Answers for Gravity Lesson Homework Questions

This lesson was posted online on May 7,2020.

I. Questions from Nelson. Answers are provided in the textbook.
Ask me if you want any questions worked out in detail.

II. Calculate the force of gravitational attraction between a boy and a girl, each massing 60 kg if they are 1m apart.

Solution: Since it's not between an object and the earth, we cannot use $F_g = mg$. We have to use Newton's Law of Universal Gravitation

$$F_g = \frac{Gm_1m_2}{d^2}$$

$Fg = 6.67\text{ E-}11 \times 60 \times 60 \ / \ 1^2 = 2.40 \times 10^{-7}$ N . *This is a very small force. Other forms of attraction are stronger ;)*

III. *Well, we didn't get any answers from anyone on this question.*
a) List two ways to reduce the weight of an object.
b) List one way to reduce the mass of an object.

a) * Go somewhere where gravity is less and you'll weigh less
* or measure the weight when you're falling. Because of the way that weight is measured, if you're falling (accelerating downwards) then the scale will not read as much (if anything)
* or reduce the mass
b) Remove some matter from the object and the mass will decrease – that's the only way.

IV. *An ion drive on a spacecraft can produce a thrust of 200 milliNewtons.*
a) What is the acceleration that this provides on a 70kg spacecraft?
b) If this is the only force on the space craft, how fast will the spacecraft be travelling after 1 day? after 1 week? after 1 month?

This is mostly an equations of motion question.
a) F = ma so a = F/m = 0.200N / 70kg = 2.86 mm/s^2 .

That's VERY small. Each second the speed increases by only 2.86 mm/s .
This is more than 3000 times less than the acceleration that gravity (on earth) causes.

b) v = at + v1.
We just want to know the change in speed, so we can set $v_1 = 0$ and get $v_2 = at$
or we can just look for $\Delta v = at$

After a day, $v = a\,t = 0.00286\ m/s^2 \times 3600$seconds/hour x 24 hours/day = 247 m/s .
Almost 1000 km/hr. Pretty fast, getting close to the speed of sound (except that it's in space).

After 1 week: multiply at v by 7 days
v = 1728 m/s = 6000 km/hr

After 1 month: multiply the daily amount by 30 days (or 4.333 weeks / month)
So now v = 7406 m/s = 27,000 km/hr

This shows that in space, where there is no friction, if you can apply a very small force continually, the constant acceleration can lead to incredibly huge speeds. Unfortunately, the stars are so far away, that there's still zero chance of ever getting there. Even so, we don't use this method to get space probes to the outer planets in our solar system. We use gravitational assists from inner planets (normally Jupiter and/or Saturn) because it's free and needs no fuel to speed the probe up.

V. We know that the force of gravity is equal and opposite on both objects that attract each other. If you jump down from a 2m high ledge, you fall down because the earth's gravity pulls you down. But your equal and opposite gravitational force would also be pulling the earth up at the same time! How much does the earth move up while you move down the 2 m ?

Solution:

We need the force of gravity. Since it's between an object and the earth, within 200km of the earth's surface, we can use $F_g = mg$. What is m?
Well there was a mass of a person of 60kg earlier. That's 132 lbs.
Let's try 70kg. That's154 lbs

Fg = 70kg * 9.8 N/kg = 686 N

acceleration of person = net force / mass = 686 N / 70kg = 9.8 m/s^2
(there are no other forces on the person)
acceleration of earth = net force / mass = 686 N / 5.98 x 10^24 kg = 1.15 x 10-22 m/s^2
(assume that no one else is jumping at the same time!)

Time it takes person to fall 2 metres:
$\Delta d = \frac{1}{2} at^2 + v_1 t$. $v_1 = 0$

$-2 = \frac{1}{2}(-9.8)\,t^2$ $t^2 = -4 / -9.8$ t = 0.639 seconds.

How far up does the earth move in this amount of time given its acceleration?
$\Delta d = \frac{1}{2} at^2 + v_1 t$. $v_1 = 0$
$\Delta d = \frac{1}{2}(1.15 \times 10\text{-}22\ m/s^2)(0.639\ s)^2$ = 4.68 x 10^-23 m.

A proton has a radius of about 10^-15 m. This is far far smaller than that.
So when you jump down, the earth does move up, but it moves up by an amount that's maybe 1 billionth the radius of a proton. That's why we don't feel the earth move.