Q 1. Newton's Third Law. The action-reaction pair are always acting on different bodies, and is the same regardless of their masses.

Q 2. You need to add two vectors (the boat in still water and the water flow) to get the resultant which is where she really goes. Taking y to be across the river (i.e. up on the paper), the boat in still water goes at 2sin(theta)**I** + 2cos(theta)**j** , whereas the river goes at -1**i**. The resultant is in the y-direction. So we can look at the x-components of the two vectors we are adding and say:

2sin(theta)**i**– 1**i** = 0

sin(theta) = 0.5, and so theta = 30^0

Q 3 The speed on an x versus t graph is the magnitude of the slope. Graph A has a slow speed (small negative slope) to begin with, but it gets bigger as time goes on. Note that had we said "velocity" then this would not work, as the velocity in graph A is negative and becomes more negative with time.

Q 4. This is actually just Newton's 2^{nd} Law, F=ma, together with the acceleration when traveling at uniform speed in a circle, of $a= v^2/R$.

$F=mv^2/R$ = 200*5*5/10 = 500 N.

Q 5. The bathroom scale senses the normal force on you, and divides by g to make it a mass which it tells you. Here we note that your acceleration, a = dv/dt = 4-4t = -4 m/s^2 at t=2 s. So, therefore, by Newton's 2^{nd} Law, F = ma, the net force on you is -4m (the minus sign indicating down). This comprises the normal force (up) and the gravitational force (down)

F_N – mg = -4m and so F_N = m(g-4) = 5.8m

The scale therefore reads (5.8/9.8)m = 23.7 kg

Note that a common mistake was to put 40 kg, presumably because at t = 2 s the velocity is instantaneously zero. However, it is not the velocity that matters, it is the acceleration.

Let's hope the elevator does not continue with this equation too long, because soon you will be in free-fall!

Q 6. This is very similar to an example in class, and also an example on the second test. The key is that the center-of-mass of the grenade follows the conventional laws of kinematics. In 2D trajectories, the two dimensions can be considered to be independent. We are not worried at all about "y". The x position of the center of mass is simply x = vt = 10t = 20m (at t=2 seconds). As it is in two equal halves, one is as far away from the center of mass as the other. So if one is at 25 meters, the other is at 15 meters (everything measured in x). Neither the y motion, nor the time of the explosion, are important.

Q 7. A very simple version of "the ladder problem". The ladder in Exam 2 was difficult, but this wasn't. Take torque around the pivot point. There are two forces giving torque, the force of the wall which we take to be positive, and the force due to the mass. They must add to zero to have stability. As the question simple asks for the torque due to the wall, this must be equal and opposite to the torque due to the mass which we can calculate. It is given by torque = (force x perpendicular distance) and we note that the mass acts as if it is concentrated at the center of mass.

So torque = 1.5(mg), and as (mg) = 100 N, so the torque = 150 N.m

Q 8. We must remember that angular momentum of a moving point-like object, with respect to a position, is given by **L** = **r** x **p** . Its magnitude is easiest to calculate as (perpendicular distance) x (mv)

$= 1 \sin(60^0) \times 2 \times 5 = 5\sqrt{3}$

Q 9. This is reminiscent of an HiTT question in class and also a question on exam 2, except this one also involves the parallel axis theorem.

For a stick around its center of mass (and perpendicular to the stick), $I = (1/12)ML^2$

Add to that a term due to the parallel axis theorem, the extra is $I = Mh^2$ where $h = (L/4)$, so

$I_2 = (1/12)ML^2 + M(L/4)^2 = 0.148\ ML^2$

Q 10. Work = **F.d** as all directions are the same that is simply Fd, and as the velocity is constant that is Fvt. As the velocity is constant, the NET force must be zero, and so the applied force must be equal and opposite to the frictional force which we know as $\mu_k Mg$. So, therefore, the work done is $\mu_k Mgvt$.

Q 11. There was a homework question very like this one. We have to be careful about which distances we are talking about. Let's call the total distance between them, r, so they are going in a circle that has a radius of r/2.

F=ma, so $Gm_1m_2/r^2 = mv^2/(r/2)$ and so $T^2 = (2*\pi^2r^3)/(Gm_2)$

Now let's call the earth-sun distance R and the earth's mass M.

