Science-1A Lecture: Week-4, Monday, August 31, 2020

Quiz-2 is next week, so today I will go over the Example Questions for Quiz 2 and their solutions. These are located pages 141-144 of your printed handouts and also at
http://yosemitefoothills.com/Science-1A/QuizAndTestPractice/SampleQuestions-Quiz-2.pdf and
http://yosemitefoothills.com/Science-1A/QuizAndTestPractice/SampleQuestions-Quiz-2-Solutions.pdf .

See the boxed note at the start of the Week-2 Monday lecture at
http://yosemitefoothills.com/Science-1A/OnlineLectureAndLabNotes/Week-02-Lecture-Monday-August-17-2020.pdf
for an explanation of the Equation Sheet and its use.

The following discussion is long, but I needed to try an anticipate the points of confusion that I easily clarify during a spoken lecture. It may be a pain to read, but it was also a pain to write.

The calculation answer style shown in the solutions sheet is the style that should be followed when writing calculation solutions. I will be fussy about writing the starting equation and alterations to it if required. Also, the setup should have proper mathematical form and values should be written with their units using parentheses if appropriate. The final answer should have 3 or 4 significant figures unless more are requested, and of course answers should have the correct units.

Question 1: This is to check that you understand the difference between speed and velocity. Both are about how fast an object is moving measured in m/s or equivalent metric units, but velocity has direction. An object moving in a straight line at a constant rate of 5 m/s has a constant speed and also a constant velocity. An object moving at a constant rate of 5 m/s, but turning as it moves, has a constant speed, but a changing velocity. The sample solution

Speed is distance moved in any direction divided by time required.
Velocity is speed combined with direction of motion.

conveys this idea. There are different ways to say this, but the words used must convey this distinction that velocity has direction and speed does not.

Question 2: I will go through this answer in a tediously careful manner. This question has only 2 possible points, so I am limited in offering partial credit. Most calculations will have more points, and deductions will be made when answers deviate significantly in form and unit use from the style in the examples.

A car odometer measures how far you travel irrespective of direction so average speed is obtained by dividing its reading by the time required. The Chapter 2 section of the Equation Sheet hints at this when it talks about average velocity being change in position divided by change it time. Average speed uses the same formula but the change in position is from an odometer which doesn't care about direction. A bar on top of a value is the standard mathematical way of saying average, and the letter *s* is a nice choice for speed. So your starting equation is

$$\bar{s}=\frac{d}{t}$$

where the letter *d* is used to represent the odometer distance reading and the letter *t* for time. The problem statement gives a distance of 150 km and a time of 2 hours, so you continue the above equation by writing an equal sign and putting numbers and units in for *d* and *t*:

$$\bar{s}=\frac{d}{t}=\frac{150\,\text{km}}{2\,\text{h}}$$

More complicated equations require parentheses to show which values are connected with which units.

This problem does not require any unit conversion, so you can finish up with an equal sign, the correct calculated final value and the units of that final value:

$$\bar{s}=\frac{d}{t}=\frac{150\,\mathrm{km}}{2\,\mathrm{h}}=75\,\frac{\mathrm{km}}{\mathrm{h}}$$

Writing the units as km/h is also perfectly OK.

> **Note:** When I write equations using my free libreoffice word processor (*http://libreoffice.org*), I write variables in italics and units without italics. You should not try to emulate that distinction in your hand-written answers. Learning how to do equations in libreoffice is a major challenge so although I mention it, I do not think it is worth your time to learn how to word process equations – maybe when you are a teacher, but not now.

Question 3: This question gives a speed in km/h and asks you to convert it to m/s. Conversion is easy to do incorrectly, but careful use of units with your conversion factors can protect you. I discussed unit conversions in the section entitled "6. Unit Conversion" of the Algebra Refresher handout on page 11-12 of your printed handouts and on page 9-10 of the Algebra Refresher handout at *http://yosemitefoothills.com/Science-1A/Handouts/Week-01/AlgebraRefresher.pdf*

