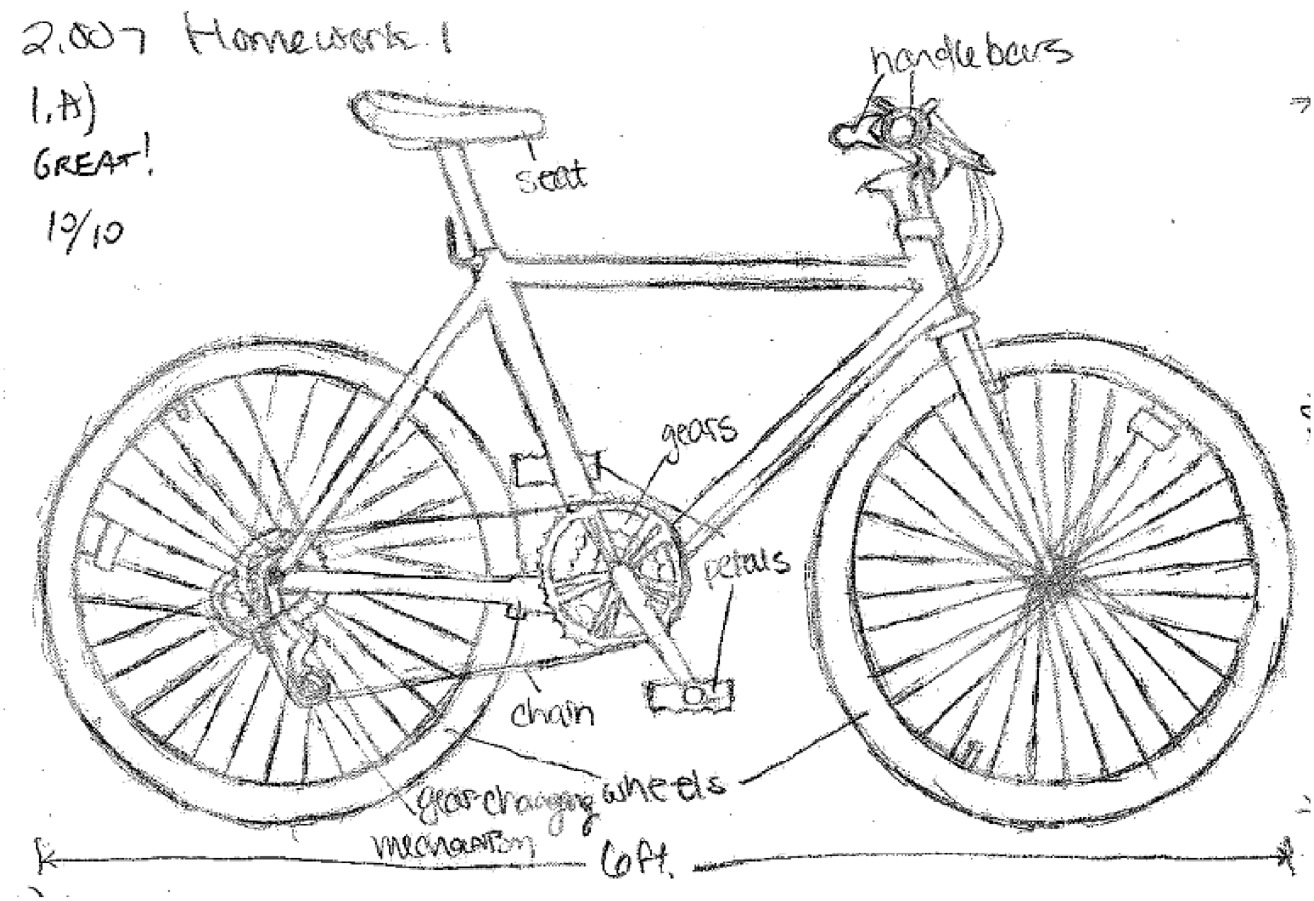
2.007 Design and Manufacturing I
Spring 2009

“Solution” to 2.007 Homework #1

This “solution” is just a composite of students’ solutions that I considered particularly good.

