Physics II Test
Rotational Motion (Answers)

(1)

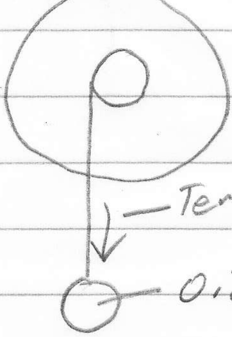
1. $d = V_0 t + \frac{1}{2} a t^2$

V_0: zero

$0.7m = \frac{1}{2} a (10s)^2$

$a = 0.014 m/s^2$

2.



Tension ≈ mg

0.2kg = 200g

Tension is actually

$F_{Tension} = m(g - a)$

a is small, so Tension ≈ mg

$F_{Tension} = 0.2kg(9.8 m/s^2 - 0.014 m/s^2)$

$F_{Tension} = 1.95N$

3. $\tau = Fr$

F: Force applied (string tension)

r: radius at which force is applied

$\tau = 1.95N(0.05m)$

$\tau = 0.098 m \cdot N$

4. $\alpha = \frac{a}{r} = \frac{0.014 m/s}{0.05 m/radian} = 0.28 rad/s^2$

0.014 m/s: From #1

m/radian: meters per radian (1 radian = 1 radius = 0.5m)

2

5. $\tau = I\alpha$

$0.098\,m \cdot N = I(0.28\,rad/s)$

From #3

$I = 0.35\,kg\,m^2$

6. $PE_1 + KE_1 = PE_2 + KE_2$

mgh zero zero

This is $KE_{Translational} + KE_{rotational}$

$mgh = KE_{Trans.} + KE_{rot}$

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

$mgh - \frac{1}{2}mv^2 = \frac{1}{2}I\left(\frac{v}{r}\right)^2$

$2kg(9.8\,m/s^2)(1.5\,m/s) - \frac{1}{2}(2kg)(5\,m/s)^2 = \frac{1}{2}I\left(\frac{5\,m/s}{0.8\,m}\right)^2$

$I = 0.23\,kg\,m^2$

7. $KE_{rot} = \frac{1}{2}I\omega^2 = \frac{1}{2}I\left(\frac{v}{r}\right)^2$

$KE_{rot} = \frac{1}{2}(0.23\,kg\,m^2)\left(\frac{5\,m/s}{0.8\,m}\right)^2$

$KE_{rot} = 4.4\,J$

★ I told you to use $F = 80N$ last year we used 40N

Force

3

8. Torque applied by big crank $= Fr = 40N(0.3m)$

crank length

This same torque is applied to sprocket A, so the

$Torque_{sprocket A} = 40N(0.3m) = 12m \cdot N$

This torque applies a force to the chain at the sprocket radius of 0.02m, so

$$\tau = Fr$$

$$12m \cdot N = F(0.02m)$$

$$F = 600N$$

This is the force applied to the chain -- and which the chain transfers to sprocket B, so...

$$\tau_{sprocket\ B} = 600N(0.8m) = 480m \cdot N$$

s.B. radius

This torque is equal throughout sprocket B and smearing wheel, so

$$\tau = Fr$$

$$480m \cdot N = F(0.83m)$$

$$F_{smearing\ wheel} = 578N$$

9. Sprocket A circumf = $2\pi(0.02m)$
$= 0.126m$

Sprocket A turns once per rotation of the big crank, and a point on its edge travels 0.126m during this one rotation.

So, one crank rotation moves the chain 0.126m.

Sprocket B circumference = $2\pi(0.83m)$
$= 5.02m$

This means that a 5.02m length of chain would have to move by for sprocket B to rotate once.

$$0.126\text{m of chain}\left(\frac{1\text{ rotation}}{5.02\text{m of chain}}\right) = 0.025\text{ rotations}$$

→ Sprocket B + smearing wheel make 0.025 rotations per each crank turn.

⇓

9 (contd)

Smearing Wheel circumf $= 2\pi(0.83m)$
$= 5.21m$

$\frac{5.21m}{\text{rotation}}(0.025 \text{ rotations}) = 0.13m$

from previous page

10. Each rotation of crank moves a point on the edge of the smearing wheel a distance of 0.13m.

$\left(\frac{0.13m}{\text{crank rotation}}\right)\left(\frac{1 \text{ crank rotation}}{1.8s}\right) = 0.072 m/s$

11. $d = \underset{\text{zero}}{V_0 t} + \frac{1}{2}at^2$

$0.4m = \frac{1}{2}a(2s)^2$
$a = 0.2 m/s^2$

12. Mass does not spin, so

$KE_{mass} = \frac{1}{2}mv^2$

we need v @ bottom

$v = v_0 + at$ ⇒ $v = at$

v_0: zero

From #11

$v = 0.2\,m/s^2\,(2s)$

$v = 0.4\,m/s$

$KE = \frac{1}{2}(0.15kg)(0.4\,m/s)^2$

$= 0.012j$

13. $PE_{1_{mass}} = KE_{2_{mass}} + KE_{2_{pulley}}$ ← this is what we're looking for