The task is to convert 25000 km/h to m/s. Converting km to m is easy, just replace the unit prefix k with its power of 10 equivalent, 10^3 . Converting hours to seconds requires that you remember that there are 60 minutes in an hour and 60 seconds in a minute: $60\,\mathrm{min}=1\,\mathrm{h}$ and $60\,\mathrm{s}=1\,\mathrm{min}$. These then make these equations into the conversion factors. The four possible candidate factors are

$$1=\frac{60\,\mathrm{min}}{1\,\mathrm{h}} \qquad 1=\frac{1\,\mathrm{h}}{60\,\mathrm{min}} \qquad 1=\frac{60\,\mathrm{s}}{1\,\mathrm{min}} \qquad 1=\frac{1\,\mathrm{min}}{60\,\mathrm{s}}$$

The 2^{nd} and 4^{th} choices are needed for this problem. A km-to-m conversion is shown here, but can be avoided by replacing the k in km by a 10^3.

$$25000\,\frac{\mathrm{km}}{\mathrm{h}}\cdot\left(\frac{1000}{1}\,\frac{\mathrm{m}}{\mathrm{km}}\right)\cdot\left(\frac{1}{60}\,\frac{\mathrm{h}}{\mathrm{min}}\right)\cdot\left(\frac{1}{60}\,\frac{\mathrm{min}}{\mathrm{s}}\right)=6944\,\frac{\mathrm{m}}{\mathrm{s}}$$

or if you happen to remember that there are 3600 seconds in an hour, you can do

$$\mathbf{25000\,\frac{km}{h}\cdot\left(\frac{1000}{1}\,\frac{m}{km}\right)\cdot\left(\frac{1}{3600}\,\frac{h}{s}\right)=6944\,\frac{m}{s}}$$

As shown above, the conversion factors are equivalent to a 1. Inserting them is like multiplying by 1 so nothing is changed but the units. Now, you can see that the km's, h's, and min's cancel leaving m/s as our final units.

Question 4: Here, we are given an initial speed v_i=0 km/h and a final speed v_f=1800 km/h along with a time, and are asked to calculate the average acceleration. The relevant formula on the Equation Sheet is at the 2^{nd} line of the Chapter 2 section

$$\bar{a}=\frac{v_f-v_i}{t}=\frac{\left(1800\,\frac{\mathrm{km}}{\mathrm{h}}-0\,\frac{\mathrm{km}}{\mathrm{h}}\right)}{25\,\mathrm{s}}=\frac{\left(1800\,\frac{\mathrm{km}}{\mathrm{h}}\right)\cdot\left(\frac{1}{3600}\,\frac{\mathrm{h}}{\mathrm{s}}\right)\cdot\left(\frac{1000}{1}\,\frac{\mathrm{m}}{\mathrm{km}}\right)}{25\,\mathrm{s}}=20.0\,\frac{\mathrm{m/s}}{\mathrm{s}}=20.0\,\frac{\mathrm{m}}{\mathrm{s}^2}$$

As usual, we write the starting equation, then an equal sign and add the speed and time values given in the problem. The question requires that the answer be in m/s^2, so we need to do some conversions. In this case rather than replace the k in km by a 10^3, an explicit conversion factor for m and km was used. Either way is fine. Also, the number of seconds in an hour was used rather than converting h to min and then min to s. With these conversions in place the km's and h's are eliminated leaving m/s divided by s which should be written as m/s^2. The answer has units of acceleration as required.

Questions 5 and 6 look very similar. You must read them carefully and notice that Question 5 requests an answer of final **speed** while Question 6 requests an answer of final **distance**.

Question 5: This questions asks for the speed after an acceleration at a uniform rate of 8 m/s^2 for a time of 10 s. Partway down the Chapter 2 section of the Equation Sheet is an equation that connects acceleration, velocity and time, $v = at$. This assumes starting from no speed at t=0 which applies to this question. A slightly more general equation described in the text is $v_f = v_i + at$ in case the object is already moving at velocity v_i before the acceleration. In our case, and in any question you will see in this course, v_i=0. So we can write the equation, and insert the acceleration and time values as follows:

$$\boldsymbol{v_f = v_i + at = 0\,\mathrm{m/s} + (8\,\mathrm{m/s^2}) \cdot (10\,\mathrm{s}) = 80\,\mathrm{m/s}}$$

Notice how the units multiply, m/s^2 multiplied by s becomes m/s. The answer has units of velocity which is essential if we are calculating a speed or velocity. If we use the wrong formula, it is unlikely the final units will be m/s. When the final units do not match what you are trying to obtain, you have made an error either in your initial equation or in the setup.