A nice example of 1A

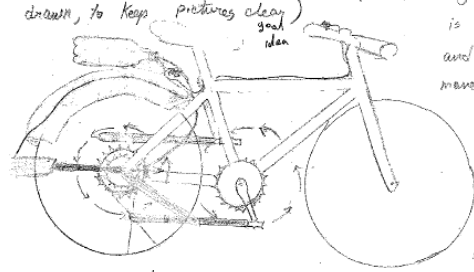


A strong performance on 1B

Prob 1 (B)

Pneumatics System – It's done by utilizing the pressure, saved in a bottle to boost off and accelerate uphill, or just start moving. A lever is attached between the pedal and the back wheel which moves in a circle (when it is set at the 1:1 gear ratio). The circular movement of the red lever causes the blue lever to pump air into the bottle, which is then used at the press of a button! (2.670 style!). The pressure is released which causes the lever on the other side to rotate the back wheel.

(No spokes or default chain are drawn, to keep pictures clear) good idea

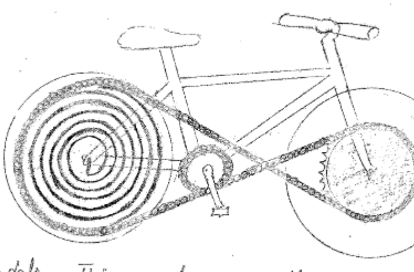


good!

Wind-up Mechanism –

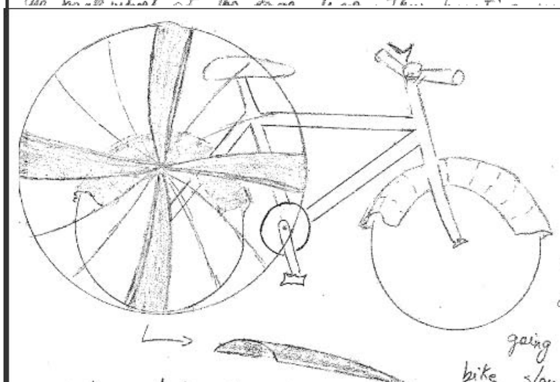
One end of a spiral spring is attached to the back wheel, while the other end is attached the chain that surrounds gears in the front wheel and pedals. This mechanism allows for the biker to store energy as he goes downhill in the spiral spring. Whenever he wants that extra speed, with the press of a button (I make it sound so easy !!), the chain is released from the spiral (same way as gears change) causing the spiral spring to go back to its original state, but rotating

yes, some mechanism is needed!



Wind Powered

This bike uses wind power (drag Force) to its advantage. When going downhill, this bike slows down as the wind rotates the fan which powers up the battery that later converts the energy so it can be used later. To avoid the wind from ALWAYS slowing you down, a switch at the bike hand can close the fan so it can be used when needed



A fine job on 1C

	Pneumatic	Electric	Elastic
weight	+ air is light	D	+ electronics (battery, motor) tend to be heavy. This would be lighter
safety	− explode if overpressurized	A	+ no risk of electric shock or fire
ease to make	+	T	−
reliability	− air could leak needs to be repumped	U	− plastic teeth could break
size	− multiple bottles, see below	M	n/a (see below)

Energy 80 kg person to go 1 m

Pressure · Area = Force

$P = \frac{800}{\pi(0.015)^2} = 1.3 \times 10^6\ N/m^2 = 164\ psi$ too much for 1 bottle

$P = \frac{800}{2 \cdot \pi (0.015)^2} = 5.6 \times 10^5\ N/m^2 = 82\ psi$

$P = \frac{800}{3 \cdot \pi \cdot (0.015)^2} = 55\ psi < 60\ psi$

so use 3 bottles to be safe

Elastic

Good!

