Feb 21/20

Possible Questions for BCENGRPHYS 3

Chapter 13: Force and Acceleration

13.1 – 13.4 F=ma : rectilinear

8	13-24	★★	pulleys & masses → §12.9 needed	✓
8	13-28	★★	pulley, but not needing §12.9	✓
9	13-24	★	springs & pulleys, dropping mass	✓
12	13-8	★	basic kinematics	✓
12	13-12	★★	basic kinematics disguised	✓
13	13-28	★★★	kinematics ~~A~~ $f=\mu g$, friction	✓
8	13-8	★	concepts	
11	13-12	★★	calculus, concept (viscous drag)	
12	13-36	★★★	friction, impending motion, variables	

13.5 Normal Tangential

8	13-80	★★★	ρ, FBD, lots of detail	✓
11	13-68	★★	forces along path, ρ	✓
12	13-60	★★★	ball spinning around axis – spring	✓
12	13-80	★★	basic motion but disguised, ρ	✓
8	13-69	★	basic energy and concepts, multiple techniques	✓
13	13-82	★★★	collar on guide, spring	✓
8	13-76	★★	springs on parabolic surface	

13.6 Cylindrical

8	13-104	★★★	calculus, multiple coordinates, ψ	✓
12	13-96	★★★	calculus, multiple coordinates, ψ	✓
8	13-102	★★	ball lifted on hemisphere r, θ, geometry	✓
13	13-104	★★★	multiple coordinate systems	✓
10	13-100	★★	rθ, forked rod, ψ	

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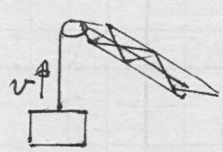
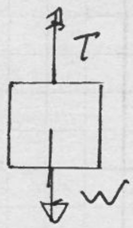
Page 1/1

Problem: Hibbeler 8th ed: 13 - 8



The 200 kg crate is suspended from the cable of a crane. Determine the force in the cable when $t = 2s$, if the crate is moving upward with
a) a constant velocity of 2 m/s and
b) a speed of $v = (0.2t^2 + 2)$ m/s where t is in seconds



a) using $\sum \vec{F} = m\vec{a}$

when $\vec{v}$ is constant, $\vec{a} = 0$

$$T - W = 0$$

$$\therefore T = (200\,kg)(9.81\,m/s^2)$$

$$\boxed{T = 1.96\,kN}$$ ← T

b) when $\vec{v} = (0.2t^2 + 2)$ m/s upward

$$\vec{a} = \frac{d\vec{v}}{dt}$$

$$\vec{a} = 0.4t \ m/s^2$$

when $t = 2s$ $\quad \vec{a} = 0.8\ m/s^2$

so $\sum \vec{F} = m\vec{a}$

$\hat{j}$: $\quad T - W = ma$

$$T = W + ma$$

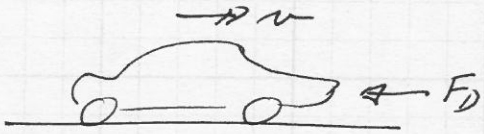
$$= (200\,kg)(9.81\,m/s^2) + 200\,kg(0.8\,m/s^2)$$

$$\boxed{T = 2.12\,kN}$$ ← T

When the crate is moving at constant velocity, the tension is 1.96 kN. When the crate is moving up at increasing speed, the tension is 2.12 kN at 2 s.

← Final Answer

Hibbeler 11th ed 13-12



A car of mass m is travelling at a slow velocity v_0. If it is subjected to the drag resistance of the wind, which is proportional to $F_D = kv$, determine the distance and the time the car will travel before its velocity becomes $0.5 v_0$. Assume no other frictional forces act on the car.

Consider only the horizontal component.

The only horizontal force on the car is F_D

$\therefore$

$$\Sigma F = ma$$

$$-kv = ma$$

(The force is negative to the left if v is positive to the right)

