$M_E = 5.98 \times 10^{24}$ kg

1. The moon has a mass of 7.35×10^{22} kg and orbits the Earth at a radius of 3.84×10^{8} m. $= r$
a) What is the gravitational potential energy of the Moon-Earth system?
b) What is the Moon's kinetic energy and speed in circular orbit?
c) What is the Moon's binding energy to Earth?

a) $PE_g = -\frac{GMm}{r}$

$= \frac{(-6.67 \times 10^{-11} \frac{Nm^2}{kg^2})(5.98 \times 10^{24} kg)(7.35 \times 10^{22} kg)}{3.84 \times 10^{8} m}$

$= -7.63 \times 10^{28}$ J

b) $F_g = F_c$

$\frac{1}{2} \frac{GMm}{r^2} = \frac{1}{2} \frac{mv^2}{r}$

IN ORBIT

$\frac{1}{2}|PE| = KE$

So $KE = \frac{1}{2}(7.63 \times 10^{28} J)$

$= 3.82 \times 10^{28}$ J

$KE = \frac{1}{2}mv^2$

$v^2 = \frac{2KE}{m} = \frac{2(3.82 \times 10^{28} J)}{7.35 \times 10^{22}}$

$= 1.04 \times 10^{6}$

$v = 1.02 \times 10^{3}$ m/s

c) What is binding energy?
The energy required to separate the objects.

To "free" the moon from the earth, we need to take it an infinite distance away ($r = \infty$), so

PE = 0 and KE = 0 So $E_T = 0$

In orbit

$E_T = PE + KE = -7.63 \times 10^{28} + 3.82 \times 10^{28}$ J

$= -3.81 \times 10^{28}$ J (or 3.82 if we hadn't rounded KE before the calculation)

So $BE = +3.81 \times 10^{28}$ J

2. What is the total energy needed to place a 2000 kg satellite into circular orbit around Earth at an altitude of 5.0×10^2 km?

$r_E = 6.38 \times 10^6$ m

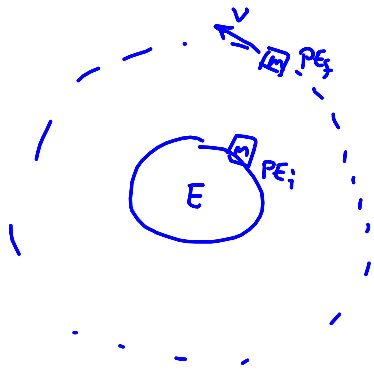
$M_E = 5.98 \times 10^{24}$ kg

$r_i = r_E$

$r_f = r_E + alt = 6.88 \times 10^6$ m

$PE_f = -\frac{GMm}{r_f} =$

$PE_i = -\frac{GMm}{r_i} =$



$KE = \frac{1}{2}|PE_f| =$

$W = \Delta PE + KE$

$KE = \frac{1}{2}|PE_f|$

Gravitational Potential Energy

1. What is the gravitational potential energy of a satellite of mass 1000 kg at a radius of orbit of 2×10^7 m relative to infinity? Relative to the surface of the Earth? (-1.99×10^{10} J, 4.26×10^{10} J)
2. A satellite of mass 1500 kg is placed in orbit at a radius of $4r_E$ (r_E is Earth's radius).
   (a) How much potential energy does the satellite gain if launched from Earth's surface? (7.02×10^{10} J)
   (b) What kinetic energy does the satellite require to be in orbit at this height? (1.17×10^{10} J)
   (c) What is the total energy required to put the satellite in this orbit? (8.19×10^{10} J)
3. What is the escape velocity of a rocket from the surface of the Earth? (11.2 km/s)
4. What velocity would the Earth have to obtain to escape the sun? (42.2 km/s)