Phys 131 2022

Final Review

Final:

Class meeting time	Exam Time
(001) 9am Class	Wednesday, Dec 14 8am
(002) 10am Class	Monday, Dec 12 10am

Covers: Entire Semester

Bring: Calculator

Total four 3"x5" single sided index cards (or equivalent surface) are

Review: Previous finals: 2018 All questions

2016 All questions

Note: Version 2 only has solutions for problems different to version 1.

This review only covers Ch 10, 11, 12, 13

Chapters 10 - 12

Equations:

$\omega = \omega_0 + \alpha t$

$\theta = \theta_0 + \omega_0 t + \frac{1}{2}\alpha t^2$

$\omega^2 = \omega_0^2 + 2\alpha \Delta\theta$

$v_t = \omega r$

$a_t = \alpha r$

$x_{cm} = \sum m_i x_i / \sum m_j$

$y_{cm} = \sum y_i m_i / \sum m_j$

$I = \sum m_i r_i^2$

others given

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

$= rF\sin\phi$

$\tau = I\alpha$

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

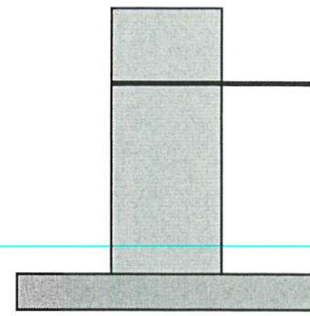
$\vec{L} = I\vec{\omega}$

vector cross product rules

Quiz 1: 50% – 80% 30% – 50%

290 Flywheel and axle

A particular flywheel is a solid disk with mass 0.150 kg and radius 0.075 m. This is mounted to an 0.400 kg axle which is a hollow cylinder with radius 0.020 m. The entire arrangement is initially at rest and is subsequently pulled with constant tension by a string that is wound around the axle. It reaches an angular velocity of 40 rad/s in 5.0 s. A side view is illustrated. Determine the tension in the string. *(131F2022)*



Answer: Rotational kinematics $\rightsquigarrow$ angular accel α

Rotational dynamics $\rightsquigarrow$ torque $\rightsquigarrow$ tension in string

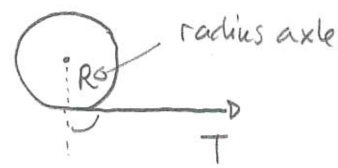
Angular acceleration $\omega = \omega_0 + \alpha t$ $\quad t_0 = 0s$, $\omega_0 = 0 rad/s$ $\quad t = 5.0s$, $\omega = 40 rad/s$

$$\Rightarrow \alpha = \frac{\omega - \omega_0}{t} = \frac{40 rad/s}{5.0s} = 8.0 rad/s^2 \Rightarrow \boxed{\alpha = 8.0 rad/s^2}$$

Rotational dynamics $\tau_{net} = I\alpha$ From above

$\tau_{net} = \tau_{string} + \underbrace{\tau_g + \tau_{axle}}_{0 \text{ since } r=0}$

$\tau = rF\sin\phi$



$\tau_{net} = \tau_{string} = TR\sin 90^\circ = TR$ $\hookrightarrow$ radius axle.

$$I = I_{disk} + I_{axle} = \frac{1}{2} M_{disk} r_{disk}^2 + M_{axle} r_{axle}^2$$

$$= \frac{1}{2}\, 0.150kg \times (0.075m)^2 + 0.400kg \times (0.020m)^2$$

$$= 4.2 \times 10^{-4} kg\,m^2 + 1.6 \times 10^{-4} kg\,m^2$$

$$= 5.8 \times 10^{-4} kg\,m^2$$

$\tau_{net} = I\alpha \Rightarrow TR = 5.8 \times 10^{-4} kg\,m^2 \times 8.0 rad/s^2 = 4.66 \times 10^{-3} Nm$

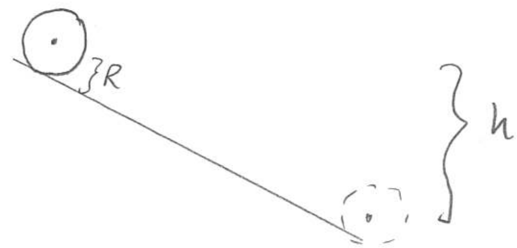
$\Rightarrow T \times 0.020m = 4.66 \times 10^{-3} Nm \Rightarrow T = \frac{4.66 \times 10^{-3} Nm}{0.020m}$

$T = 0.23 N$

Quiz 2 : 50% - 90% $\rightsquigarrow$ 70% - 100%

Consider each ball

mass M.



