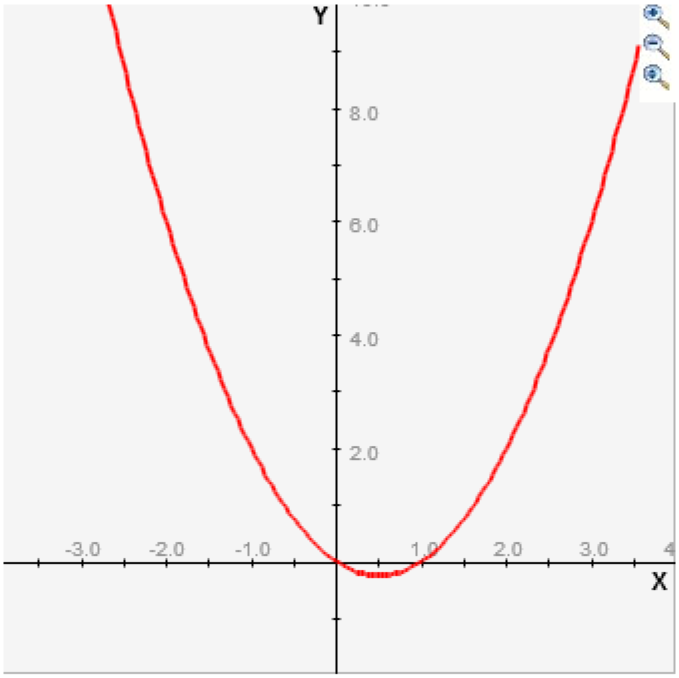
1. 

Drawing the graph is always a good idea. Here we see U (on the y-axis). If we release something at x=0, where y=0, it will "fall" down to the lower potential (minimum at x=0.5), and then continues until U=0 again (which is at x=1), then it will oscillate. Therefore the answer is x = 1.0

You don't need to draw the graph so long as you realize that the function has no maxima to confuse the issue. You can just solve U(0) = 0 = $x^2 - x = x(x-1)$, which give gives x=1 as the second solution. It has to end at the same value of U as it began.

2. $\Delta U + \Delta K = 0$ for a conservative force. In this case, that is the same as saying that the potential energy lost is equal to the kinetic energy gained. Therefore $mg(h_1-h_2) = 0.5mv^2$ and so we get that v =sqrt($2g(h_1-h_2)$)

3. Potential energy lost is equal to kinetic energy gained. If it is at an angle of 37^0 then the distance dropped in the vertical direction is $L*(1-\cos37^0) = L*0.2$ meters

   Therefore v (at bottom) is given by $0.5mv^2 = 0.2Lmg$
   $v^2 = 0.4Lg\ m^2/s^2$

   Now, look at the tension in the rope. The acceleration is v^2/R where R is the length of the rope (L), so $T-mg = mv^2/R$
   $T = mv^2/L + mg = m0.4Lg/L + mg = 1.4mg = 1.4*5*9.8 = 68N$

   A common mistake was to forget about the mg part.

4. This is best done by impulse. The change in momentum is equal to (average force)x(time)

   Remembering that momentum is a vector, $\Delta(mv)$ = 0.25*25-(-0.25*30) kg.m/s (where we have defined up to be positive). Therefore 0.25*55 = $0.0025F_{ave}$
   F_{ave} = 5500 Newtons

5. During the collision kinetic energy is not conserved but momentum has to be. Therefore we will use momentum conservation to find the final velocity of the block, and then find its kinetic energy.
   (Momentum before = 0.02*350) = (Momentum after = 0.02*150 + $0.75v_f$)
   v_f = 4/0.75 m/s. So the energy of the block is 0.5*0.75*16/(0.75^2) = 8/0.75 = 11 J

6. We don't know if this is an elastic collision or not, but we do know that momentum is conserved. So, taking the initial direction of the ball as positive:
   0.35v + 0 = -0.35*8 + 70*0.1
   v = 12 m/s

7. Here we have an elastic collision. We can work out the speed of the ball just before the collision using energy conservation mgh = $0.5mv^2$ where h is the distance dropped (0.5 meters), and so v = sqrt(2*9.8*0.5) = 3.13 m/s.
   Now for the collision. We can find v_{2f} where v_{2i} = 0. Looking at the equation sheet:

   v_{2f} = (2*0.75)*3.13/(0.75 + 4) $\approx$ 1.0 m/s

8. As above, except we are asked for the first ball's final velocity. That is
   v_{1f} = (-3.25)*3.13/(0.75 + 4) $\approx$ -2.1 m/s (the minus sign indicates that the ball rebounds).

9. Because the decrease is uniform, we know that the average revs/minute is half way between the beginning and ending values, i.e. 350 rev/minute = 350/60 rev/second. So in 3 seconds that is 1050/60 = 17.5 revolutions.

10. It changes from 3 rad/s to 1 rad/s in 5 seconds, so will take a further 2.5 s to come to a halt. Therefore the answer is 7.5 seconds.

11. N.b. This question was changed to make clear that it was the angular acceleration of the flywheel that is asked for – it makes no sense otherwise.
    Here we can do a free diagram of the block, and say that mg-T = ma. Therefore,
    T = m(g-a)
    We cannot solve yet as we have too many unknowns.

Now for the flywheel. We have the torque equation, $\boldsymbol{\tau} = \mathbf{r} \times \mathbf{F} = I\alpha$. Here the torque is = RT as the angle between **r** and **F** is a right angle, the lever arm is the radius of the flywheel (0.20 meters, be careful as it is the diameter that is given), and the force is the same quantity as we have already, that is T.

