Fall 2017 PHY2048 Exam 1 Solutions

1. 100 cm = 1 m. Therefore, cubing both sides, $(100\ \text{cm})^3 = 1\ \text{m}^3$
   $100^3 = 10^6$

2. The average velocity is $\Delta\mathbf{r}/\Delta t$, where $\Delta\mathbf{r}$ is the total displacement (which depends only on the beginning and ending locations), and Δt is the total time. Here we go 30 meters north in 20 seconds, and 40 meters south in 20 seconds, and so we have $\mathbf{v_{ave}}$ = 10/40 m/s south, but the magnitude is asked so that is just 10/40 = 0.25 m/s.

3. We differentiate the x and the y components separately to get v_x and v_y. Moving at 45 degrees to the x and y axes tells us that $v_x=v_y$ so we equate the two.
   $18t = 18t^2$
   and therefore t = 1.0

4. This is a standard trajectory problem, albeit rather computationally intense. First we need to find how long it takes to reach the goalposts in terms of the initial speed (v_0), then we can find how high the ball is at that moment.
   Working in the x-direction (horizontal), we have $D/v_0\cos\vartheta = t$, where D = 30 meters.
   In the y-direction, setting the ground to y=0, we have $y = v_0\sin\vartheta t-0.5gt^2$ where we have set "up" to be the positive y-direction, and so the uniform acceleration is –g.
   So, $y = D\tan\vartheta-0.5gD^2/(v_0^2\cos^2\vartheta)$ and $(D\tan\vartheta-y) = 0.5gD^2/(v_0^2\cos^2\vartheta)$
   $v_0^2 = 0.5*9.8*30*30/((30*0.577-3)*0.75) = 4410/10.73 = 20.3$ m/s

5. We need to set up a right-angle triangle of three velocity vectors, where the resultant vector is directly across the river, the flow (2 m/s) is downstream, and the swimmer relative to the water is the hypoteneuse and is 4 m/s. So, the resultant vector therefore has a size of $\text{sqrt}(4^2-2^2) = 3.46$ m/s. As you need to go 50 meters, this takes a time of 50/3.46 = 14.4 seconds. This is an easier version of one of the homework problems.

6. The mass in not important, nor the 2 m/s (but it is important that it is constant). The net force must be zero, so the third force must by equal and opposite to the vector sum of F_1 and F_2 which are conveniently at 60 angles so that the answer is $2*3*\cos(60^0) = 3$ N. This is a classic "Newton's First Law" question similar to one we had in class.

7. This immediately can be seen as a "Newton's 3rd Law" question. The action and reaction must be equal in magnitude. (There are all sorts of more complicated methods using momentum conservation, F=ma, etc. Of course, they all yield the same answer as they must). This is probably easier than the H-iTT question we had in class concerning the car pushing another, but the principle is the same.

8. Standard kinematics with constant acceleration (g, down). Let up be positive and y=0 be the ground level.
   Use $y=y_0+v_0t+0.5at^2$
   Ball 1: $y = 40 -0.5*9.8*t^2$

Ball 2 $y = 0 + 20t – 0.5*9.8*t^2$
Set them equal to each other, and the term in t^2 disappears.
40 = 0 + 20t and so t = 2 seconds.
Now we have when they hit each other, we can use either equation to find where. Doing both is a good check.
y = 40-0.5*9.8*4 = 20.4 = 0 + 40 – 0.5*9.8*4 = 20.4 meters

9. First we need to do the part in the brackets. That give 4**k** (using the right-hand rule).
Now we have 2**i** x 4**k** = -8**j** (probably the hardest part of the question is getting the minus sign).

10. This is 3D relative motion question, and was thought in advance to be the hardest question on the exam. In the direction of motion, the velocity is a constant 4 m/s. In the direction at right angles, horizontally, the velocity component is a constant 4 m/s. For the vertical direction, life is more complicated. How long does it take to fall? We can use $v^2-v_0^2 = 2a\Delta y$ where I use y for the vertical. So v=sqrt(2*9.8*2) = 6.2 m/s. So now we add the 3 components to get the speed = sqrt(6.2^2+ 4^2 +4^2) = 8.4 m/s.

11. AFTER the kick, there are no forces (in the plane of the ice), so it MUST go in a straight line. As there was an x (i.e. left-right) component before the kick and the kick was orthogonal to this direction, there must still be an x-component. So that makes (1) the only possibility.

12. The bathroom scale senses the force it is supplying (the “normal” force), and then gives you the answer in kilograms. First let’s find the acceleration by differentiating the equation and putting t = 1. a = 8-8t, at t=1 a = 0. So there is no acceleration at that moment. So if there is no acceleration, there is no deviation from the regular situation of it being stationary (all inertial rest frames have the same physics) in which case the normal force is equal in magnitude to the force on you from gravity. So the answer is 40 kg.

13. Look at the forces that are applied to the car at the moment that it is at the bottom of the circle. There is mg down. There is the unknown force F which is up. These forces combine to give the centripetal force which is given by mv^2/R up.
So, with up as positive, $F-mg=mv^2/R$ and so F = 200g + 200*5*5/10 = 1960 + 500 = 2460 N.

14. The normal force must be such that there is no net force perpendicular to the slope. The forces on the block in this direction must be the component of F perpendicular to the slope, gravity, and the unknown normal force. In case 1 this gives $Mg + F\sin\vartheta$, in the second it gives $Mg- F\sin\vartheta$ in the third it is $Mg\cos\vartheta$. There is no information about whether there is friction and whether it moves. It is not important to know about the forces parallel to the surface, just the ones normal to it.

15. Rather easy question. Add the three components separately and we get 6**i**+6**j**+6**k** and to find the magnitude we have to add them in quadrature. Sqrt(36+36+36) = 10.3

16. Clearly you have to read the question carefully. It asks for the force on the driver. You know the force on the driver because it is F=ma, where "a" is the centripetal acceleration which is down and of magnitude v^2/R.
    Therefore the F = 50*20*20/50 = 400 N

17. The first task is to see if it moves. Note that the relationship connecting the force with the static coefficient of friction is an inequality not an equation. The maximum value of the static friction force is mgx0.7, as the normal force has a magnitude the same as the gravitational force, i.e. it is mg. This is clearly above the applied force, so it does not move. The friction force is thus the same magnitude as the applied force.

18. A classic physics set-up which you have seen before. Look at the forces on block B and take down to be positive.
    $M_B g - T = M_B a$
    Then look at the second one. Clearly if it moves (you are told this), so kinematic friction applies and the force to the left is $M_A g$*0.6. Therefore we have:
    $T - M_A g * 0.6 = M_A a$

    Add the two equations and we have that a=9.8*(8-6*0.6)/(8+6) = 9.8*3.2/14.=3.1 m/s^2

19. The most important point to note is that the acceleration is not constant, so we cannot use the regular kinematic equations. Instead, we need to integrate with respect to t and find the the distance moved is $At + Bt^2/2 + Ct^3/3$ integrated between 0 and 2 (there are no negative terms nad so there is no problem with the wording implying distance rather than displacement).
    That gives 2+ 4 + 8/3 -0 -0 -0 = 6.7 meters

20. Why sadistic? Because I don't see the fun in experiencing accelerations of this size. However, the question itself is not sadistic, it is one of the easier ones. After the release, the velocity is whatever the velocity was before the release. However, accelerations are caused only by forces, and after the release the only force is due to gravity and this is regular value and is DOWN (i.e. negative in this coordinate system).