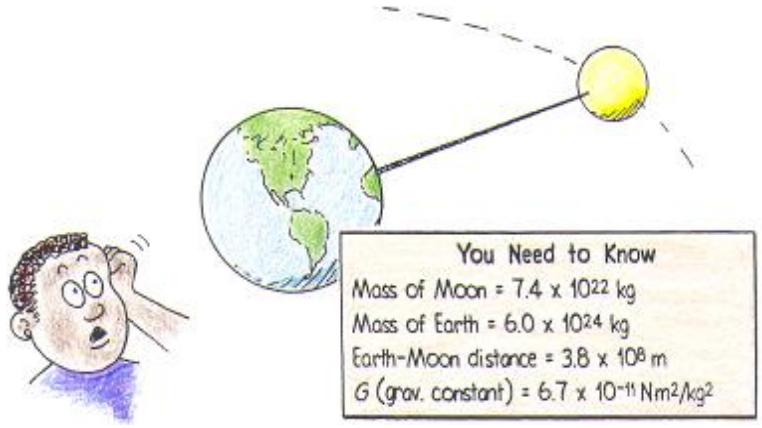

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Answer: e

From strength $S = \frac{F}{A}$ we find the area A of the cable to be

$$A = \frac{F}{S} = \frac{Gm_E m_M / r^2}{S} = \frac{\left(6.7 \times 10^{-11}\ \text{N}\cdot\text{m}^2/\text{kg} \cdot 6.0 \times 10^{24}\ \text{kg} \cdot 7.4 \times 10^{22}\ \text{kg}\right) / \left(3.8 \times 10^{8}\ \text{m}\right)^2}{5.0 \times 10^{8}\ \text{N/m}^2}$$

$$= \frac{2.0 \times 10^{20}\ \text{N}}{5.0 \times 10^{8}\ \text{N/m}^2} = 4.0 \times 10^{11}\ \text{m}^2$$

That's about 400,000 square kilometers, which is more than *3 times* the area of New York state! (Area of New York = 129,000 km^2.) Although gravitation is the weakest of the fundamental forces, we see that between great masses even long distances apart, it can be enormous.