Science-1A Lecture: Week-2, Friday, August 21, 2020

We will now continue watching a few more Crash Course Videos that have information useful during the next few weeks. **Remember, you will not be responsible for many of the details in these, but they provide an excellent background for what you do need to understand.** We will refer to these ideas when we study each of the next few Practice Quizzes. At that time, it may be useful to view some of these videos again.

Newton's Laws (CC 5) 11 min, 3 s

https://www.youtube.com/watch?v=kKKM8Y-u7ds&list=PL8dPuuaLjXtN0ge7yDk_UA0ldZJdhwkoV&index=6

This video is full of important facts relevant to our course. You will probably benefit by watching it more than once. **Inertia** of an object is the result of it having **mass**. So the two ideas of inertia and mass are not really distinct. An object's mass (or inertia) determines how hard it is to shake that object.

Newton's 1st law states that objects just keep moving in a straight line unless acted on by an external force. Friction (the topic of the next video) normally hides this fact from us. But Newton was able to imagine how things might move in the absence of friction. That led to his formulation of his 1st Law of motion. We see a hint of it when watching stones sliding along a flat frozen lake or when we coast on a bicycle on level ground (without turning). It would be really obvious if we were in a spacesuit outside of our spaceship and happened to push away from the spaceship. Without any safety line, we would helplessly just keep going farther and farther from the spaceship.

I actually like to ignore Newton's 1st law, because it is just a special case of **Newton's 2nd law** that states a proportionality between the **"net" force** on an object and its **acceleration**, $\boldsymbol{F_{\text{net}} = m\,a}$. When $F_{\text{net}} = 0$, the 2nd law states that the acceleration *a* must be zero. When acceleration is zero, and object is neither speeding up, nor slowing down, and is not changing direction. It is therefore obeying Newton's 1st law. Also, if an object is not accelerating $F_{\text{net}} = m\,a = m \cdot 0 = 0$, there must be no net force on the object.

The video nicely explains the concept of "net" force, written as F_{net}.

Newton's 2nd law tells rocket and dragster designers that $a = \frac{F_{\text{net}}}{m}$. So for the greatest acceleration, the engine thrust must be maximized while the vehicle mass is minimized.

Weight is the force caused by gravity on an object, $F_g = \text{weight} = m\,g$ where *g* everywhere on the Earth is close to 9.81 m/s^2. (Our Equations Sheet gives it as 9.80 m/s^2, either is OK.) **It is important to know the difference between mass and weight. Mass determines how hard it is to shake an object. Weight is the force from gravity pulling on a mass.** Objects will have the same mass on the Earth, Moon, and Mars, as well as in interstellar space, but they have different weights on the Earth, Moon, and Mars. They have no weight in interstellar space. If you want to lose weight, go to the Moon and you will weigh 1/6 as much. You will, however, still have the same mass.

To sense your weight you must not be **free falling** (e.g. falling without a parachute). When free falling, gravity is accelerating you, but you cannot feel that acceleration. A ball in front of you that is also free falling will appear to float "weightlessly" in front of you. Astronauts feel **weightless** because they are free falling around the Earth in their orbit.

Also, gravity and acceleration from motion are indistinguishable. Trying to fly an airplane on a level path with your eyes closed will lead to a crash as your vestibular (balance) system gradually looses track of horizontal. (If you want to know more, look up "pilot spatial disorientation" in Google or YouTube.)

Newton's 3rd Law about action-reaction is just the result of a better understanding of net force. An object resting on a table is not accelerating because the gravitational force is balanced by an **upward ("normal") force** from the table, and as she explains, that upward force will exactly match the downward force unless the object is so massive that the table breaks. You will be expected to do calculations about falling things, but not more complicated problems like the ramp and elevator problems she explains. I also do not test you about free-body diagrams.

I can't resist mentioning that the book she put on the table is one of the three volumes of The Feynman Lectures on Physics. Richard Feynman, a very interesting Nobel Prize winner, is one of the physics heroes of my generation of physicists. When I was a graduate student, I boldly got Feynman to autograph my copy which I still treasure and refer to. Those lectures were given to freshman and sophomore physics students at Cal-Tech, but the rest of the world studies them in graduate school while preparing for the exams for admission into Ph. D. study programs.

