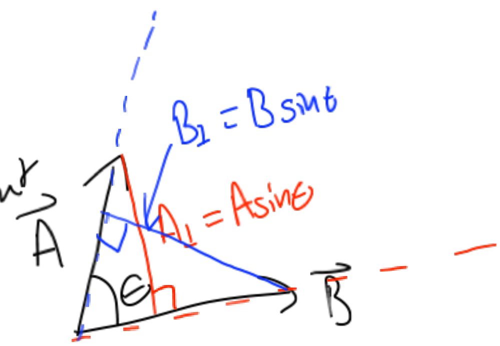
November 17

Get clickers and whiteboards

Cross products



fingers start out along this — curl to

$$\vec{C} = \vec{A} \times \vec{B}$$

$$= \langle A_y B_z - A_z B_y,\ A_z B_x - A_x B_z,\ A_x B_y - A_y B_x \rangle$$

$$= |\vec{A}||\vec{B}| \sin\theta$$

$$= A_\perp |\vec{B}|$$

$$= |\vec{A}| B_\perp$$

→ RHR for direction

$$\vec{A} \times \vec{B} = -\vec{B} \times \vec{A}$$

Q1:

What is the direction of < 0, 0, 3> x < 0, 4, 0>?	A) +x B) –x C) +y D) –z E) zero magnitude

$\hat{z} \times \hat{y} = -\hat{x}$

$A_y B_z - A_z B_y = 0 \cdot 0 - 3 \cdot 4 = -12$

$A_x \hat{x} + A_y \hat{y} + A_z \hat{z}$

$\hat{x} \times \hat{y} = \hat{z} = -\hat{y} \times \hat{x}$

$\hat{y} \times \hat{z} = \hat{x} = -\hat{z} \times \hat{y}$

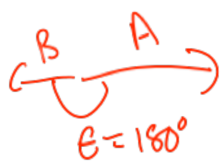
$\hat{z} \times \hat{x} = \hat{y} = -\hat{x} \times \hat{z}$

Q2:

What is the direction of < 0, 4, 0> x < 0, 0, 3>? $\hat{y} \times \hat{z} = x$	A) +x B) –x C) +y D) –z E) zero magnitude

Q3:

What is the direction of < 0, 0, 6> x < 0, 0, -3>? $\hat{z} \times (-\hat{z})$	A) +x B) –x C) +y D) –z E) zero magnitude



$\sin(180°) = 0$

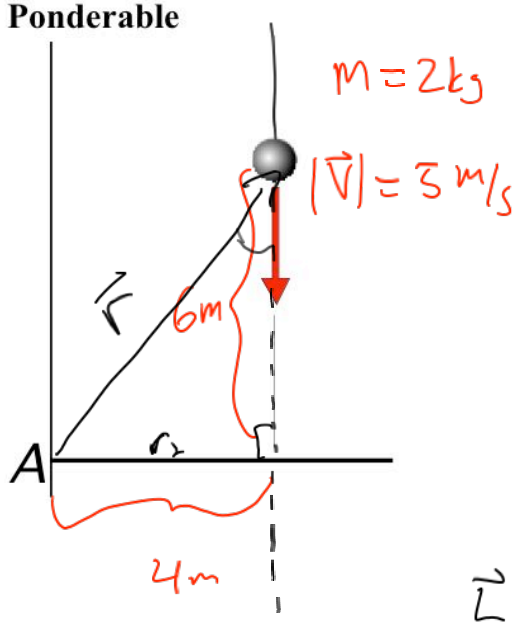
$\hat{x} \times \hat{x} = 0$

$\hat{y} \times \hat{y} = 0$

$\hat{z} \times \hat{z} = 0$

crossproduct.py

Ponderable



What is angular momentum about point A?

$$\vec{L} = \vec{r} \times \vec{p}$$

$$|\vec{L}| = |\vec{r}||\vec{p}|\sin\theta = r_\perp p = 40\ \text{kg}\,\text{m}^2/\text{s}$$

