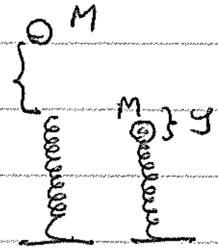
① $v = f\lambda = \sqrt{F/\mu}$, λ, μ constant

$\therefore \quad f^2\lambda^2 = F/\mu$,

$$f_1^2 = \frac{T}{\lambda^2\mu}, \quad f_2^2 = \frac{T_2}{\lambda^2\mu} \Rightarrow \frac{f_1^2}{f_2^2} = \frac{T}{T_2}, \quad \underline{\underline{T_2 = T\frac{f_2^2}{f_1^2}}}$$

② $\omega^2 = k/m$ so



$$K_1 + U_1 = K_2 + U_2$$

$$0 + Mg(h+y) = 0 + \frac{1}{2}ky^2$$

$$\therefore \quad \frac{k}{M} = \frac{2g(h+y)}{y^2}$$

③ First conserve angular momentum (not energy since skater has to do work) since no external torques.

① I, ω, K_1 ② bI, ω_2, K_2

$$I\omega = bI\omega_2 \Rightarrow \omega_2 = \omega/b$$

$$K_2 = \frac{1}{2}I_2\omega_2^2 = \frac{1}{2}bI\frac{\omega^2}{b^2} = \frac{1}{2}\frac{I\omega^2}{b}, \quad K_1 = \frac{1}{2}I\omega^2$$

$$\therefore \text{ Work done} = K_2 - K_1 = \frac{1}{2}I\omega^2\left[\frac{1}{b} - 1\right] = \underline{\underline{K\left[\frac{1-b}{b}\right]}}$$

b ~~f~~ is ~~the~~ ~~factor~~ $\frac{I_2}{I} = b$

④ Rolling disk have translational and rotational KE, $I = \frac{1}{2}MR^2$ and $R\omega = v$

$$\therefore \quad \frac{1}{2}mv^2 + \frac{1}{2}I\omega^2 = mgh$$

$$\therefore \quad \frac{1}{2}mv^2 + \frac{1}{4}mv^2 = \frac{3}{4}mv^2 = mgh \Rightarrow v^2 = \frac{4gh}{3}$$

Sliding disk $\Rightarrow$ $u^2 = 2gh$.

$$\therefore \quad \frac{v^2}{u^2} = \frac{3}{2}$$

(5) Since there is no vertical acceleration

$T - M_2 g = 0 \Rightarrow T = \underline{\underline{M_2 g}}$

Now for M_1, only accelerating force is T

$\therefore T = M_1 a \Rightarrow a = \frac{T}{M_1} = \frac{M_2 g}{M_1}$

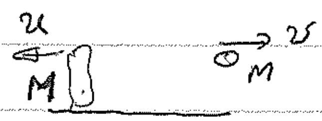
answer is (a)

(6) $\omega = 2\pi f = 2\pi\,(\text{rpm}/60)$

$v = r\omega$ (remember r should be in meters)

$a_r = \frac{v^2}{r} = r\omega^2$

(7)



There are no horizontal forces. so, $p = 0$ before and after throwing the ball

$\vec{p} = 0$ gives C.M velocity $\underline{0}$

and $Mu = mv \Rightarrow \boxed{u = \frac{m}{M} v}$ $\quad \frac{m}{M} = 0.01, 0.02,$ or 0.05 depending on the version

so 0 and 0.01V or 0 and 0.02V or 0 and 0.05V

(8) No external torques for the bullet and disk.

$\therefore$ L conserves. $L_1 = L_2$

$L_1 = mvR$, $L_2 = muR + I\omega$

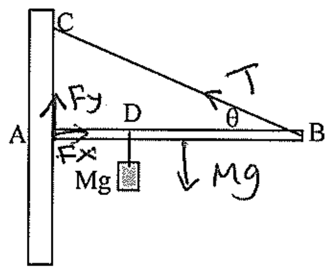
$\therefore mvR = muR + I\omega$

$\frac{mR(v-u)}{I} = \omega$, put appropriate I for the version of your exam!