$U = \frac{1}{2} k x^2$ ← cover part of top tube

$800 = \frac{1}{2} k (0.5)^2$

$6400 = k$

I played around with:
http://www.engineersedge.com/calculators/comp-spring-k-pop.htm

$k = 6400$

for various wire diameter, # coils, and mean coil diameter
$(0.25 < d < 1)$ $(30 < n < 100)$ $(2.5 < D < 4)$

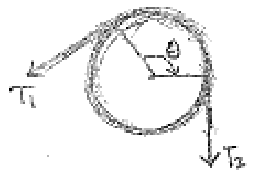
The calculator then gave me a modulus of rigidity.
I compared values to
http://www.engineeringtoolbox.com/modulus-rigidity-d_946.html
and could not find a strong enough material.
This design is not feasible without changing desired energy storage or some dimensions.

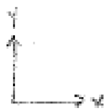
Electric

I looked up energy storage in batteries at:
http://www.allaboutbatteries.com/Energy-tables.html
Even AAA batteries store more than 800 J. (~1200-5000 depending on type of battery).
This solution would not need to be recharged as often as a bottle needs air (depending on use) and could store more energy.

True.

2) A)





V = constant, ∴ $a = 0 \Rightarrow \Sigma F = 0$ $\theta = 110° = \frac{11\pi}{18}$ rads

$\Sigma F_y = T_2 - mg = 0$

$T_2 = mg$

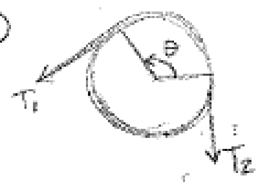
Capstan equation: $T_1 = T_2 e^{\mu\theta}$

Friction works opposite to direction of motion

$T_1 = mg e^{\mu_k \theta}$ ⇒ use μ_k since the rope slides over the capstan

$T_1 = 5 \cdot e^{0.2 \cdot \frac{11\pi}{18}} = 7.34$ N ✓

B)



$T_1 = mg e^{-\mu_k \theta}$

$T_1 = 5e^{-0.2 \cdot \frac{11}{18}\pi} = 3.41$ N ✓

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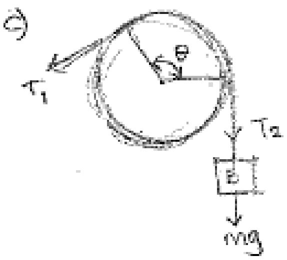
C)



⇒ use μ_s since rope is not moving, is static

$T_1 = 5e^{-0.3 \cdot \frac{11}{18}\pi} = 2.81$ N ⇒ to keep from slipping down

$T_1 = 5e^{0.3 \cdot \frac{11}{18}\pi} = 8.89$ N ⇒ to keep from pulling too far back

$2.81 \text{ N} \leq T_1 \leq 8.89 \text{ N}$ ✓   Good!

D) Friction always acts in the direction opposite of motion. In the case of (A), we are pulling the rope towards us, so friction works to oppose us making it harder to raise the block than it would be without friction. In the case of (B), the block is moving down, so friction works to slow that down. In that case, friction is making it easier to lower the block slowly. In both (A) and (B), the block and rope are moving so we use the kinetic coefficient of friction, which you use for moving objects. We know it is harder to fight friction from a stand still than it is once something is already moving, so we know the coefficient of kinetic friction is less strong than that of static friction - the coefficient we use for still objects. To get the rope to move in (C) we would have to overcome the force due to static friction. This could happen either by pulling too hard, or not hard enough, such that the weight of the block pulls the rope down. If we pull with a force somewhere in between, we can hold the block steady.

