Physics 151 Exam #1 Solutions

1. (7 points) The acceleration of gravity on the moon is 5.33 ft/s². Calculate the value of this quantity in units of in/hr². State your answer in scientific notation with 3 significant figures.

\[
\frac{5.33 \text{ ft}}{s^2} \left( \frac{12 \text{ in}}{1 \text{ ft}} \right) \left( \frac{3600 \text{ s}}{1 \text{ hr}} \right)^2 = 8.29 \times 10^8 \text{ in/hr}^2
\]

2. (8 points) Estimate how many times a typical person’s heart beats during their lifetime. Clearly state any assumptions/estimations you are making to do this. State your answer to the nearest order of magnitude.

Assume:
Rate of Heartbeat: 80 beats/min
Average Lifetime: 75 years

\[
80 \text{ breaths/min} \left( \frac{60 \text{ min}}{1 \text{ hr}} \right) \left( \frac{24 \text{ hr}}{1 \text{ day}} \right) \left( \frac{365 \text{ day}}{1 \text{ yr}} \right) \left( \frac{75 \text{ yr}}{1 \text{ lifetime}} \right) = 3.15 \times 10^9 \text{ breaths/lifetime} \approx 1 \times 10^9 \text{ beats/lifetime}
\]

3. (5 points) Three projectiles (a, b, and c) are launched with the same initial speed but with different launch angles, as shown in the figure below. List the projectile in order of increasing

(a) horizontal component of initial velocity

\[ \text{c b a} \]

(b) time of flight.

\[ \text{a b c} \]

4. (15 points) When driving you see a traffic light turn red and you apply the brakes until you come to a stop. If your initial speed was 12 m/s, (a) what was your average velocity during braking? (b) Suppose the car comes to rest in 35 m. How much time does this take?

a) Since you started at 12 m/s and end at a stop (0 m/s), your average velocity must be 6.0 m/s. It must be positive since it is in the same direction as the original 12 m/s.

b) The time involved must be 35 m / 6.0 m/s = 5.8 s.
5. (20 points) Calculate each of the following quantities (with units) based on the velocity-time graph below. The particle is at the origin of our coordinate system at time \( t = 0 \).

a. (3 points)
\[
\mathbf{x}(4) = 20 \text{ m}
\]
Area under curve: \( (5 \text{ m/s})(4 \text{ s}) = 20 \text{ m} \)

b. (3 points)
\[
\mathbf{x}(10) = 75 \text{ m}
\]
Area of rectangle + area of little triangle
Rectangle area = \( (5 \text{ m/s})(10 \text{ s}) = 50 \text{ m} \)
Triangle Area = \( \frac{1}{2}(\text{base} \times \text{height}) \)
= \( \frac{1}{2}(4\text{ s})(10 \text{ m/s}) = 20 \)
Total distance traveled = \( 60 \text{ m} + 20 \text{ m} = 70 \text{ m} \)

c. (3 points)
\[
\mathbf{v}(10) = 15 \text{ m/s}
\]
Read directly off of graph. Note that at time \( t = 6 \) the value of velocity is \( 5 \text{ m/s} \) and at \( t = 12 \) it is \( 20 \). Thus at \( t = 10 \text{ s} \) velocity must be \( 15 \).

d. (3 points)
\[
\mathbf{a}(2) = 0 \text{ m/s}^2
\]
Slope at \( t = 2 \text{ s} \).

e. (3 points)
\[
\mathbf{a}(10) = 2.5 \text{ m/s}^2
\]
Slope at \( t = 10 \text{ s} \). Compare points (6,5) and (12,20)

\[
slope = \frac{\text{rise}}{\text{run}} = \frac{v_2 - v_1}{t_2 - t_1} = \frac{20 \text{ m} - 5 \text{ m}}{12 \text{ s} - 6 \text{ s}} = 2.5 \text{ m/s}^2
\]

f. the average velocity between time \( t = 0 \) and \( t = 10 \)

\[
\text{velocity} = \frac{\text{displacement}}{\text{time}} = \frac{70 \text{ m}}{10 \text{ s}} = 7.0 \text{ m/s}
\]

Answer: \( 7.0 \text{ m/s} \)
5. (10 points) A girl runs straight off a cliff with a horizontal velocity of 4 m/s and falls for 2 sec before landing on the ground. Circle the (closest) correct answer to each of the following questions.

<table>
<thead>
<tr>
<th>Question</th>
<th>Options</th>
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</thead>
<tbody>
<tr>
<td>What is her horizontal component of velocity just before she hits the ground?</td>
<td>0 m/s 2 m/s 4 m/s 8 m/s 20 m/s</td>
</tr>
<tr>
<td>How far from the base of the cliff does she hit the ground?</td>
<td>0 m 4 m 8 m 10 m 20 m</td>
</tr>
<tr>
<td>What is her vertical component of velocity just before she hits the ground?</td>
<td>2 m/s 4 m/s 8 m/s 10 m/s 20 m/s</td>
</tr>
<tr>
<td>About how high was the cliff?</td>
<td>5 m 10 m 15 m 20 m 40 m</td>
</tr>
<tr>
<td>What is the magnitude of her acceleration just before she hits the ground?</td>
<td>0 m/s 5 m/s 10 m/s 10 m/s² 20 m/s²</td>
</tr>
</tbody>
</table>

6. (15 points) The pilot of an airplane wishes to fly due north but there is a 75.0 km/hr wind blowing toward the east. (a) In what direction should the pilot head her plane if its speed relative to the air is 310 km/hr? (b) What is the effective speed in the northern direction? **Draw a diagram with map directions given that illustrates your result.**

Note that the pilot must fly toward the west (into the wind) to be blown in a straight northern direction.

\[
\theta = \sin^{-1} \left( \frac{75.0}{310} \right) = 13.6^\circ \text{ west of north}
\]

\[
speed_{\text{north}} = \sqrt{\left( 310 \text{ km/hr} \right)^2 - \left( 75.0 \text{ km/hr} \right)^2} = 301 \text{ km/hr}
\]
8. (5 points) A 50-kg man is riding in an elevator. Under certain conditions, his apparent weight (i.e. the magnitude of the force between his feet and the elevator floor) is less than his weight. Under which conditions is this true?

<table>
<thead>
<tr>
<th>True</th>
<th>False</th>
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<tr>
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9. (15 points) A force of magnitude 7.50 N pushes three boxes with masses $m_1 = 1.30$ kg, $m_2 = 3.20$ kg, and $m_3 = 4.90$ kg, as shown in the figure below. Find the contact force between boxes 1 and 2. Ignore friction.

We can determine the acceleration from looking at the total mass of the 3 boxes.

$$a = \frac{F}{m_{\text{total}}} = \frac{(7.50 \text{ N})}{(9.40 \text{ kg})} = 0.798 \frac{m}{s^2}$$

The horizontal force that box 1 exerts on box 2 must be responsible for the acceleration of both boxes 2 and 3. The combined masses of boxes 2 and 3 is 8.1 kg. Thus,

$$F_{12} = m_{2,3}a = (8.10 \text{ kg}) \left(0.798 \frac{m}{s^2}\right) = 6.46 \text{ N}$$

Or you can think of some of the force being “used up” to accelerate box 1 and the remainder must push against box 2.

$$F_{12} = F_d - m_1a = (7.50 \text{ N}) - (1.30 \text{ kg}) \left(0.798 \frac{m}{s^2}\right) = 6.46 \text{ N}$$