$E_f = E_i$

$K_f + U_{gf} = \cancel{K_i} + U_{gi}$

$K_f = U_{gi} - U_{gf}$

$= mgh$

$K_{transf} + K_{rotf} = mgh$

$\frac{1}{2} M v_f^2 + \frac{1}{2} I \omega_f^2 = mgh \Rightarrow v_f^2 = 2gh - I\omega_f^2$

Slipping ball $\omega_f = 0 \Rightarrow v_f$ larger

Rolling ball $\omega_f > 0 \Rightarrow v_f$ smaller

$\hookrightarrow$ In this case $\omega_f = v_f / R$. So

$\frac{1}{2} m v_f^2 + \frac{1}{2} I/R^2 \, v_f^2 = mgh$

$\Rightarrow v_f^2 \left(1 + \frac{I}{mR^2}\right) = 2gh.$

$\Rightarrow v_f = \sqrt{2gh \Big/ \left(1 + \frac{I}{mR^2}\right)}$

For slipping ball same expression except $I = 0$

$\Rightarrow$ larger v_f

Quiz 3 30% - 50% $\rightsquigarrow$ 30% - 100%

Chapter 13

Equations: $F = G\frac{M_1 M_2}{r^2}$ $\quad U = -G\frac{M_1 M_2}{r}$

Use: Newton's 2^{nd} Law and Universal Law of gravity to describe

* gravitational acceleration
* orbital motion.

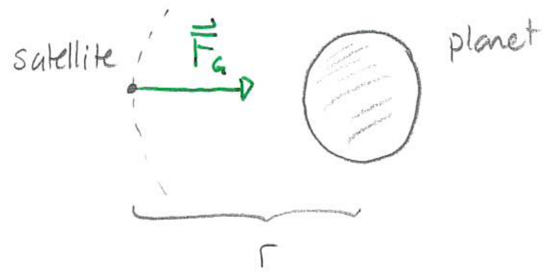
323 Orbiting satellite

A satellite orbits a planet with mass M_p in a circular orbit with radius r. The satellite's speed is constant. *(131F2022)*

a) **Starting with and using** Newton's Second Law, derive an expression for the satellite's speed in terms of M_p and r.

b) Determine the speed of a satellite in a uniform circular orbit ~~1000~~ 60000 m above the surface of the dwarf planet Ceres (mass 9.4×10^{20} kg and radius 4.7×10^{5} m).

Answer a)



essential

$$\vec{F}_{net} = m\vec{a}$$

$$\Rightarrow \vec{F}_G = m\vec{a} \qquad a = \frac{v^2}{r} \text{ (centripetal}$$

Horizontal components:

$$F_G = mv^2/r$$

$$F_G = G\frac{m M_p}{r^2} \quad \leftarrow \text{essential}$$

$$\Rightarrow G\frac{\cancel{m} M_p}{r^{\cancel{2}}} = \frac{\cancel{m} v^2}{\cancel{r}} \Rightarrow v^2 = G\frac{M_p}{r} \Rightarrow v = \sqrt{\frac{G M_p}{r}}$$

b) $r = (4.7 \times 10^5 + 0.6 \times 10^5)\,\text{m} = 5.3 \times 10^5\,\text{m}$

$$v = \sqrt{\frac{6.67 \times 10^{-11}\,\text{Nm}^2/\text{kg}^2 \times 9.4 \times 10^{20}\,\text{kg}}{5.3 \times 10^5\,\text{m}}} = 344\,\text{m/s}$$