So we have $RT = I\alpha$, and substituting T from above $mR(g-a) = I\alpha$

Still we have too many unknowns, but we know that there is a relationship between the acceleration of the block and the angular acceleration of the flywheel, and that is: $R\alpha = a$

So, therefore, $mRg - mR^2\alpha = I\alpha$ and so $\alpha(I + mR^2) = mRg$

This gives $\alpha = 16*0.2*9.8/(0.5 + 16*0.2*0.2) \approx 28$ rad/s

(n.b. this gives $a = 0.2*28 = 5.6$ m/s^2) which is quite reasonable, whereas most of the answers are not reasonable as they would imply $a > g$ which is not possible in this set-up).

12. Here we have to set up two free body diagrams and remember that the Tension in the rope to the left and right of the pulley is NOT the same (because the pulley has rotational inertia and the system is accelerating – it needs a difference in Tensions to accelerate it).

    First the left mass, which is called mass 1 and is going up, so we take up as positive.

    $T_1 - m_1g = m_1a$

    Now the right one, which is going down, but has the same value of a. We take down as positive because this one goes down as the other one goes up.

    $m_2g - T_2 = m_2a$

    Two equations so far, but 3 unknowns. The third equation is the torque equation, and (remembering that the angle between **r** and **F** is a right angle):

    $(T_2 - T_1)R = -I\alpha$ (where angular acceleration is positive when counter-clockwise)

    But again we have $a = -R\alpha$, so that is: $(T_2 - T_1)R^2 = Ia$

    So now we have 3 equations and 3 unknowns.

    Adding the first two equations, we get that

    $T_1 - T_2 + (m_2 - m_1)g = (m_1 + m_2)a$, then substituting in the result of the third equation:

    $(m_2 - m_1)g - Ia/R^2 = (m_1 + m_2)a$, and so $I = [(m_2 - m_1)g - (m_1 + m_2)a]R^2/a$

    $I = [0.5*9.8 - 1.5*0.5]*0.25*0.25/1.0 \approx 0.21$ kg.m^2

13. Each of the particles contributes mr^2 to the total rotational inertia, where r is the distance to the axis of rotation.

    So we have $I = 2(ma^2) + m(2a)^2 = 6ma^2$

14. This is energy conservation, remembering that we have to take into account the energy associated with the rotation around the axis as well as the energy associated with the movement of the center-of-mass.

    $0.5mv^2 + 0.5I\omega^2 = mgh$, where h is height to which it goes.

For a solid sphere we know that $I = (2/5)mR^2$ and we also know that rolling without slipping has $|v| = R\omega$

So $0.5mv^2 + 0.5*0.4mv^2 = 0.7mv^2 = mgh$, and so $h = 0.7*4.0*4.0/9.8 = 1.14$ meters.

But the question asks for how far along the incline, so that has to be divided by $\sin(30^0)$ to give 2.3 meters.

15. Angular momentum conservation. The angular momentum before is the same as that afterwards. The child has no rotational inertia when at the center.

    $(I + MR^2)\omega = I\omega_f$

    $\omega_f = (1 + MR^2/I)$

16. Everything is in equilibrium so we know that there are no net forces in any direction and that there are no net torques around any pivot point. If we take torque around the place where the strut is attached to the wall, and we call the strut length L, we get

    $T * L \sin(30^0) = MgL + mgL/2$

    And that gives us $T = 2*(525)g$ N (because we know the sine of 30^0 is 0.5)

    Now, we can equate vertical forces (up is positive)

    $T*0.5 + F = 550*g$

    $F = 25g = 240N$ (note the fact that it is positive means that the wall is helping support the beam = this is not completely obvious).

17. This can be done in one step by working out the torque around the OTHER end of the scaffold. The net torque has to equal zero, and it has torques due to two competing forces, the tension near the person, and the weight of the person.

    $Mg(7.2) = T(8.0)$

    $T = 706$ N

18. As above. $Mg(0.8) = T(8.0)$, and so $T = 78$ N

19. There are many short cuts to doing this problem. We should remember for mass-less pulleys (and also non-accelerating pulleys, in this case the pulley is both), then the tension in the rope either side of the pulley is the same. Equating forces on the right-most pulley, we get that $T=W/2$ in the rope circling that pulley.

    Now look at the middle pulley, it is being pulled down by W/2, so the tension in the rope circling it is W/4. That rope then extends to where the F is drawn, so $F = W/4$.

20. $F/A = Y(\Delta L)/L$

    $\Delta L = FL/YA = 10*9.8*10/(1.2*10^{11}*3.14159*0.001*0.001)$

    $= (9.8*10^{-3})/(1.2*3.14159)$

    $= 2.6$ mm

21. There are many ways of doing this, but here is one.
    $\Delta U + \Delta K + \Delta E = 0$, where ΔE is due to friction (which ends up as heat).
    $\Delta E = +0.25mgL$ (this is positive, the heat changes)
    $\Delta U = -mg*(6-2)$ (this is negative, PE is lost)
    $\Delta K = mg(4-0.25L) = 9.8m$ J (and it's positive, which is not at all obvious until you work it out)
    But it starts off with $K = 0.5m*6^2 = 18m$ J
    So it ends with 27.8m Joules
    $27.8m = 0.5mv^2$ and so: $v = \text{sqrt}(55.6) = 7.5$ m/s

22. Angular momentum conservation strikes again. If their final separation decreases by a factor of three, their rotational inertia decreases by a factor of 9. Thus their angular velocity goes up by a factor of 9, and so the answer is 60/9 = 6.7 seconds. (They are now probably going uncomfortably fast…….)