Simplified for clarity

Only energy at beginning (mgh)

$\frac{1}{2}mv_2$ (mass is not spinning)

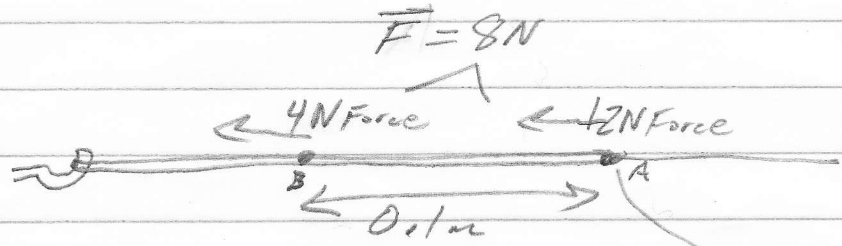
$mgh = KE_{2_{mass}} + KE_{2_{pulley}}$

$(0.15kg)(9.8\,m/s^2)(0.4m) = 0.012j + KE_{2_{pulley}}$

$KE_{2_{pulley}} = 0.576j$

14. $F_{Ave} = \frac{F_1 + F_2}{2} = \frac{4N + 12N}{2} = 8N$

15.



Force is applied as this end of the rubber band moves from point A to point B.

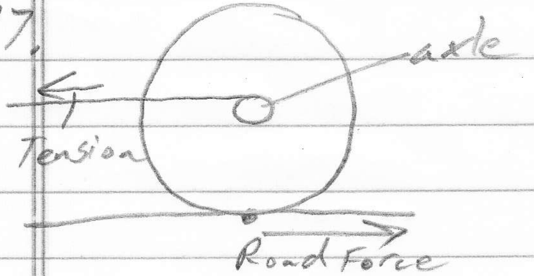
Distance over which force was applied = 0.1m

16. PE ≈ work put into stretching band = Fd

8N 0.1m

$8N(0.1m) = 0.8j$

17.



String tension creates torque by applying force at axle radius

$\tau = Fr = 12N(0.003m) = 0.036\,m\cdot N$

Initial Force   axle radius

This torque exists throughout wheel, so

$\tau = F_{road}\, r_{wheel}$

wheel radius

$0.036\,m\cdot N = F_{road}(0.03m)$ $F_{road} = 1.2N$

18. $\underbrace{PE_1}_{mgh} + \underbrace{KE_1}_{zero} = \underbrace{PE_2}_{zero} + \underbrace{KE_2}_{zero} + \underbrace{Fd}_{Friction}$

$mgh = Fd$

$0.2kg(9.8m/s^2)(0.6m) = F_{Friction}(25m)$

$F_{Friction} = 0.047N$

19. Drive axle circumference $= 2\pi r = 2\pi(0.0003m)$
$= 0.019m$

According to diagram, 0.1m of string unwinds.

0.019m of string forms 1 "wrap" around axle. Pulling off that much string causes 1 rotation.

$\left(\frac{1\ \text{rotation}}{0.019\ \text{m string}}\right)(0.1m\ \text{string}) = 5.26$ rotations of wheel + axle

Wheel circumf $= 2\pi(0.03m) = 0.19m \leftarrow$ Distance traveled per rotation

$5.26\ \text{rotations}\left(\frac{0.19m}{\text{rotation}}\right) = 1m$

20. $PE_1 + KE_1 = PE_2 + KE_2 + Fd$

work done in winding string (from #16)

zero

Zero

Friction

Pull distance (From #19)

$$PE_1 = KE_2 + Fd$$

$$0.8j = KE_2 + (0.047N)(1m)$$

$$KE_2 = 0.75j$$

21. $KE_2 = 0.75j = \frac{1}{2}mv^2 + \frac{1}{2}I_F\omega_F^2 + \frac{1}{2}I_R\omega_R^2$

$\omega_F = \frac{V}{r_F}$, $\omega_R = \frac{V}{r_R}$

$$0.75j = \frac{1}{2}(0.2kg)v^2 + \frac{1}{2}(0.00004)\frac{v^2}{0.02^2} + \frac{1}{2}(0.00006)\frac{v^2}{0.03^2}$$

I left out units to squeeze this in.

$$2(0.75j) = v^2(0.2kg + 0.1kg + 0.066kg)$$

$$V = 2.03 \, m/s$$

Friction

22. $PE_1 + KE_1 = PE_2 + KE_2 + Fd$

zero

Zero

zero, since it's rolling as far as it can .. and then stopping

$PE_1 = Fd$

$0.8j = 0.047N(d)$

$d = 17m$