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Solutions of problems set # 1 **Physics 168**

1. By measuring several people's arms we can estimate that a cubit is about a half of a meter. Hence, the dimension of Noah's ark would be 150 m long, 25 m wide, 15 m high. The volume is the about 5.6×10^4 m^3.

2. See slides.

3. See slides.

4. By definition the instantaneous velocity is $v_x(t) = \lim_{\Delta t \to 0} \frac{\Delta x}{\Delta t} = \lim_{\Delta t \to 0} \frac{x(t+\Delta t) - x(t)}{\Delta t}$. Now, $x(t) = 5t^2$ and $x(t + \Delta t) = 5(t + \Delta t)^2 = 5t^2 + 10t\Delta t + 5\Delta t^2$, so $\Delta x = 10t\Delta t + 5\Delta t^2$. Since $\langle v_x \rangle = \frac{\Delta x}{\Delta t} = 10t + 5\Delta t$, we obtain $v_x = \lim_{\Delta t \to 0} \langle v_x \rangle = 10t$.

5. Choose downward to be the positive direction and $y_0 = 0$ to be at the top of the Empire State building. The initial velocity is $v_0 = 0$ and the acceleration is g. (a) $y = \frac{1}{2}gt^2$ and so $t = \sqrt{2y/g} \approx 8.8$ s. (b) $v = gt = 86$ m/s.

6. See slides.

7. See slides.

8. See slides.

9. Choose downward to be the positive direction and $y_0 = 0$ to be the height from which the stone is dropped. Call the location at the top of the window $y_{\rm w}$ and the time for the stone to fall from release to the top of the window $t_{\rm w}$. Since the stone is dropped from rest we have $y_{\rm w} = y_0 + v_0 t_{\rm w} + \frac{1}{2}at_{\rm w}^2 = \frac{1}{2}gt_{\rm w}^2$. The location of the bottom of the window is $y_w + 2.2$ m and the time for the stone to fall from release to the bottom of the window is $t_w + 0.28$ s. Since the stone is dropped from ret we have $y_w + 2.2 \text{ m} = \frac{1}{2}g(t_{\rm w} + 0.28 \text{ s})^2$. Substituting the first expression for y_w into the second one we have $\frac{1}{2}gt_{\rm w}^2 + 2.2 \text{ m} = \frac{1}{2}g(t_{\rm w} + 0.28 \text{ s})^2$, which leads to $t_{\rm w} = 0.662$ s. Using this time in the first equation we have $y_{\rm w} = \frac{1}{2}gt_{\rm w}^2 = 2.1$ m.

10. For the falling rock, choose downward to be the positive direction, and $y_0 = 0$ to be the height from which the stone is dropped. The initial velocity is zero, the acceleration is $a = g$, the displacement is $y = H$, and the time of fall is t_1. Then $H = y_0 + v_0 t_1 + \frac{1}{2}at_1^2 = \frac{1}{2}gt_1^2$. For the sound wave use the constant speed equation $v_s = H/(T - t_1)$, which can be rearranged to give $t_1 = T - H/v_s$, where $T = 3.2$ s is the total time elapsed from dropping the rock to hearing the sound. Insert this expression for t_1 into the equation for H and solve for H. It follows that $H = \frac{1}{2}g(T - H/v_s)^2$, yiedling $\frac{g}{2v_s^2}H^2 - \left(\frac{gT}{v_s} + 1\right)H + \frac{1}{2}gT^2 = 0$. Solving for H we have $H = 46$ m and/or $H = 2.57 \times 10^4$ m. If the larger number is used in $t_1 = T - H/v_s$, we obtain a negative

time of fall, and so the physically correct answer is $H = 46$ m.

11. For the free falling part of the motion, choose downwards to be the positive direction and y_0 to be the height from which the person jumped. The initial velocity is $v_0 = 0$, the acceleration is $a = g = 9.8$ m/s^2 and the location of the net is $y = 15$ m. Find the speed upon reaching the net $v = \pm\sqrt{2ay} = 17.1$ m/s. The positive root is selected since the person is moving downard. For the net strecthing part of the motion choose downward to be the positive direction, and $y_0 = 15$ m to be the height at which the person first contact the net. The initial velocity is $v_0 = 17.1$ m/s, the final velocity is $v = 0$, and the location of the strectched position is $y = 16.0$ m. Then we have a system of two equations: $y = y_0 + v_0 t + \frac{1}{2}at^2$ and $v = v_0 + at$. From the second expression we first get $t = -v_0/a$ and then substituting this relation for t in the first equation we obtain $a = -v_0^2/[2(y - y_0)] = -150$ m/s^2.

12. Choose downward to be the positive direction, and $y_0 = 0$ to be the height of the bridge. 007 has an initial velocity $v_0 = 0$, an acceleration of g, and when reaching the truck will have a displacement of $y = 12$ m $-$ 1.5 m $= 10.5$ m. You can now find the time of fall using $y = y_0 + v_0 t + \frac{1}{2}at^2$ which leads to $t = \sqrt{2y/a} = 1.47$ s. If the truck is approaching at $v_{\mathrm{tr}} = 25$ m/s then he needs to jump when the truck is a distance away given by $d_{\mathrm{tr}} = v_{\mathrm{tr}} t = 36.75$ m. Convert this distance into poles $d_{\mathrm{tr}} = (36.75$ m$)(1$ pole$/25$ m$) = 1.5$ poles.

13. Choose downward to be the positive direction and $y_0 = 0$ to be at the start of the pelican's dive. The pelican has an initial velocity $v_0 = 0$ and an acceleration $a = g$. The final location of the pelican will be at $y = 16.0$ m. Find the total time of the pelican's dive using $y = y_0 + v_0 t + \frac{1}{2}at^2$. This yields $t_{\mathrm{dive}} = \sqrt{2y/a} = 1.81$ s. The fish can take evasive action if he sees the pelican at a time 1.81 s – 0.20 s = 1.61 s into the dive. Now, you can find the position of the pelican at that time: $y = y_0 + v_0 t + \frac{1}{2}at^2 = 12.7$ m. Therefore, the fish must spot the pelican at a minimum height from the surface of the water of $\Delta y = 16$ m – 12.7 m = 3.3 m.

14. See slides.

15. See slides.