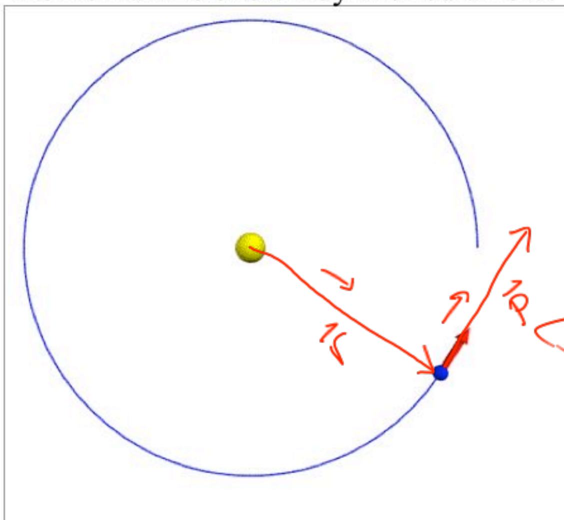
$$r_\perp = 4\text{m} \qquad p = 10\ \text{kg}\,\text{m}/\text{s}$$

$$\vec{L} = \langle 4\text{m}, 6\text{m}, 0\rangle \times \langle 0, -10\ \text{kg}\,\text{m}/\text{s}, 0\rangle$$

$$= \langle 0, 0, -40\ \text{kg}\,\text{m}^2/\text{s}\rangle$$

by RHR $-\hat{z}$

Q4: A planet orbits a star, in a circular orbit in the xy plane. Its momentum is shown by the red arrow.



What is the direction of the angular momentum of the planet?

A) same direction as $\vec{p}$

B) opposite to $\vec{p}$

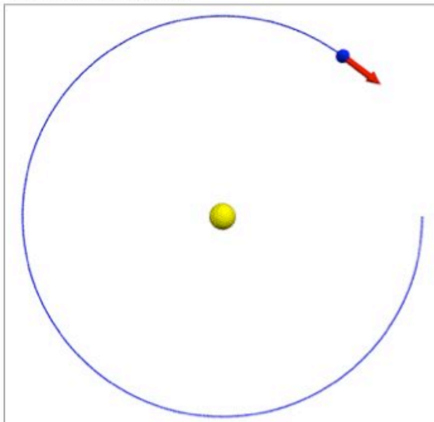
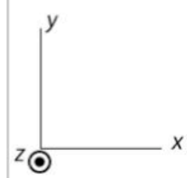
C) into the page

D) out of the page

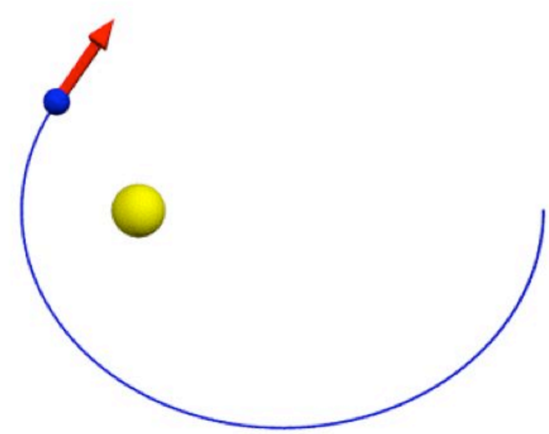
E) zero magnitude

grab onto axis with right hand, with fingers curling in direction of motion, Thumb points in dir of $\vec{L}$.

Q5: A planet orbits a star, in a circular orbit in the xy plane. Its momentum is shown by the red arrow. What is its angular momentum?

	A) +x B) –y C) +z D) –z E) zero magnitude	 (z-axis points out of page)

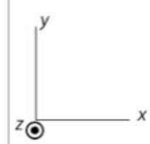
Q6: A comet orbits the Sun, in the xy plane. Its momentum is shown by the red arrow.
What is the direction of the comet's ***angular momentum*** about the Sun?



A) same direction as $\vec{p}$
B) opposite to $\vec{p}$
C) into the page
D) out of the page
E) zero magnitude

Q7: A comet orbits the Sun, in the xy plane. Its momentum is shown by the red arrow. What is the direction of the comet's ***angular momentum*** about the Sun?

A) –x
B) +y
C) –y
D) +z
E) zero magnitude



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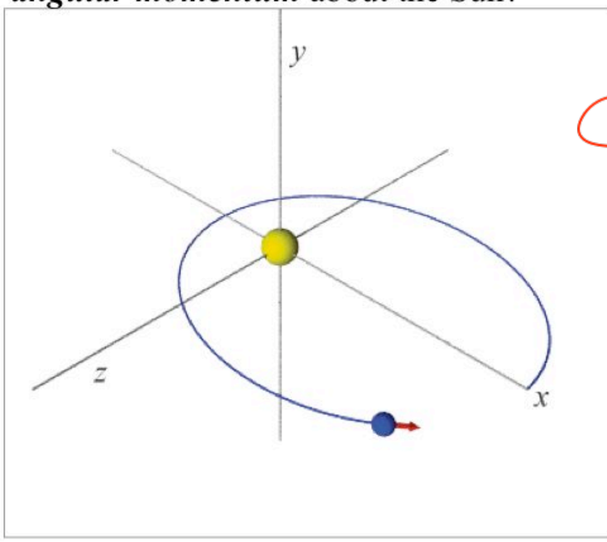
Q8: A comet orbits the Sun in the ***xz*** plane. Its momentum is shown by the red arrow. What is the direction of the comet's ***angular momentum*** about the Sun?