Full work out questions

9 (Chapter 11). One end of a stick AB (length $2l$, *mass M*) is placed against a rough vertical wall. The other end is attached to the wall using a weightless cord CB that makes an angle $\theta=30°$ with the stick. Another mass M is attached to the stick at a point D. It is found that the stick will not stay horizontally at equilibrium if AD is less than $2l/3$ ($AD<2l/3$). The maximum value for the coefficient of static friction between the end of the stick and the wall is μ_s. Mark all the forces (except the thrust or tension in the stick) and a) Find the tension in the cord, b) the vertical force acting on the stick at A. c) the horizontal force acting on the stick at A e) Calculate the value of μ_s.

15



4

a) A torque $Mg\frac{2l}{3} + Mgl - 2l\sin\theta \cdot T = 0$

5

$$\frac{5Mgl}{3} = 2l \times \frac{1}{2} T$$

$$T = \frac{5Mg}{3}$$

b) $\uparrow \Sigma F = 0$ $\quad F_y - 2Mg + T\sin\theta = 0$

2.

$$F_y = 2Mg - \frac{5Mg}{3} \cdot \frac{1}{2} = \frac{7}{6}Mg$$

c) $\rightarrow \Sigma F = 0$ $\quad F_x - T\cos\theta = 0$

2

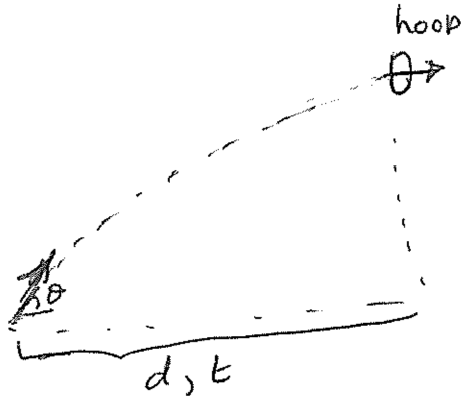
$$F_x = T\cos\theta = \frac{5Mg}{3} \times \frac{\sqrt{3}}{2} = \frac{5\sqrt{3}Mg}{6}$$

e) $\mu_s = \frac{F_y}{F_x} = \frac{\frac{7}{6}Mg}{\frac{5\sqrt{3}Mg}{6}} = \frac{7}{5\sqrt{3}}$

4.

$14.6/4$

10 (Projectile motion)A basketball player running at a constant velocity (~~v=15.2/5m/s~~)aims to throw a ball through a vertical hoop. He releases the ball when the hoop is at a distance d directly in front of him. He can throw the ball at a speed (relative to him) u (=9.8x5/4)m/s and an angle θ above horizontal. The vertical displacement from the point he release the ball and the center of the hoop is 4.9m and a stationary observer near the hoop sees the ball travels horizontally through the hoop. A) What must be the vertical component of the initial velocity (relative to the observer) for the ball to travel horizontally through the hoop? b) How many seconds after the release of the ball it will go through the hoop? c) What is the value of angle θ? d) What is the distance d?



θ = angle with respects to player.
player = P
Ball = B
Earth = E

$$v_{BE} = v_{BP} + v_{P,E}$$

$$= u\angle\theta + \underset{v}{\rightarrow} = \uparrow w_y \rightarrow w_x \quad \text{at } t=0$$

$$\therefore v_{BE,x} = u\cos\theta + v = w_x$$
$$v_{BE,y} = u\sin\theta = w_y \qquad 3$$

a) at the hoop $v_{BE,y} = 0$

$\therefore \uparrow v^2 = v_0^2 + 2ay \Rightarrow 0 = w_y^2 - 2\times 9.8\times 4.9$ 3

$\therefore w_y = 9.8\,m/s$

b) $\uparrow\ V = V_0 + at \Rightarrow 0 = w_y - 9.8t \Rightarrow \underline{t = 1s}$ 3

c) $w_y = u\sin\theta \Rightarrow 9.8 = 9.8\times\frac{5}{4}\sin\theta$ 3

$\therefore \sin\theta = \frac{4}{5},\quad \theta = 53.1,\quad \cos\theta = \underline{3/5}$

d) $d = (u\cos\theta + v)\,t = \left(9.8\times\frac{5}{4}\times\frac{3}{5} + \frac{14.6}{4}\right)\times 1$