3) A) 5V

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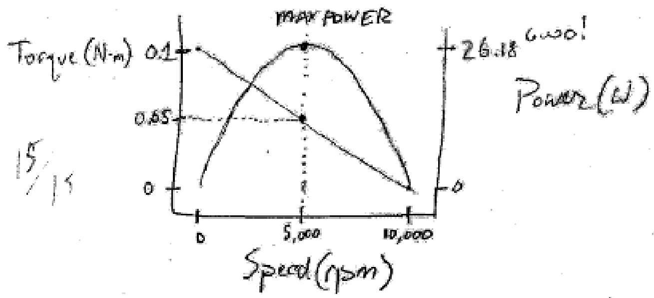
$w(T)$

$W(0) = 10{,}000 \cdot \frac{2\pi}{60}$

$w(0.1\,Nm) = 0$



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The electrical connections of a DC motor are shown in the figure below.

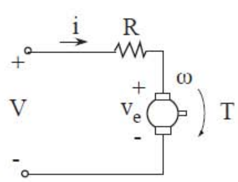

Figure 1: Electrical schematic of DC motor

The voltage applied to the input terminals, V_{in}, and the output torque, T, are given by the following formulae,

$$V_{in} = Ri - K_v\omega$$

$$T = K_t i$$

where K_v and K_t are the back-emf and torque constants respectively. While these constants are typically provided by the manufacturer of a particular motor, they are known to depend upon the number of windings, the rotor length, the rotor radius and the magnetic field strength as follows.

$$K_v = K_t = 2nLrB$$

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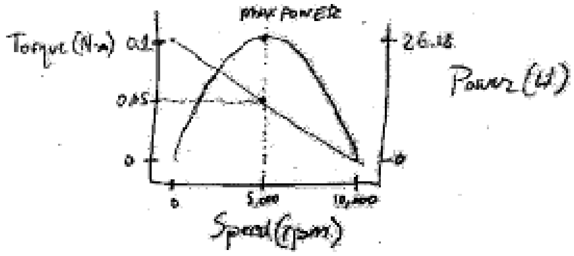
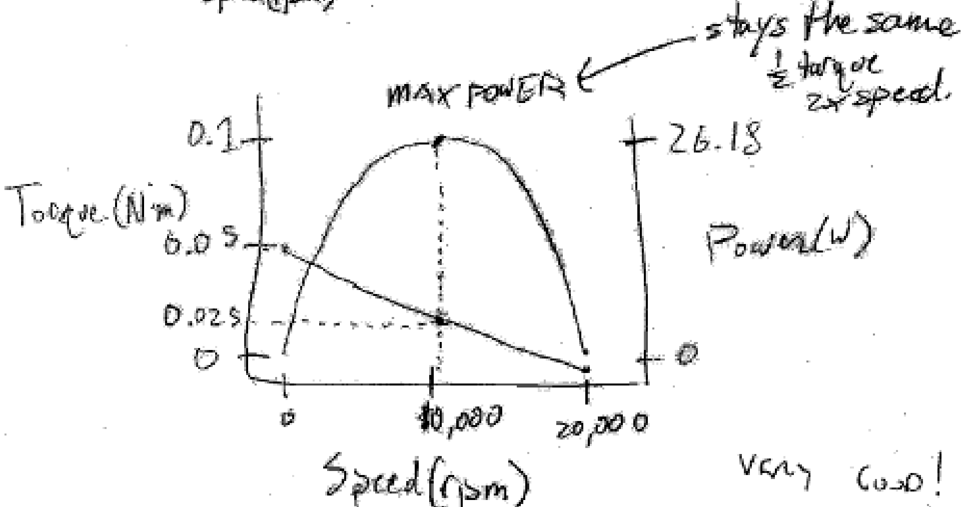

MAX POWER
Torque (N·m)
0.1
0.05
0
26.18
Power (W)
0
5,000
10,000
Speed (rpm)


stays the same
½ torque
2x speed
MAX POWER
0.1
Torque (N·m)
0.05
0.025
0
26.18
Power (W)
0
10,000
20,000
Speed (rpm)

Very Good!