A) +x
B) +y
C) –y
D) +z
E) zero magnitude

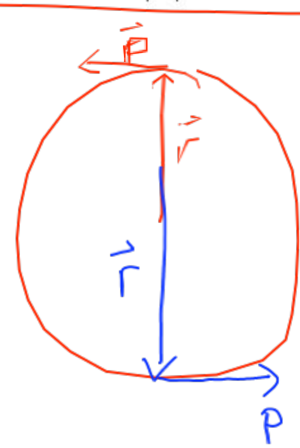
Q9: If an object is traveling at a constant speed in a vertical circle, how does the object's angular momentum change as the object goes from the top of the circle to the bottom of the circle?

A) $|\vec{L}|$ increases.

B) $|\vec{L}|$ decreases.

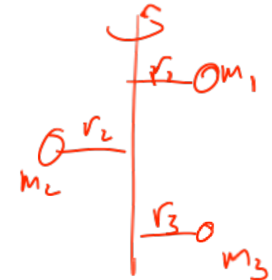
C) $|\vec{L}|$ stays the same, but the direction of $|\vec{L}|$ changes.

D) The direction and magnitude of $|\vec{L}|$ remain the same.



$$I = m_1 r_1^2 + m_2 r_2^2 + \cdots$$

What is I_{N_2}?

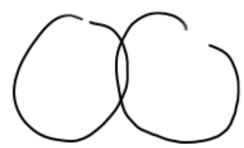


Demo

Ponderable: Moment of Inertia for Nitrogen

$$I = m_1 r_1^2 + m_2 r_2^2 + \ldots = \sum_i m_i r_i^2$$

$$I_{N_2} \, ?$$



Discussion

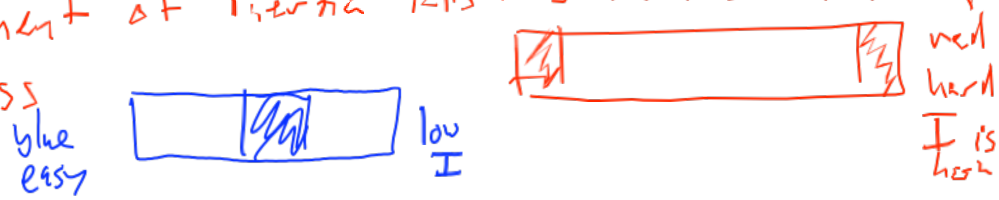
$$I = M_N r^2 + M_N r^2 = 2 M_N r^2$$

$$= 2(2.3\times10^{-26}\,kg)(10^{-10}\,m)^2$$

$$= 4.6\times10^{-46}\,kg\,m^2$$

Care about I because it tells us how easy to rotate.

Moment of Inertia tells us about distribution of mass



$$|\vec{p}| = m|\vec{v}|$$

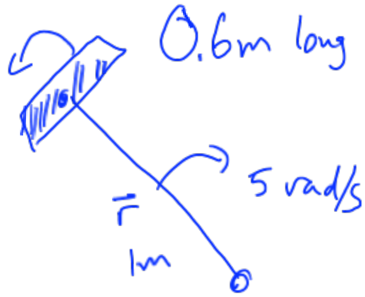
$$|\vec{L}| = I|\vec{\omega}|$$

ω is angular speed in rad/s

$$K_{tran} = \frac{1}{2}mv^2 = \frac{p^2}{2m}$$

$$K_{rot} = \frac{1}{2}I\omega^2 = \frac{L^2}{2I}$$

0.6m long $m = 2.0\,kg$ 3 times in 1 sec



$$I = \frac{1}{12} M L^2$$

↑ uniform bar about center

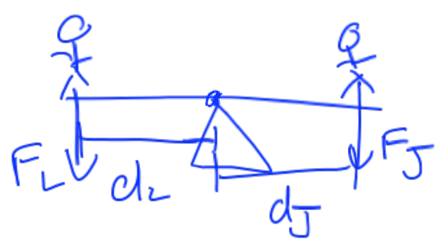
$$\vec{L}_{rot} = ? = I\omega \odot = \frac{1}{12} M L^2 \omega \odot = \frac{1}{12}(2\,kg)(0.6\,m)^2 \frac{3 \times 2\pi}{1\,s} \odot = 1.1\,\frac{kg\,m^2}{s} \odot$$

$$\vec{L}_{trans} = ? = I\omega \otimes = m r^2 \omega \otimes = 2\,kg\,(1\,m)^2\, 5\,\frac{rad}{s} \otimes = 10\,\frac{kg\,m^2}{s} \otimes$$

$$\vec{L}_{tot} = ? = \vec{L}_{rot} + \vec{L}_{trans} = 8.9\,\frac{kg\,m^2}{s} \otimes$$