Question 6: This is similar to question 5, but asks for a distance traveled after accelerating for a length of time. The equation for it is in the Equation Sheet just to the right of the velocity equation used above. It is $d = \frac{1}{2} a t^2$. The 1/2 here is important. Its source is discussed on page 60 of our printed handouts and also at
http://yosemitefoothills.com/Science-1A/Handouts/Week-02/AccelerationVelocityDistance-Simpler.pdf

So, the solution to this question is

$$\boldsymbol{d = \frac{1}{2} a t^2 = \frac{1}{2} \cdot (8\,\mathrm{m/s^2}) \cdot (10\,\mathrm{s})^2 = 400\,\mathrm{m}}$$

In this case, the s^2 from the t^2 cancels the s^2 in the m/s^2 so that the final units are just m. Again, using the wrong starting equation or forgetting the square on 10 s will likely give you other units than m for your distance. Points will be lost if the 1/2, parentheses, units values, or square are not correct.

Question 7: Acceleration is a change in velocity, not just a change in speed. So even though the satellite is moving at a constant speed, it is changing direction as it goes around the Earth, and therefore its velocity is changing. Any change in velocity (speed or direction) is an acceleration. This distinction is important in the application of Newton's 2nd law of motion that connects force with mass and acceleration.

Question 8: In physics, we rarely use the term "deceleration". Instead, slowing down is just a negative acceleration, just like moving backwards is a negative velocity and behind you might be considered a negative position.

Question 9: This should look familiar. The first Calculations Test question was like this. When confronted with a question about gravitational force between two masses, you check near the bottom of the first page in the Equation Sheet to find Newton's Gravitational force law $F = G\frac{m_1 m_2}{d^2}$ where $G = 6.67 \times 10^{-11} \frac{\mathrm{N \cdot m^2}}{\mathrm{kg^2}}$ is a universal constant of nature provided at the right side on the same line of the Equation Sheet. So, just like in the Calculations Test, you write the equation setup as follows using G and the masses and distance given in the question:

$$F = G\frac{m_{\text{Moon}}\,m_{\text{Earth}}}{d^2_{\text{Moon-Earth}}} = \left(6.67\times10^{-11}\,\frac{\text{N}\cdot\text{m}^2}{\text{kg}^2}\right)\cdot\frac{(7.35\times10^{22}\,\text{kg})\cdot(5.97\times10^{24}\,\text{kg})}{(3.84\times10^{8}\,\text{m})^2} = 1.98\times10^{20}\,\text{N}$$

Don't forget the square on the distance! If you were to forget it, your units would not work out; you would end up with units of N·m, not N. As always, the units are your friend.

> **Note:** In this case *d* was the distance from the center of the Earth to the center of the Moon, but the same equation works for objects on the surface of the Earth where *d* is the distance from the center of the Earth to the center of the object. For all practical purposes, that is just the radius of the Earth. Even though *d* might make you think of "diameter", it represents "distance". At the surface of the Earth, the appropriate distance is the radius of the Earth.

Question 10: This question is very similar to Question 6, but here a rock is being accelerated downward by gravity. The formula is the same, but we use g=9.80 m/s^2 for the acceleration and the height of fall represented by the letter *h* for the distance.

$$h = \frac{1}{2}gt^2 = \frac{1}{2}\cdot(9.80\,\text{m/s}^2)\cdot(5\,\text{s})^2 = 122.5\,\text{m}$$

Both Question 6 and Question 10 could be altered on an actual Quiz or Test to ask for the time when given the distance. In that case, the formulas would be $t=\sqrt{\frac{2d}{a}}$ or $t=\sqrt{\frac{2h}{g}}$, respectively. You would then start with the equation from the Equation Sheet, and use algebra to make it into the appropriate *t*=... equation.

Question 11: This is similar to Question 9, but asks for an acceleration, not force. Know which question you are answering!

