Test 3 Review

Dr. Isaac Yuen, Kennesaw State University, PHYS 2211, Fall 2024

Scope

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- Chapters 12, 13, 15, 16
- Four short questions (15 points total) with one long bonus question (5 points)
- 50 minutes

Formula sheet

PHYS 2211 PRINCIPLES OF PHYSICS I
SECTIONS 51-54 **TEST 3 FORMULA SHEET** FALL 2024
DEPARTMENT OF PHYSICS, KENNESAW STATE UNIVERSITY

You may need:

1. Torque by a force: $\vec{\tau} = \vec{r} \times \vec{F}$; Magnitude: $\tau = rF \sin \phi$
2. Conditions for static equilibrium: $\sum \vec{\tau} = 0, \sum \vec{F} = 0$
3. Total energy for circular orbit: $E = -\frac{GMm}{2r}$
4. Kinetic energy for circular orbit: $K = \frac{GMm}{2r}$
5. Gravitational potential energy for circular orbit: $U_g = -\frac{GMm}{r}$
6. Energy transfer for changing orbit: $W = \Delta K + \Delta U_g$
7. Position in simple harmonic motion: $x(t) = A \cos(\omega t + \phi)$
8. Velocity in simple harmonic motion: $v(t) = -\omega A \sin(\omega t + \phi)$
9. Acceleration in simple harmonic motion: $a(t) = -\omega^2 A \cos(\omega t + \phi)$
10. Angular frequency for the mass-spring system: $\omega = \sqrt{\frac{k}{m}}$
11. Wave number: $k = \frac{2\pi}{\lambda}$
12. Angular frequency: $\omega = \frac{2\pi}{T} = 2\pi f$
13. Frequency: $f = \frac{1}{T}$
14. Speed of a wave: $v = f\lambda = \frac{\lambda}{T}$
15. Wave function: $y(t) = A \sin(kx - \omega t)$
16. Power of a transverse wave: $P = \frac{1}{2}\mu\omega^2 A^2 v$

Chapter 12 (Static Equilibrium) Review

The net external force on the object must equal zero:

$$\boxed{\sum \vec{\mathbf{F}}_{\text{ext}} = 0}$$

The net external torque on the object about *any* axis must be zero:

$$\boxed{\sum \vec{\boldsymbol{\tau}}_{\text{ext}} = 0}$$

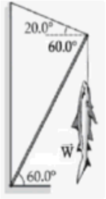
- No translational or angular speed ($v_{CM} = 0$ and $\omega = 0$)

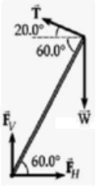
Problem-Solving Strategy:

1. Identify the moveable system.
2. Draw diagram and label all external forces acting on object
3. Guess the direction for any forces not specified
4. Choose convenient axis for calculating net torque on rigid object.

Ways of Calculating Torque

This is a static problem where the sum of the forces and torques must be zero.
To find the unknown forces, draw a force diagram of the rod, apply Newton's second law, and add the torques together.





Part 3 of 4 - Analyze Tension between cable & rod

(a) From the diagram, the angle $\vec{T}$ makes with the rod is given by

$$\theta = 60° + 20.0° = 80°,$$

and the perpendicular component of $\vec{T}$ is

$$T \sin 80°.$$

Summing torques around the base of the rod, and applying Newton's second law in the horizontal and vertical directions, $\sum \tau = 0$, and we have

$$-(5.1 \text{ m})(9450 \text{ N})\cos 60° + T(5.1 \text{ m})\sin 80° = 0,$$

which gives

$$T = \frac{(9450 \text{ N})\cos(60°)}{\sin(80.0°)}$$

$$= 4.8 \times 10^3 \text{ N}.$$

(b) From $\sum F_x = 0$, we have $F_H - T\cos(20.0°) = 0$, so

Horizontal Force $F_H = T\cos(20.0°) = 4.51 \times 10^3$ N.

Part 4 of 4 - Analyze Vertical Force

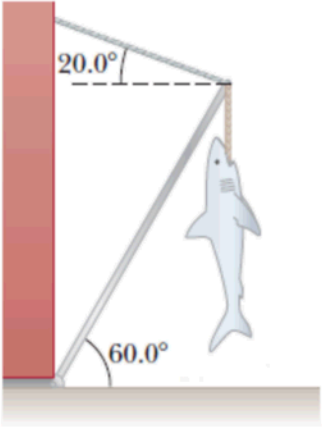
(c) From $\sum F_y = 0$, we have

$$F_V + T\sin(20.0°) - 9\,450 \text{ N} = 0,$$

and we find

$$F_V = (9450 \text{ N}) - T\sin(20°)$$

$$= 7.81 \times 10^3 \text{ N}.$$



Week 11 HW Q3

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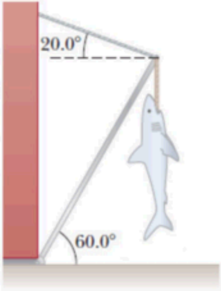
A 8 600-N shark is supported by a rope attached to a 4.60-m rod that can pivot at the base.



(a) Calculate the tension in the cable between the rod and the wall, assuming the cable is holding the system in the position shown in the figure.