Torque is combination of position + Force

$\vec{\tau} = \vec{r} \times \vec{F}$



Dr L 200 lbs

J 100 lbs

$d_L = 2m$

$d_J = ?$ so balanced?

$F_J \neq F_L$

Want torques to be the same

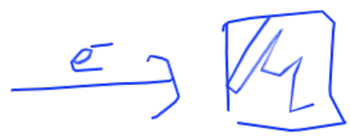
$F_L d_L = F_J d_J$

$\vec{\tau}_L = F_L d_L$ ⊙ $\vec{\tau}_J = F_J d_J$ ⊗ $d_J = 4m$

Review

Chapter 7 Energy Quantization

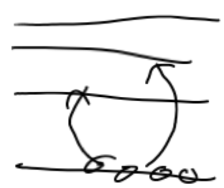
3 processes



1) electron excitation

e^- loses K to excite electrons in gas

2) Photon emission



3) Photon absorption

↳ dark lines

Chapter 8: Multiparticle Systems

Use point particle system to figure out K_{trans}, $\vec{P}_{cm}$ ↖ all mass at center of mass, no internal structure (no vibration, rotations, etc)

Use real system to figure out K_{rot}, K_{vib}, ...

Chapter 9: Collisions

$$\vec{P}_{f,tot} = \vec{P}_{i,tot} + \vec{F}_{net,ext} \Delta t$$

pick our system to be things colliding

For collision Δt small $\Rightarrow$ $\vec{P}_{f,tot} = \vec{P}_{i,tot}$

1) elastic $\rightarrow$ no change in K

2) inelastic $\rightarrow$ change in K

Chapter 10:

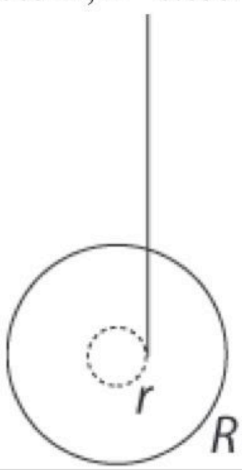
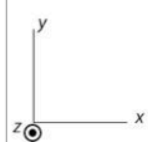
$$\vec{L} = \vec{r} \times \vec{p}$$

$$|\vec{L}| = I\omega$$

$$I = \sum_i m_i r_i^2$$

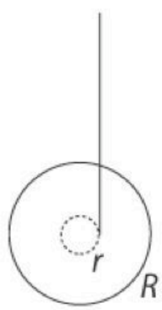
RHR

Q1: A yo-yo is in the xy plane. You pull up on the string with a force of magnitude 0.6 N. What is the direction of the torque you exert on the yo-yo?

<table>
<tr>
<td>r = 0.005 m, R= 0.035 m

</td>
<td>A) +x
B) –x
C) +y
D) –y
E) +z</td>
<td>

(z-axis points out of page)</td>
</tr>
</table>

Q2: A yo-yo is in the xy plane. You pull up on the string with a force of magnitude 0.6 N. What is the magnitude of the torque you exert on the yo-yo?

$r = 0.005$ m, $R = 0.035$ m 	A) 0.003 N· m B) 0.021 N· m C) 0.035 N· m D) 0.6 N· m E) cannot be determined without knowing the length of the string

$\vec{L}_f = \vec{L}_i + \vec{\tau}_{net,ext}\Delta t$ angular momentum principle

$\vec{\tau}_{net}$ small

$\Rightarrow \vec{L}_f = \vec{L}_i$

$\uparrow \vec{L}_i$ $\quad$ $\downarrow \vec{L}_{wheel}$ $\quad$ $\uparrow \vec{L}_{reber}$

$L = I\omega$ $\quad$ $I = mr^2$ $\quad$ $K = \frac{1}{2}I\omega^2$

$r\downarrow$ $\quad$ $I\downarrow^2$ $\quad$ $\omega\uparrow$