The earth's period is given by $GMm/R^2 = Mv^2/R$ and so $T^2 = 4*\pi^2R^3/(GM)$

So, putting r = 6R and $m_2 = 9M$

We have (planet's period)^2/(earth's period)$^2 = 6^3/(2*9) = 12$.

And the ratio of the planet's period to the earth's period is sqrt(12) = 3.5

(note that Kepler's Laws were not put on the formula sheet, but are unnecessary and can be misleading. They refer to a planet going around the sun – here we have two stars revolving around a point in the center. Newton's Universal Law, together with his basic Laws of Motion will never lead you astray).

Q 12. The mechanical energy at the end can be zero (PE is defined to be zero a long way away, and the KE can also be zero). Mechanical energy is conserved. Therefore it can start with zero (which will comprise a load of KE, and negative PE as defined by the question).

Q 13. By Newton's universal law of gravity, once you are on the surface or above the surface of a planet, the acceleration is inversely proportional to the square of the distance to the planet's center. Therefore to get to (1/4) of the acceleration at the surface, you need to be twice as far away from the center, so the answer is 5000 km.

Q 14. Newton's Universal Law of Gravity gives the force. Newton's Second Law gives F=ma, and for an object going in a circle, $a = v^2/R$. Putting these together:

$F = GMm/R^2 = mv^2/R$ and therefore $v^2 = GM/R$. and so $M = Rv^2/G$

We are not given v, but we are given the period, and v = Circumference/Period = $(2\pi R)/T$

So, $M = 4\pi^2R^3/GT^2 = 1.14 \times 10^{22}$

Q 15. As the block moves up and down on the piston, it will have the same acceleration as the piston EXCEPT if the piston's downward acceleration exceeds g, because then it lose contact. So we need to find the situation where the piston's acceleration (magnitude) exceeds g. Homework 15 had a similar problem.

So, lets look at y as a function of t.

$y(t) = 0.049 \sin(\omega t + \phi)$

$dy/dt = 0.049\ \omega\cos(\omega t + \phi)$

$d^2y/dt^2 = -0.049\omega^2\sin(\omega t + \phi)$ with a maximum value of $0.0495\ \omega^2$

So we set that equal to g and find that $\omega^2 = 9.8/0.049$

$\omega = 14.1$ rad/s

But we have to change to Hz, so that is 14/6.28 = 2.25 Hz

Q 16. We know the equation for the angular frequency of a "physical oscillator" is $\omega=\sqrt{(mgh/I)}$

Here, h = 0.2 m

$I = 0.5mR^2 + mh^2$ by the parallel axis theorem so, therefore $\omega=\sqrt{(mgh/(mR^2 + mh^2))}$

And the m cancels (which it must).

Put in the numbers and we get that $\omega=5.15$ rad/s

Period = $2\pi/\omega$ = 1.2 s

Q 17. It may look complicated, but it really isn't. If we differentiate y, we get dy/dt, and the maximum is when the angular term = 1. Therefore the max is 1.77*9.02*3.14159 cm/s = 0.5 m/s

Q18. Wave speed is given by $\sqrt{(T/\mu)} = \sqrt{(117/0.00553)}$ = 145.4 m/s

The wavelength is clearly, from the diagram, 0.914*(2/3) = 0.61 meters

So the frequency is speed/wavelength = 145.4/0.61 = 239 Hz

Q 19. An intensity minimum means that the two waves are (some integer times) half-a-wavelength out of phase. So difference in the two paths must be half-a-wavelength. So the difference is 20 cm.

(3.14159-2)r = 20 and r = 17.5 cm

Q 20. We look at the formula on the formula sheet, and note that f_{obs} = 1590 Hz, f_s = 1600 Hz, v_{sound} = 330 m/s , the detector is the bike and we have to change to m/s , v_D = 20*1000/(60*60) = 5.5 m/s.

$1590 = 1600*(343+5.5)/(343+V_{source})$

$343+V_{source} = 350.6$ and so $V_{source} = 7.6$ m/s

Note that the sound itself is going in the opposite direction to both the source and the detector, hence the minus signs in the formula both becoming + signs.