ISP220, fall 2021: In-Class Project #2; 15 pts + 15 pts (!!) extra

Quarks, Spacetime, and the Big Bang

Thursday, September 9, 2021

Name: KEY Student # __________

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1 Bye-Bye Beetle: 3 pts

My wife's red beetle has a mass of 800 kg. I don't like it...getting in and out is hard with my knees. I'm working on a deal with SpaceX to launch it beyond the atmosphere where there is no friction. After I get it up there, I am able to then apply a force to it of 1600 Newtons, what acceleration can I impart to it?

$a =$ 2 m/s^2

$\frac{1600 \text{ N}}{800 \text{ kg}} = 2 \text{ m/s}^2$

Figure 1: That red VW beetle.

2 Hammer Throw: 12 pts

Remember this:

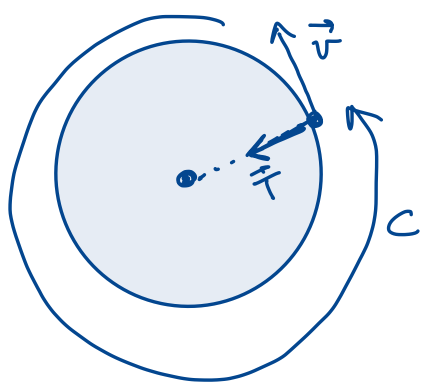
Figure 2: 2015 Big Ten Outdoor Track and Field Championship Hammer Throw champion, MSU athlete Cynthia Watt (Photo by Matt Mitchell).

In Men's Hammer Throw at the Olympics a 16 pound ball (the hammer) is attached to a wire that's approximately 4 ft long and whirled around a circle and let go. Olympians spin their bodies incredibly fast—during their last "wind" before release they spinning at less than a second per revolution.

For the men's sport, given a few facts we're going to find out the speed of the ball, the force that the athlete must exert in order to keep the ball moving in a circle, and what fraction of the weight of the ball that centripetal force must be.

Draw a picture that shows the circle that the ball follows looking down from above. Show athlete at the center, the chain connecting the athlete to the hammer, and the hammer as a...well, a ball. Label the **radius, R**; the **circumference, C**; the **velocity vector,** $\vec{v}$, at the position of the ball; and the **force of tension vector in the chain, T**:

Answer 1 point: looking down from above:



Here's what we know for Olympic Men's Hammer throw:

- The ball's weight is 16 pounds.
- The time for the last wind, the last rotation, is 0.3 seconds.
- The radius of the chain is 4 ft.

What is the relationship for the circumference of a circle, C in terms of the radius, R?

Answer 1 point: $C =$ $2\pi R$

The speed of the ball is just the distance that it travels in a revolution divided by the time that it took, right? After all, $v = C/t$.

What is the circumference of the ball's path in meters ($\pi = 3.14$)?

(your work:)

$C = 2\pi R = (2)(3.14)(4) = 25.1$ ft
$= 7.7$ m

Answer 1 point: $C =$ 7.7 m

What was the time of that last rotation? (It's the second bullet above.)

Answer 0 points: $t =$ 0.3 sec

What is the speed of the ball?

(your work:)

$$v = \frac{c}{t} = \frac{7.7\ m}{0.3\ s} = 25.7\ m/s$$

Answer 1 points: $v =$ 25.7 m/s

What is the radius *in meters*? You know who to ask.

Answer 1 points: $R =$ 1.2 m

What is the mass of the ball in kg?

Answer 1 points: $m =$ 7.3 kg

What is the centripetal acceleration of the ball?

(your work:)

$$a_c = \frac{v^2}{R} = \frac{(25.7)^2}{1.2} = 550\ m/s^2$$

Answer 2 points: $a_C =$ 550 m/s^2

What is the centripetal force in Newtons?

(your work:)

$F_c = ma_c = (7.3)(550)$
$= 4000\ N$

Answer 1 points: $F_C =$ 4000 N

What is the force that the athlete must exert in order to keep the ball in a circle?

Answer 1 points: $F_A =$ 4000 N

What is the weight of the ball in Newtons?

(your work:)

$7.3\ kg \rightarrow W = mg = (7.3)(10) = 73\ N$

Answer 1 points: $W =$ 73 N

What factor of the ball's weight is the centripetal force?

(your work:)

$\frac{W}{F_c} = \frac{73}{4000} = 0.018$

Answer 1 points: $W/F_C =$ 0.018

3 Falling Guy: extra 15 pts!!

The video showed that nut-case jumping out of a perfectly good airplane and landing in a net. We want to know what average force he felt in the net and how many "gee's" that corresponds to.

Here's what we know:

- His weight is 180 pounds.
- His terminal velocity is 150 mph.

What time did you measured for him to come to rest?

Answer 1 point: $t =$ 2 s

What is his mass in kg? You might ask Mr Google.

Answer 1 point: $m =$ 82 kg

What is his terminal speed in m/s? Mr Google can help.

Answer 1 point: $v_t =$ 67 m/s

What's his momentum at terminal velocity?

(your work:)

$p = mv = (82)(67) = 5500$

Answer 2 points: $p_t =$ 5500 kg-m/s

What is his final velocity **after he stops**?[1]

Answer 1 point: $v_f =$ 0 m/s

What is the **change in momentum** that he experiences?

(your work:)

$\Delta p = v_f - v_o = 0 - 5500$

don't worry about the sign

Answer 1 points: $\Delta p =$ 5500 kg-m/s

[1] That's a, "Who's buried in Grant's Tomb" question.

What is the impulse that he experiences? Remember the expression for impulse: $F\Delta t = \Delta p$.

Answer 2 points: $I =$ 5560 kg-m/s

What is the average force that he feels in stopping.

(your work:)

$\langle F \rangle \Delta t = I$

$\langle F \rangle = \frac{I}{\Delta t} = \frac{5560}{2} = 2750 \text{ N}$

Answer 3 points: $< F >=$ 2750 N

What is his weight in Newtons?

Answer 1 point: $W =$ 800 N

A slang term for the unit of force that we feel on earth is a "g-force" or " gee." Inertial forces that someone may experience can be quantified as factors of g. It can also refer to the acceleration one experiences when that force is applied to you. For example, if you accelerate your car to a value of about 18 m/s^2, you'll be pushed back in your seat because you'd experience 2 g's of acceleration, or a g-force of 2. You also should lose your license.

Given your calculation above, how many g's of acceleration (actually, deceleration, right?) did he experience in the net? You know the average force he felt, so you can calculate the average deceleration (forget about the negative sign of decelerating).

(your work:)

$$\frac{\langle F \rangle}{W} = \frac{a}{g} = \frac{2750}{800} = 3.5$$

Answer 2 points: "gees"= $\dfrac{< a >}{g}$ = 3.5