Friction (CC 6) 10 min, 58 s

https://www.youtube.com/watch?v=fo_pmp5rtzo&list=PL8dPuuaLjXtN0ge7yDk_UA0ldZJdhwkoV&index=7

This video nicely explains friction, but we will not do any problems involving friction in Science-1A. Still, it is good to understand the basic phenomenology of friction. The symbol for friction, μ_f, that she talks about uses the lower case Greek letter pronounced mu with a subscript of *f* for friction. **Enjoy her discussion of ramps and the associated trigonometry, but relax, we will not be doing problems about those either.**

It is important to remember that frictional forces are always in the opposite direction of the net force causing or attempting to cause motion.

Uniform Circular Motion (CC7) 9 min, 53 s

https://www.youtube.com/watch?v=bpFK2VCRHUs&list=PL8dPuuaLjXtN0ge7yDk_UA0ldZJdhwkoV&index=8

There are lots of good concepts in this video. Remember that the **circumference** of a circle of **radius** *r* is $C=2\pi r$, and the time for something to travel once around the circle is called its **period**, represented by the letter *T*. Remember also that we might refer the **frequency** of the circular motion as $f=\frac{1}{T}$ with units of $\frac{1}{\mathrm{s}}=\mathrm{Hz}$ (See the last page of our Equation Sheet for a bit more about the frequency unit Hz.) The object will then have an average speed $s=\frac{C}{T}$. Because velocity has direction, the average velocity for a full trip around a circle is zero since it was moving right to left on one side and a matching, but opposite velocity left to right on the opposite side of the circle. Also, even though its speed is constant, its direction, and therefore its velocity is continuously changing. A changing velocity, whether because of speed change or direction change or both, is an acceleration. So the object in circular motion is constantly accelerating; its velocity keeps turning toward the center of its motion, but never can reach there. From our equation sheet, its acceleration is $a_c=\frac{v^2}{r}$ and the centripetal force that makes that happen must be $F_c=m\,a_c=\frac{m\,v^2}{r}$.

Newtonian Gravity (CC8) 9 min, 19 s

https://www.youtube.com/watch?v=7gf6YpdvtE0&list=PL8dPuuaLjXtN0ge7yDk_UA0ldZJdhwkoV&index=9

This video is worth watching more than once. The part about Kepler's laws for planetary orbits is interesting, but is outside of the scope of our course. The part near the end, where she connects the simple equation for the weight of an object at the surface of the earth to **Newton's Law of Gravitation**, is an example of how new knowledge can connect two things, falling objects and orbiting planets, that previously were thought to have nothing to do with each other.

Newton's Law of Gravitation when applied to the force between the Earth and Moon is $F=G\frac{m_{\text{Earth}}m_{\text{Moon}}}{d^2_{\text{Earth-Moon}}}$.

The same equation applies for the force between the Earth and an apple at the surface of the Earth $F=G\frac{m_{\text{Earth}}m_{\text{apple}}}{d^2_{\text{Earth-apple}}}$, but since the apple is at the surface of the Earth $d_{\text{Earth-apple}}=r_{\text{Earth}}$, where r_{Earth} is the radius of the Earth. So the Earth-apple force equation becomes simply $F=G\frac{m_{\text{Earth}}m_{\text{apple}}}{r^2_{\text{Earth}}}$. When we are playing with things near the surface of the Earth, we can separate this equation into two parts $F=\left(G\frac{m_{\text{Earth}}}{r^2_{\text{earth}}}\right)m_{\text{apple}}$, and can call the first part $g_{\text{Earth surface}}=G\frac{m_{\text{Earth}}}{r^2_{Earth}}$ so that the force becomes

$F = g_{\text{Earth surface}} m_{\text{apple}}$ which we usually write as $F = m\,g$ where the m is any particular mass and g is nearly the same everywhere at the surface of the Earth.

Work, Energy, and Power (CC9) 9 min, 54 s
https://www.youtube.com/watch?v=w4QFJb9a8vo&list=PL8dPuuaLjXtN0ge7yDk_UA0ldZJdhwkoV&index=10

This video has lots of important points, but you will not need to understand her use of vectors, derivatives, and integration. Also, we will not talk about the forces and energy of springs.

Still, watch this through and absorb what you can. The many parts of this you will need to know that we will describe later when discussing Practice Quiz 3.

OK. That's enough to chew on for now. Next week, I will pass out Quiz 1, and we will learn about pressure, an important physics topic that the textbook skips. In lab, we will drop marbles and examine a pendulum.