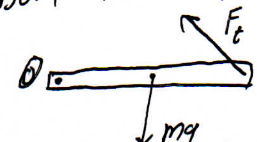
Equilibrium, Torque Equilibrium and C.O.M Answer Explanations

1984

1. D - Textbook definition. Force is to linear motion as torque is to rotational motion.

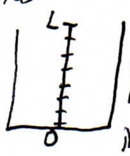
6. A - Make sure torques and forces cancel out. Last 5N force must be pointed down to combat the upward 10N force. Additionally, the last 5N force should make the block spin counter-clockwise since the first 5N force makes the block spin clockwise. Choice A fulfills both these requirements.

22. B, Net Forces should be 0.



mg is pointed down so there should be a component at point O that is pointed upward. F_t has a component pointed to the left, therefore the force at O should have a component that is pointed to the right. Choice B is an arrow pointed up and to the right.

29. E - For simplicity lets make each length of wire, L, have a mass of M. We need to find the center of mass in the y direction since all the answer choices have different y coordinates.

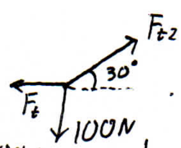


Imagine a sideways numberline like pictured. The bottom wire has a radius of 0 and a mass of M. Plugging this into the C.O.M formula we have $\frac{(0m)(M)}{M} = 0$.

Therefore the C.O.M. is at point E.

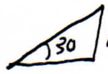
* This intuitively makes sense by just looking at the picture.

32. D - Make a force diagram



Object is in equilibrium so the vertical part of F_{t2} must be 100N to balance out the downward 100N force.

Draw a triangle:

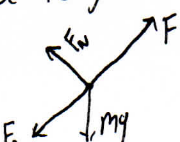


Solving for the hypothenuse gives us 200N.

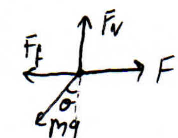
1993

29. B - C.O.M. always shifts to the side with more mass. If you don't believe me, make up a length for the rod and plug and chug.

34. B - Force Diagram



Rotated:



Find angle: $\tan^{-1}\left(\frac{3}{4}\right) = 36.87°$ (θ)

$F_N = mg\cos\theta$

$F_f = \mu F_N = (0.3)(mg\cos\theta)$

$F = F_f + mg\sin\theta$

* since pulling at constant speed

$F = (0.3)mg\cos\theta + mg\sin\theta = 41.16 \approx$ **42N**

1998

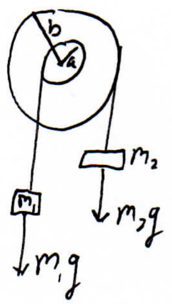
5. C - $\tau = rF\sin\theta$. $\theta = 90$ in this problem so the equation simplifies to $\tau = rF$

Split into clockwise and counter-clockwise torques

Clockwise	Counter-Clockwise
$(2F)(3R) = 6FR$	$(F)(3R) = 3FR$
	$(F)(2R) = 2FR$
	$(F)(3R) = 3FR$
	Net: $8FR$

Subtract the 2: $6FR - 8FR = -2FR$

Therefore magnitude is $2FR$, C

30. B - 

Ropes need to carry same force as the F_g on the blocks to keep system in equilibrium

Clockwise Torque	Counterclockwise Torque
$(m_2g)(b) = \tau_C$	$(m_1)(g)(a) = \tau_{cc}$

set them equal: $m_2 g b = m_1 g a$

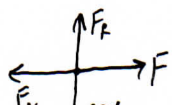
$\boxed{m_2 b = m_1 a}$, B

2004

9. D - look at explanation for question #32 from 1984

11. C - only diagram that has balances forces and all forces going in the right direction. Figure D would be right but $mg\cos\theta$ and $mg\sin\theta$ are switched.

12. C - force diagram would look no different since its falling down at constant speed.

28. C - Draw a force diagram 

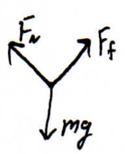
$F_N = F$

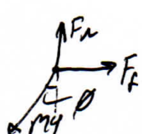
$F_f = F_N\mu = F_g$

$\mu F = mg$

$F = \frac{mg}{\mu}$, C

2009

19. E - Force diagram 

Rotate it 

$F_N = mg\cos\theta$

$F_f = mg\sin\theta$

$\mu(mg\cos\theta) = mg\sin\theta$

$\mu = \tan\theta$, E

* This is a handy thing to keep in mind, shows up a lot.

21. E - The C.O.M. of a system always stays in the same place. As the person walks to the other end of the raft, the C.O.M. will reflect across the center and will be a distance, d, to the left of the center. To keep the C.O.M at the same place, the raft has to move a distance 2d to the right. E.