using $a = \frac{dv}{dt}$

$$-kv = m\frac{dv}{dt}$$

$$-\frac{k}{m}\,dt = \frac{dv}{v}$$

$$-\frac{k}{m}\int_0^t dt = \int_{v_0}^{v}\frac{dv}{v}$$

$$-\frac{k}{m}(t-0) = \ln v \Big|_{v_0}^{v}$$

$$-\frac{k}{m}t = \ln\left(v/v_0\right)$$

when $v = \frac{1}{2}v_0$

$$t_{\frac{1}{2}} = -\frac{m}{k}\ln\left(\frac{\frac{1}{2}v_0}{v_0}\right)$$

$$\boxed{t_{\frac{1}{2}} = \frac{m}{k}\ln 2} \longleftarrow t_{\frac{1}{2}}$$

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Hibbeler 11th ed 13-12 2/2

now for the distance

$$-\frac{k}{m} t = \ln(v/v_0)$$

$$e^{-\frac{k}{m}t} = v/v_0$$

$$\therefore \quad v_0 e^{-\frac{k}{m}t} = \frac{ds}{dt}$$

$$\int_{t_0}^{t} v_0 e^{-\frac{k}{m}t}\, dt = \int_0^s ds$$

$$v_0\left(-\frac{m}{k}\right) e^{-\frac{k}{m}t}\Big|_{t_0}^{t} = s - 0$$

$$\therefore \quad s = -\frac{m v_0}{k}\left(e^{-\frac{kt}{m}} - 1\right)$$

~~assuming~~ using $t_0 = 0$

so when $t = \frac{m}{k}\ln 2$

$$s = -\frac{m v_0}{k}\left(e^{-\ln 2} - 1\right)$$

$$s = \frac{v_0 m}{k}\left(1 - e^{-\ln 2}\right)$$

$$s = \frac{v_0 m}{k}\left(1 - \frac{1}{2}\right)$$

$$\boxed{s = \frac{v_0 m}{2k}}$$

s

The car travels $\frac{v_0 m}{2k}$ as the speed halves, and this takes $t = \frac{m}{k}\ln 2$.

Final Answer

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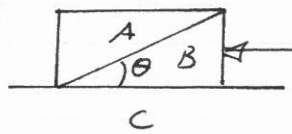
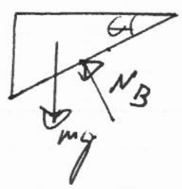
Hibbeler 12th ed 13-36 1/1



Blocks A and B each have a mass m. Determine the largest horizontal force P which can be applied to B so that A will not move relative to A. All surfaces are smooth.

Without P, block A will be supported by the normal force from B and a normal from where A touches C. Eventually P will rise high enough to remove the normal from C, but will not have the normal from B raise the A block.

Consider Block A



$\Sigma \vec{F} = m\vec{a}$

$\hat{\imath}$ component

$-N_B \sin\theta = ma$

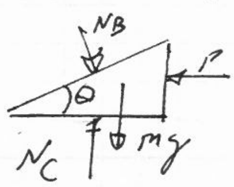
$\hat{\jmath}$ component

$N_B \cos\theta - mg = 0$

$\therefore$ $\boxed{a = -g\tan\theta}$ — a

and $\boxed{N_B = mg/\cos\theta}$ — N_B

Consider Block B



$\Sigma \vec{F} = m\vec{a}$

$\hat{\imath}$ component

$N_B \sin\theta - P = ma$

combining

$mg\tan\theta - P = -mg\tan\theta$

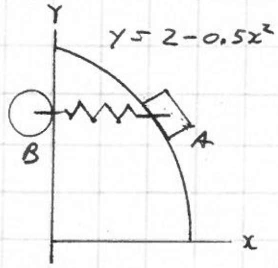
$\boxed{P = 2mg\tan\theta}$ — P

The maximum P that will not lift A is $2mg\tan\theta$	— Final Answer

TOPS. 35500

Peter Mulhern Physics 113 January 31/99
Page 1/2

Problem: Hibbeler 8^{th} ed. 13-76



The 6kg block is confined to move along the smooth parabolic path. The attached spring restricts the motion and, due to the roller guide, always remains horizontal as the block descends. If the spring has stiffness of $k = 10$ N/m, and an unstretched length of 0.5m, determine the normal force of the path on the block at the instant $x = 1$m and the block has a speed of 4 m/s. Also, what is the rate of increase in speed of the block at this point? Neglect the mass of the roller guide and the spring.

Calculating the curvature at the point in question

$Y = 2 - 0.5x^2$ at $x = 1$ $Y = 1.5$

$\frac{dy}{dx} = -x$ at $x = 1$ $\frac{dy}{dx} = -1$

$\frac{d^2y}{dx^2} = -1$

The curvature is then

$$\rho = \frac{\left(1 + \left(\frac{dy}{dx}\right)^2\right)^{\frac{3}{2}}}{\left|\frac{d^2y}{dx^2}\right|}$$

$$= \frac{(1 + (-1)^2)^{\frac{3}{2}}}{|-1|} = \sqrt{8}$$

$\boxed{\rho = 2.8284 \text{ m}}$ ← ρ

The direction of the surface at this point is

$\theta = \arctan\left(\frac{dy}{dx}\right)$

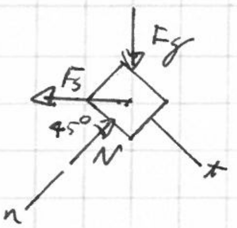
$\theta = \arctan(-1)$

$\boxed{\theta = -45°}$ ← θ

Peter Mulhern Physics 113 January 31/99
Page 2/2

Problem: Hibbeler 8th ed. 13-76

Free body diagram of the mass



Force of spring

$$F_s = k(l - l_0)$$
$$= \cancel{10\ N/m\,(1 - 0.}$$
$$= 10\ N/m\,(1m - 0.5\ m)$$