$= \left(\frac{29.4}{4} + \frac{14.6}{4}\right) = \frac{44}{4} = \underline{11\ m}$ 3

11 (Chapter 8) A stationary object of mass M is struck head on by an object with mass N and moving with a velocity v. Consider this as an elastic collision and the object velocity of the object M is u and that of the object N is w after the collision. a) Write down the equations needed to obtain u and w. b) Obtain u and w in terms of v, M and N. c) What happens in the limit N/M very large, does it make sense? d) How does the objects share the kinetic energy when M=N? (find the ratio)

a) Conservation of Momentum $NV = Nw + Mu$ -- ① 1+1 pt

Conservation of Energy $\frac{1}{2}NV^2 = \frac{1}{2}Nw^2 + \frac{1}{2}Mu^2$ -- ② 1+1 pt

or relative velocity reverses $v = -(w-u)$ ③ 2 pts

$\therefore u = v + w$ ...

b) ① ⇒ $N(v-w) = Mu$ -- ④

② ⇒ $N(v^2-w^2) = Mu^2$ -- ⑤

⑤/④ ⇒ $\frac{v^2-w^2}{v-w} = u \Rightarrow v+w = u$ same as ③

③ in ① ⇒ $NV = Nw + M(v+w) \Rightarrow (N-M)v = (N+M)w$

$\therefore w = \frac{N-M}{N+M}v$ and then in ③

5 pts

$u = v+w = v + \frac{N-M}{N+M}.v = \frac{2Nv}{N+M}$

3 pts c) N/M very small i.e. $M >> N$ $u \approx 0$ and $w = -v$

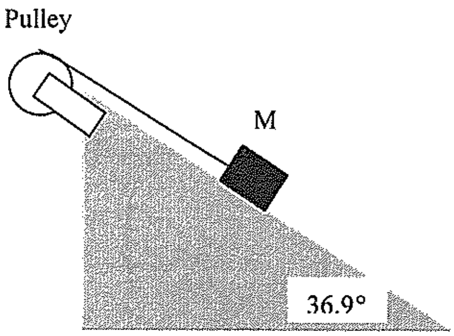
(~~ignore~~ $N \neq 0$)

yes, when a lighter object hits a massive object, big mass hardly changes velocity, light one reverses the speed.

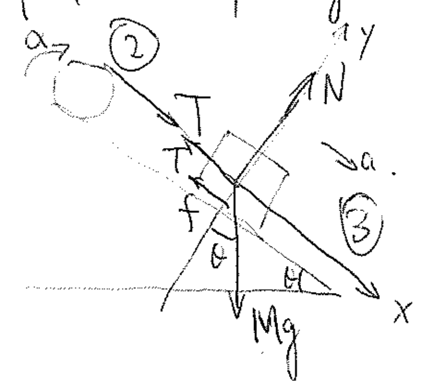
3 pts d) $M = N \Rightarrow w = 0,\ u = v$

Moving object stops and all the energy is ~~taken~~ given to the object initially at rest.

12 (Chapter10)A block with mass M is attached to a rope wrapped around a pulley of mass 2M and radius R as shown in the figure and held still on the wedge. After releasing the block it slides down the wedge with a constant acceleration a. Pulley rotates on a frictionless axel and the coefficient of kinetic friction between the block and the wedge is μ_k. a) Draw free body diagrams (indicate all the forces) needed to calculate a. b) Calculate a.



a). Free body diagram



b) y: $N - Mg\cos\theta = 0$

$N = Mg\cos\theta$. 2

x: $Mg\sin\theta - T - f = Ma$

$Mg\sin\theta - T - \mu_k N = Ma$. 3

Pulley: $TR = I\alpha$

$T\cdot R = \frac{1}{2}\cdot 2MR^2\alpha = MR^2\cdot\frac{a}{R}$ 3

$T = Ma$.

$Mg\sin\theta - Ma - \mu_k Mg\cos\theta = Ma$

$a = \dfrac{\sin\theta - \mu_k\cos\theta}{2}g = \dfrac{\frac{3}{5} - \mu_k\cdot\frac{4}{5}}{2}g = \frac{g}{10}(3 - 4\mu_k)$. 2