Name: Solutions

ID:

Physics 202

Quiz 1

7/29/2024

Collaboration is not allowed. Allowed on your desk are: one 8.5 x 11 inch doubled sided sheet of notes, any "survival sheets", a non-communicating graphing scientific calculator, a page of scratch paper, writing utensils, and the exam. You will have 40 minutes to complete this exam.

For questions 1 and 2 **fill in the square** next to all correct answers. A given problem may have more than one correct answer. Each correctly bubbled answer will receive two points. There are **5** correct answers in this section and only the first **5** filled in answers will be graded. There is no partial credit.

$\omega = -$

$\alpha = +$

1. An object is travelling clockwise in a circular path. The translational speed of the object is decreasing, but has not reached zero yet. Which of the following statements must be true?

   ☑ (a) The **angular acceleration** of the object is **positive**.

   ☐ (b) The **angular acceleration** of the object is **negative**.

   ☐ (c) The **translational acceleration vector** of the object points towards the center of the circle.

   ☑ (d) The radial component of the **translational velocity** is zero. radius = const

   ☐ (e) The radial component of **translational acceleration** is zero.

2. Two moles of an ideal gas are isolated from the environment within a container. The temperature of the gas doubles and the volume of the container is halved. Which of the following must be true?

   ☐ (a) The pressure in the container **increases** by a factor of 2.

   ☑ (b) The pressure in the container **increases** by a factor of 4.

   ☐ (c) The pressure in the container stays the same.

   ☐ (d) The pressure in the container **decreases** by a factor of 1/2.

   ☐ (e) The pressure in the container **decreases** by a factor of 1/4.

   ☐ (f) The average **kinetic energy** of the gas particles stays the same.

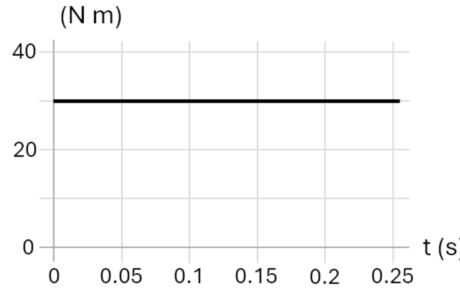
   ☑ (g) The average **kinetic energy** of the gas particles **increases** by a factor of 2.

   ☐ (h) The average **speed** of the gas particles **increases** by a factor of 4.

$$\underbrace{P}_{\uparrow\times 4}\underbrace{V}_{\downarrow\times\frac{1}{2}} = nR\underbrace{T}_{\uparrow\times 2}$$

$$\underbrace{\overline{KE}}_{\uparrow\times 2} = \frac{3}{2} k_B \underbrace{T}_{\uparrow\times 2} \qquad \underbrace{\overline{KE}}_{\uparrow\times 2} = \frac{1}{2} m \underbrace{v_{rms}^2}_{\uparrow\times\sqrt{2}}$$

3. (9 points) In physical therapy for his knee, Evan's therapist measured his quadriceps and hamstring muscle strength by placing his leg in a machine that held the knee stationary. A graph is shown of the torque from his hamstring on the lower leg, about a reference axis at the knee. Assume the lower leg starts at rest and has a moment of inertia of 0.53 kg m^2.



(a) For the first 0.25 seconds, what is the angular acceleration of the lower leg?

$$\tau = I\alpha$$

$$\Rightarrow \alpha = \frac{\tau}{I} = \frac{30\ \text{Nm}}{0.53\ \text{kgm}^2} = 56.6\ \text{rad/s}^2$$

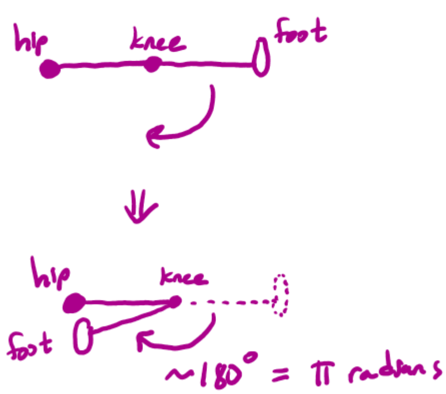
(b) After 0.25 seconds, through how many radians has the leg traveled?

$$\Delta\theta = \cancel{\omega_i}^{\,0}\Delta t + \frac{1}{2}\alpha\Delta t^2$$

$$\Delta\theta = \frac{1}{2}\left(56.6\ \frac{\text{rad}}{\text{s}^2}\right)(0.25\ \text{s})^2 = 1.77\ \text{rad}$$

101°

(c) Check your answer to part (b) by using limiting cases sensemaking. Briefly explain your answers to the following prompts using any combination of words, diagrams, algebra, etc. If the lower leg started fully extended (straight leg), through how many radians could it travel (flexion) before it reaches the upper leg (fully bent, foot against the gluteus)? Compare this limiting case value with the value you found in part (b). Is your answer reasonable? Why or why not?