4370 N

(b) Find the horizontal force exerted on the base of the rod.

magnitude 4100 N

direction ---Select--- to the right

(c) Find the vertical force exerted on the base of the rod. Ignore the weight of the rod.

magnitude 7110 N

direction ---Select--- upwards

Week 11 in-class Q2

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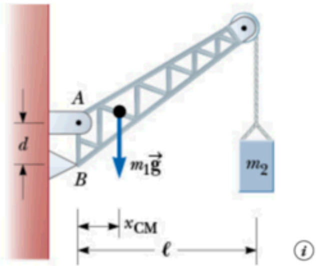
You pass by a building site and see a crane that lifts loads to upper floors of a building under construction. You wonder about the magnitude of the forces that support the beam of the crane. You snap a photograph of the crane with your smartphone. Back at home, you make a drawing of the crane from your photo. Your drawing is shown in the following figure.



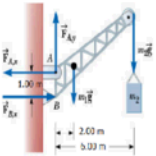
You estimate the lengths d and ℓ by measuring the distance between floors on a point of the building the same distance from your smartphone as the crane and using that distance as a scale for the drawing. This tells you that d = 1.00 m and ℓ = 6.00 m. You have drawn the force vector for the gravitational force on the beam of the crane, but then you realize you don't know where the center of mass of the beam is located. You run back to the construction office and explain your interest. You ask the construction foreman about the crane, and he tells you that the crane itself has a mas of m_1 = 2,675 kg and the load it was lifting when you took the photograph has a mass of m_2 = 11,600 kg. You then ask the foreman about the location of the center of mass of the beam. Amused by your interest, he consults his documents and finds that the center of mass of the crane is located x_{CM} = 2.00 m horizontally to the right of point A. He also tells you that the pin at A is on a bearing and essentially frictionless, and the point B against which the crane pushes is smooth. Thanking the foreman and running home, you s Question 2 preview k and determine the forces on the crane at points A and B.

$\vec{F}_A$ = (-7.35e+05 $\hat{\imath}$ + 1.40e+05 $\hat{\jmath}$) N

$\vec{F}_B$ = (7.35e+05 $\hat{\imath}$ + 0 $\hat{\jmath}$) N

Week 11 in-class Q2

Categorize At a given point in time, assuming the movement of the load is constant, the beam can be modeled as a *rigid object in both translational and rotational equilibrium*.



Because the horizontal components of the forces at *A* and *B* are the only horizontal forces on the beam, we have drawn them with equal magnitude but opposite direction. In addition, we have drawn no vertical force at *B* because the foreman told you that point *B* is smooth.

Write an equation for the translational equilibrium of the beam in the vertical direction.

$$(1)\quad \sum F_y = 0 \rightarrow F_{(A,\,y)} - m_1 g - m_2 g = 0 \rightarrow F_{(A,\,y)} = (m_1 + m_2)g$$

Write an equation for the rotational equilibrium of the beam around point *A*.

$$(2)\quad \sum \tau_{ext} = 0 \rightarrow (F_{(B,\,x)})(d) - (m_1 g)(x_{CM}) - (m_2 g)(\ell) = 0$$

$$\rightarrow F_{(B,\,x)} = \frac{(m_1 x_{CM} + m_2 \ell)g}{d}$$

Substitute numerical values into Equations (1) and (2).

$$F_{A,y} = (3{,}125\text{ kg} + 11{,}200\text{ kg})(9.80\text{ m/s}^2) = 1.40 \times 10^5\text{ N}$$

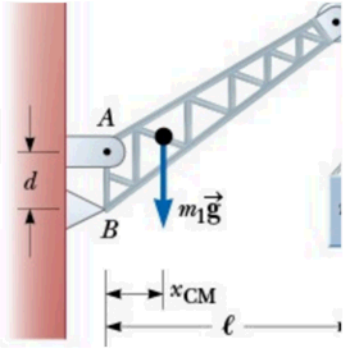
$$F_{B,x} = \frac{[(3{,}125\text{ kg})(2.00\text{ m}) + (11{,}200\text{ kg})(6.00\text{ m})](9.80\text{ m/s}^2)}{1.00\text{ m}} = 7.20 \times 10^5\text{ N}$$

Therefore, we can write the forces on the crane at points *A* and *B* as

$$\vec{F}_A = (-7.20 \times 10^5\,\hat{i} + 1.40 \times 10^5\,\hat{j})\text{ N}$$

$$\vec{F}_B = 7.20 \times 10^5\,\hat{i}\text{ N}$$

Finalize The magnitude of both forces is larger than the total weight of the beam and the load. This is because the gravitational forces on the beam and the load are at a distance from points *A* and *B*. How would this problem change if the load were picked up off the ground with an acceleration?



Ch. 13: Gravitational Potential Energy

$$\Delta U = \underline{U_f - U_i} = -\int_{r_i}^{r_f} F(r)\,dr$$

$$F(r) = -\frac{GM_E m}{r^2}$$

$\int \frac{1}{r^2} dr = \frac{-1}{r}$

$$U_f - U_i = GM_E m \int_{r_i}^{r_f} \frac{dr}{r^2} = GM_E m \left[-\frac{1}{r} \right]_{r_i}^{r_f}$$

$$U_f - U_i = -GM_E m \left(\frac{1}{r_f} - \frac{1}{r_i} \right)$$

$U_f = -\frac{GM_E m}{r_f}$