The equation to use for this is at the bottom of the first page of the Equation Sheet. It is Newton's Gravitation Law without one of the masses. This produces an acceleration which at the surface of the Earth is our gravitational acceleration, g_{Earth}=9.80 N/kg = 9.80 m/s^2 so that a mass *m* on the Earth feels a gravitational force of $F=mg_{\text{Earth}}$. In this question, we are to calculate g_{Mars} from the mass of Mars m_{Mars} and the distance from the center of Mars to its surface, *d*.

$$g_{\text{Mars}} = G\frac{m_{\text{Mars}}}{d^2} = \left(6.67\times10^{-11}\,\frac{\text{N}\cdot\text{m}^2}{\text{kg}^2}\right)\cdot\frac{6.42\times10^{23}\,\text{kg}}{(3.39\times10^{6}\,\text{m})^2} = 3.726\,\frac{\text{N}}{\text{kg}} = 3.726\,\frac{\text{m}}{\text{s}^2}$$

Just like in question 9, many students forget to square the distance, and their units would end up as N·m/kg , not N/kg . Using N=kg·m/s^2, you can see that N·m/kg is m^2/s^2 whereas N/kg is m/s^2 .

Question 12: This question is not about physics, but simply about the geometry of a circle. It provides the circle radius and asks for the distance for complete trip around its perimeter, the circle circumference. You are expected to know this from earlier schooling, but here you must also write the calculation in proper mathematical form with appropriate units:

$$d = 2\pi r = 2\pi(2\,\text{m}) = 4\pi\,\text{m} = 12.57\,\text{m}$$ (Leaving the answer as 4π m is OK.)

Question 13: This builds on Question 12. It states that the time *t* for an object to make a complete trip around a circle with a radius *r*=2 m is 3 s, and asks for the speed of the object. This is just a distance-divided-by-time question where the distance is $d=2\pi r$:

$$d = st \quad \text{so} \quad s = \frac{d}{t} = \frac{2\pi r}{t} = \frac{2\pi(2\,\text{m})}{3\,\text{s}} = \frac{4\pi\,\text{m}}{3\,\text{s}} = 4.19\,\text{m/s}$$ (Leaving the answer as $\frac{4\pi}{3}$m/s is OK.)

Question 14: This question involves some physics. It asks for the centripetal acceleration a_c of an object when it moves around a circular path of radius r=2 m at a speed of v=5 m/s. The formula for this is $a_c=\frac{v^2}{r}$ which is on the first page of your Equation Sheet 4 lines from the bottom. Writing this equation followed by the setup with values and units, we get

$$a_c=\frac{v^2}{r}=\frac{(5\,\mathrm{m/s})^2}{2\,\mathrm{m}}=12.5\,\mathrm{m/s^2}$$

This acceleration is directed inward toward the center of the circular path.

> **Note:** Here, and sometimes in other places the letter *v* is used for speed, not velocity. The letter *s* would be more sensible. In this case, however, when a quantity with direction like velocity is squared, its directional quality disappears and the result is the same as its speed squared. This follows from the rules of vector algebra which we do not use in this course.

Question 15: This final question about circular motion applies Newton's 2nd law to the acceleration around a circle to find the force necessary to maintain that circular motion. Instead of writing Newton's 2nd Law as $F=m\,a$ or $F=m\,g$, we use $F_c=m\,a_c$ where F_c and a_c refer to the centripetal force and acceleration, respectively. They are both on the 4th line from the bottom of the first page of the Equation Sheet. From the question statement, m= 2 kg and a_c = 10 m/s^2 , the answer is

$$F_c=m\,a_c=(2\,\mathrm{kg})\cdot(10\,\mathrm{m/s^2})=20\,\frac{\mathrm{kg\cdot m}}{\mathrm{s^2}}=20\,\mathrm{N}$$

Question 16: In this situation, both you and the ball are in free fall. The ball will just appear to float in front of you (assuming negligible air resistance). Gravity is rapidly accelerating both you and the ball downward together.

Question 17: This is a also a free-falling situation, but here the spaceship is moving so fast around the Earth while falling toward the center of the earth that it keeps missing the Earth, and ends up going around it nearly forever. They return to Earth by firing a rocket to slow them down enough to "hit" the Earth.