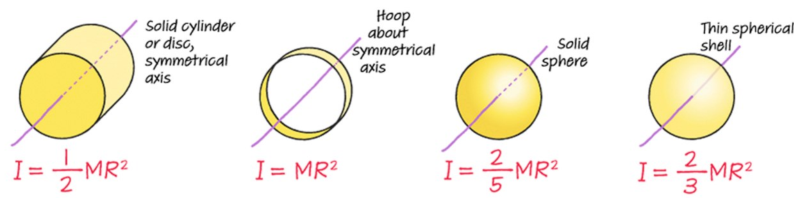


The lower leg can travel (flex) at most 180° = 3.14 radians from fully extended to fully flexed.

My answer to part (b) is 1.77 rad, which is less than the max $\Delta\theta$ I would expect. Therefore my answer to (b) is reasonable.

4. (10 points) In about 5 billion years, **our sun** (a star, just like many others in the Universe) will run out of hydrogen for the chemical reactions in its core. This will trigger a string of events causing the sun to expand into a "red giant" phase, with a radius somewhere close to the orbital distance of the Earth (there's a good chance it will "swallow" the earth)! After another 1 billion years, it **will collapse into a "white dwarf" star the size of the Earth!**

The sun's current radius is about **6.96 x 10^8 meters**. It has a mass of **1.99 × 10^{30} kg**. The Earth's radius is **6.39 x 10^6 meters**. The sun currently rotates **once every 24 days**. Let's model the sun as a solid sphere (only a very approximate model!). Let's also assume that the white dwarf will have the same mass as our current sun (this is a bad approximation, but let's make it). Common moments of inertia are given in the image here.



(a) What is the angular speed (in rad/s) of our current sun's rotation?

$$\omega = \frac{\Delta\theta}{\Delta t} = \left(\frac{2\pi \text{ rad}}{24 \text{ days}}\right) = \left(\frac{2\pi \text{ rad}}{24 \text{ days}}\right)\left(\frac{1 \text{ day}}{24 \text{ hrs}}\right)\left(\frac{1 \text{ hr}}{60 \text{ min}}\right)\left(\frac{1 \text{ min}}{60 \text{ sec}}\right)$$

$$\omega_{sun} = 3.03 \times 10^{-6} \text{ rad/s}$$

(b) What is the angular momentum of our current sun?

$$L = I\omega = \frac{2}{5} m R^2 \omega_{sun} = \frac{2}{5}(1.99 \times 10^{30} \text{ kg})(6.96 \times 10^8 \text{ m})^2 (3.03 \times 10^{-6} \tfrac{\text{rad}}{\text{s}})$$

$$L_{sun} = 1.17 \times 10^{42} \frac{\text{kg m}^2 \text{ rad}}{\text{s}}$$

(b) After it collapses, how long will it take for the white dwarf to make one rotation?

$$L_{sun} = L_{WD} = I_{WD}\,\omega_{WD} = \frac{2}{5} m_{sun} r_{Earth}^2 \, \omega_{WD}$$

$$1.17 \times 10^{42} \frac{\text{kg m}^2 \text{ rad}}{\text{s}} = \frac{2}{5}(1.99 \times 10^{30} \text{ kg})(6.39 \times 10^6 \text{ m})^2 \omega_{WD}$$

$$\omega_{WD} = 0.036 \text{ rad/s}$$

$$\Delta\theta = \omega \Delta t \Rightarrow \Delta t = \frac{\Delta\theta}{\omega} = \frac{2\pi \text{ rad}}{0.036 \frac{\text{rad}}{\text{s}}} = 175 \text{ sec} = 2.91 \text{ minutes!}$$

↑ imagine the earth with a 3 minute day!