$$F_s = 5\ N$$

Newton's second law

$$\Sigma \vec{F} = m\vec{a}$$

t component:

$$mg\sin 45° - F_s\cos 45° = m a_t$$

n component:

$$mg\cos 45° + F_s\sin 45° - N = m\frac{v^2}{\rho}$$

$$(6kg)(9.81 m/s^2)\left(\tfrac{1}{\sqrt{2}}\right) + 5N\left(\tfrac{1}{\sqrt{2}}\right) - N = (6kg)\frac{(4 m/s)^2}{2.8284 m}$$

$$\therefore \boxed{N = 11.2 N} \longleftarrow N$$

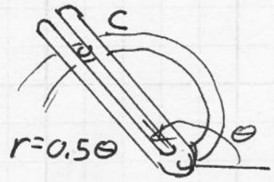
putting this into the t component

$$a_t = 9.81 m/s^2 \tfrac{1}{\sqrt{2}} - \tfrac{5N}{6kg}\tfrac{1}{\sqrt{2}}$$

$$\boxed{a_t = 6.35\ m/s^2} \longleftarrow a_t$$

The normal force on the mass is 11.2 N and it has an increase of speed of 6.35 m/s²	← Final Answer

Hibbeler 10th ed 13 – 100 1/2



Using a forked rod, a smooth cylinder C having a mass of 0.5kg is forced to move along the vertical slotted line $r = 0.5\theta$ m, where θ is in radians. If the angular position of the arm is $\theta = 0.5t^2$ rad, where t is in seconds, determine the force of the rod on the cylinder and the normal force of the slot on the cylinder at the instant $t = 2$s. The cylinder is in contact with only one edge of the rod and slot at any instant.

computing the derivatives

$$r = 0.5\theta$$

$$\dot{r} = 0.5\dot{\theta}$$

$$\ddot{r} = 0.5\ddot{\theta}$$

$$\theta = 0.5t^2$$

$$\dot{\theta} = t$$

2 $$\ddot{\theta} = 1$$

so at $t = 2$s

$r = 1$ m $\quad \dot{r} = 1$ m/s $\quad \ddot{r} = 0.5$ m/s^2

1 $\theta = 2$ rad $\quad \dot{\theta} = 2$ rad/s $\quad \ddot{\theta} = 1$ rad/s^2

also $dr/d\theta = 0.5$ m/rad

so

$$\tan\psi = \frac{r}{dr/d\theta}$$

$$= \frac{1\text{m}}{0.5\text{ m/rad}}$$

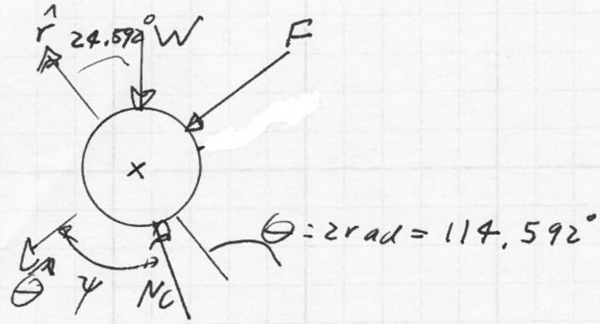
$$= 2$$

3 $$\psi = 63.43°$$

January 5, 2006

Hibbeler 10th ed 13-100 2/2

computing the FBD for the cylinder

3 

I will resolve this onto $\hat{u}_r$ and $\hat{u}_\theta$ because I can compute a_r and a_θ from the given data.
I could also use $\hat{u}_n$ (the direction of N_c) and $\hat{u}_t$, but I don't have any information about a_n and a_t

1 $\Sigma \vec{F} = 0$

$\hat{u}_r$ component

3 $-W\cos(24.592°) + N_c \sin\psi = m(a_r)$

$-(0.5\,kg)\,9.81\,m/s^2 \cos(24.592°) + N_c \sin 63.43° = 0.5\,kg(\ddot{r} - r(\dot{\theta})^2)$

$-4.460\,N + N_c\, 0.89439 = -1.75\,N$

$\therefore \boxed{N_c = 3.030\,N}$ ← N_c

$\hat{u}_\theta$ component

3 $F + W\sin(24.592°) - N_c \cos 63.43° = 0.5\,kg\, a_\theta$

$F + 0.5\,kg(9.81\,m/s^2)\sin(24.592°) - 3.030\,N\cos 63.43° = 0.5\,kg(r\ddot{\theta} + 2\dot{r}\dot{\theta})$

$F + 2.0412\,N - 1.3553\,N = 2.5\,N$

$\boxed{F = 1.81\,N}$ ← F

2 The force of the fork on the cylinder is 1.81 N and the normal force of the slot on the cylinder is 3.03 N ← Final Answer

/15