When we throw a rock horizontally, it sails forward while falling toward the Earth. If we were to throw it faster, it would go farther. Ignoring air resistance, a rock thrown with a speed of 20000 km/h would go fast enough that it would sail around the curvature of the earth and never hit the ground.

Question 18: As the Earth rotates making one turn each day, someone on the equator is actually moving at a speed of 1667 km/h in the eastern direction (toward the sunrise). Low-earth orbit satellites move much faster than that, at about 28000 km/h. If those satellites are also moving in the eastern direction, they will appear in the west and within about 12 minutes, disappear in the east. The Moon moves in that direction at a much slower speed than a person on the Earth so the Moon appears each night to move in the western direction, just a little slower than the stars appear to move.

Satellites in what is called a geostationary orbit around the earth are 42164 km from the center of the Earth, about 11% of the distance to the moon, and go in an eastern direction at a speed of 11069 km/h . At that speed, they complete one orbit each day, just like the person on the Equator completes one turn each day. As a result, satellites in a geostationary orbit appear to the person on earth to be at a fixed point in the sky. My wife and I are far enough from any city television transmitters that we must get our television via a geostationary satellite. Once we aimed our antenna at the satellite years ago, it remained pointed at it day and night, year after year. That is the advantage of using a geostationary orbit.

Weather satellites in a geostationary orbit are able to continually monitor the same part of the Earth. To them, the earth does not appear to rotate.

With that long-winded explanation, the shorter answer on the solutions sheet to this practice question should make sense. You need to remember the gist of that answer in case you see this question on a quiz or test.

Question 19: Momentum is an extremely useful quantity obtained by multiplying the mass of an object by its velocity. This definition is provided on the first page of the Equation Sheet, about 2/3 of the way down the page.

When a cannon sends its cannonball of mass $m_{cannonball}$ to the right with a velocity $v_{cannonball}$, the cannonball has a momentum in that direction of $m_{cannonball} \cdot v_{cannonball}$. The cannon that fired the cannonball will recoil with an equal and opposite momentum. Before the explosion, the cannonball was inside the cannon and together they had no momentum because they were not moving. After the explosion that shot out the cannonball, an important principle of physics called Conservation of Momentum requires that the cannon and cannonball must have equal and opposite momenta so that their total momentum remains zero. That produces the equation $m_{cannon} v_{cannon} = m_{cannonball} v_{cannonball}$ which is the key to solving this problem, but is NOT on your Equation Sheet.

The problem statement gives you m_{cannon}, $m_{cannonball}$, and $v_{cannonball}$, and you are asked to find v_{cannon}. You use your powers of algebra to rearrange the equation as follows:

$$m_{cannon} v_{cannon} = m_{cannonball} v_{cannonball}$$

Divide both sides by m_{cannon} to get

$$\frac{m_{cannon} v_{cannon}}{m_{cannon}} = \frac{m_{cannonball} v_{cannonball}}{v_{cannon}}$$

So that we end up with

$$v_{cannon} = \frac{m_{cannonball} v_{cannonball}}{v_{cannon}} = \frac{m_{cannonball}}{m_{cannon}} \cdot v_{cannonball}$$

We use the values m_{cannon} = 200 kg, $m_{cannonball}$=5 kg, and $v_{cannonball}$=10 m/s, to get the answer

$$v_{cannon} = \frac{5\,\mathrm{kg}}{200\,\mathrm{kg}} \cdot (10\,\mathrm{m/s}) = 0.25\,\mathrm{m/s}$$

It is common sense that the **cannon's recoil velocity** should be **less than** the **cannonball's velocity**. Otherwise, the pirate ship's cannons would jump right off the other side of the pirate ship into the water. Or, the person shooting a gun would be thrown back faster than the bullet. Still, I sometimes get answers with that unreasonable result because the student had the ratio of masses upside-down. Look at your answer when you get it, and see if it is reasonable.

The above explanation is more detailed than what you need to write as an answer to this equation. What is shown in the answer sheet is what is needed to get full credit.

This last question is a favorite question of mine, and you are very likely to see it more than once on the coming Quizzes and Tests!