1. c. RHR: Pinky along $x$ (x-axis), curl fingers towards $y$ (y-axis). $\vec{r} \times \vec{f} = \vec{k}$ is out of face.

2. c. All the units are OK. Use RHR on second hand. Finger curl in direction of motion (cw) so thumb points in.

$$\omega = \frac{2\pi}{T} = 1.05 \times 10^{-1} \text{ rad/sec}$$

$$\vec{\omega} = \omega \hat{n} = -1.05 \times 10^{-1} \hat{n} \text{ rad/sec}.$$

3. b. The whole idea of angular velocity is that all points on the second hand have the same $\omega$.

4. a. Contour $\delta = 0$. Answer choice (a) was the only answer that could apply to a vector.

5. a. $\vec{N} = \vec{r} \times \vec{m_p q} = r \vec{m_p q} \times \frac{\vec{s}}{2} (\hat{n})$
6. d. Right hand rule \( \vec{N} = \vec{r} \times \vec{m}_p \) \( \vec{j} \) 

7. c. 
\[
\vec{N} = \vec{r} \times \vec{m}_p \vec{j} \\
= r m_p g \sin \phi \hat{\phi} \quad (-\hat{r}) \\
= r m_p g \sin (\frac{\pi}{3} - \theta) \hat{\phi} \quad (-\hat{r}) \\
= r m_p g \sin \frac{\pi}{3} \quad (-\hat{r}) \\
= -1.06 \times 10^{-3} \hat{\phi} \quad N \cdot m 
\]

The no calculator trick? Umm... well, you have to guess that the two numerical values are designed to confuse you between taking \( \sin \theta \) or \( \sin \phi \). The correct answer is negative and larger \( (\sin \phi > \sin \theta) \).

8. d. This is the only answer that makes any sense at all, since \( \vec{a} \) is slowing the motor down it is parallel to \( \vec{a} \) and in the opposite direction, \( \vec{a} \) is in \( (-\hat{a}) \), so \( \vec{a} \) is out. \( (+\hat{a}) \)
9. I didn't really want to do this either. Let's see...

We know: \( \Delta \theta = -\pi \) (or \( \pi \))

\[ \Delta \omega = -\frac{\omega_0}{2} \]

When \( \omega_0 = \text{normal speed}. \)

Useful kinematic equation are

\[ \Delta \omega = \alpha \Delta t \]

\[ \Delta \theta = \omega_0 \Delta t + \frac{1}{2} \alpha \Delta t^2 \]

We don't know \( \Delta t \), so eliminate it and solve for \( \alpha \).

\[ \Delta t = \frac{\Delta \omega}{\alpha} \]

So

\[ \Delta \theta = \omega_0 \frac{\Delta \omega}{\alpha} + \frac{1}{2} \frac{\Delta \omega^2}{\alpha^2} \]

\[ \alpha = \frac{\omega_0 \Delta \theta}{\Delta \omega} + \frac{1}{2} \frac{\Delta \omega^2}{\Delta \theta \alpha} \]

\[ = \omega_0 \left( \frac{-\omega_0 / 2}{-\pi} \right) + \frac{1}{2} \frac{\omega_0^2 / 4}{-\pi} \]

\[ = \frac{3 \omega_0^2}{8 \pi} \]

Note that positive acceleration "slows down" a negative velocity.
This problem is perfectly analogous to a linear kinematic problem where a speed change in a known distance.

You could do this problem in one step if you remember the hourly equation

$$w_f^2 - w_o^2 = 2 a \Delta \theta \quad \text{(mean speed theorem)}$$

$$w_f = \frac{w_o}{2} \quad \Delta \theta = -\pi$$

$$\Delta = \frac{w_f^2 - w_o^2}{2 a \Delta \theta}$$

$$= \frac{w_o^2/4 - w_o^2}{-2 \pi}$$

$$= -\frac{3 w_o^2}{8\pi}$$
10. $\vec{F}$ from RHR

11. $\vec{T} = m\vec{w}$ so parallel.

12. There are actually two external forces: gravity acting on the CM, and some contact force acting on the tip of the top. But we take the tip to be a pivot point and only consider gravity. The gravitational force is $m\vec{g}$.

13. $\vec{T}$ gone from the tip of the top (like that?) to the CM, which is the point of application of the gravitational force.

14. $\vec{N} = \vec{T} \times m\vec{g}$

$\vec{N} = \vec{r}mg \sin \theta \times \vec{\theta}$

R.H.S. You gotta put your hand behind the paper to align your pinsy with $\vec{F}$.
15. b. \( \ddot{\mathbf{u}} \) for rotation is

\[ \ddot{\mathbf{u}} = \frac{\mathbf{N}}{I} \]

So \( \ddot{\mathbf{u}} = \frac{\mathbf{N}}{I} \)

by magnitude, that is \( \ddot{\mathbf{u}} = \frac{\mathbf{N}}{I} \)

- It isn’t zero because there is a torque!
- \( \dot{\mathbf{u}} \) is the angular momentum
- \( m\dot{\mathbf{r}}^2 \) is not the moment of inertia for this particular shape.

16. Well, now \( \mathbf{N} = I \ddot{\mathbf{u}} \) so the angular acceleration is into the page, at a right angle to \( \ddot{\mathbf{u}} \). Therefore the magnitude of \( \ddot{\mathbf{u}} \) will not change. But the direction will. The tip of the \( \ddot{\mathbf{u}} \) vector will move in the direction of \( \dot{\mathbf{u}} \) -- into the page. No problem moving the tip of the \( \ddot{\mathbf{u}} \) vector to the CM. The top will “precess.” The CM will slowly describe a circle around the y-\( \ddot{\mathbf{u}} \)-axis. The effect of \( m\dot{\mathbf{r}}^2 \) is to produce a torque that moves the CM in a direction 90° from the direction of the force!

Aint rotation great?