Team Name:	The Engineers	Team #:	$e^{i\pi}$

Names:	Ben Bitdiddle	Alyssa P. Hacker

Compound Machines Answer Key

Question 1	
a	C
b	D
c	A
d	A
e	A
f	B
g	E
h	D
i	D
j	A

Question 2	
a	A
b	E
c	B
d	D
e	A
f	C
g	B
h	A
i	A
j	D

Question 3	
a	A
b	B
c	B
d	A
e	D
f	B
g	B
h	E
i	A
j	E

Question 4	
a	2
b	2.4m
c	21N
d	78.4%
e	3.67

Question 5	
a	13
b	increase mechanical advantage
c	9.4
d	60.kg
e	0.058

1. (6 points) Belt Drive Turntable

   Many modern vinyl turntables are belt driven; a motor with a small pulley is coupled to a much larger record platter with a belt. For the audio to have the right tempo and pitch, it's critical that the platter spins at $33\frac{1}{3}$ rpm (for most records).

   Suppose a turntable has a platter pulley radius of 12.0 cm and its drive pulley has a radius of 1.00cm. Calculate:

   1. The speed in rpm that the motor must rotate at.
   2. The mechanical advantage of the belt system.
   3. The required torque of the motor given that the belt must apply 2.00 N of force to the platter for it to spin at a constant $33\frac{1}{3}$ rpm.

   1. 400. RPM22222222222222222222
   2. 12
   3. 0.0200 N m

2. (7 points) Guitar Tuner

   To hold guitar strings at the right tension, guitar tuning machines use a compound machine with a spur gear, a worm gear, and a wheel/axle (the knob). A particular tuning machine has a string peg radius of 3.00mm (attached to the spur gear), a spur gear with 14 teeth, and a knob radius of 9.00mm.

   1. Calculate the gear ratio of the worm gear system.
   2. When the string is tuned with 3.84 Newtons of force on the ends of the knob, the string's tension is 100. Newtons. Calculate the efficiency of the tuning machine system.
   3. Suppose a string is in tune at a tension of 80.0 Newtons and you apply a lubricant that increases the efficiency found above by 0.200. Calculate the force in newtons you must apply to the ends of the knob.

   1. 14:1
   2. 0.620t
   3. 2.32 N

3. (7 points) Bungee Drop

   Your Bungee Drop teammates need help! They ask you to devise a clamp to anchor their bungee device that can be hand-tightened to the correct pressure for maximum convenience. They've determined that the clamp must exert 210. N of force on the bungee device to hold it and request that it can be tightened with only 5.00 N of effort. The clamp will use a lever coupled to a screw, similar to many vises. The only screw available for the clamp has an outside diameter of 12.0mm and a pitch of 2.0mm. Calculate the minimum lever length needed to satisfy their requirements.

   Desired MA: $\frac{210.}{5.00} = 42.0$

   Compound MA: $\frac{L}{0.00060}\frac{0.00120\pi}{0.0020}$

   Solve for L: $L = \frac{42 \cdot 0.0020 \cdot 0.00060}{0.00120 \cdot \pi} = 0.013\text{m or } 1.3\text{cm or } 13\text{mm}$

4. (7 points) Nail Clipper

   Nail clippers can be represented as a compound machine of two levers and a wedge that cleaves the fingernail.

   1. Using the specifications found in the diagram, calculate the mechanical advantage of each simple machine and also the entire compound machine.
   2. Assuming it takes 25.0 Newtons of lateral force on a fingernail to cleave it, how much effort must a user apply to cut their fingernails?

   1. Top lever: 4.00
      Lower lever: 0.714
      Wedge: 2.5
      Entire: 7.1
   2. $\frac{25.0}{7.14} = 3.5N$

5. (7 points) Elevator Counterweights

   To lower the load on the motor in a traditional elevator, a counterweight is used on one end of a pulley system to balance with the elevator cab.

   For the elevator pulley system pictured, the elevator cab has a mass of 500. kg and must have a passenger capacity of 2.00×10^3 kg.

   1. Find a counterweight mass that minimizes the motor load at half the passenger capacity.
   2. For a lift motor with a 10.0 cm pulley radius, what is the maximum torque required to allow static equilibrium at all capacities?

   1. $1.50 \times 10^3 \cdot 2 = 3.00 \times 10^3$
   2. $1.00 \times 10^3 * 9.81 * 0.100 = 981 Nm$

6. (8 points) Crane counterweights

   In construction cranes, the main horizontal jib must be counter-weighted on the opposite side of the load so that the crane doesn't collapse at the vertical support point. You are designing a crane that must be able to lift a 5.00×10^3 kg load 70.0 meters away from the vertical support. However, the vertical support can withstand 2.00×10^6 newton meters of torque before failing. Use 9.81 as the acceleration of gravity, g.

   1. What is an appropriate counterweight mass needed if the counterweight is mounted 20.0m behind the vertical support? The crane must not collapse under no load as well.
   2. Using the counterweight mass found above, what is the maximum load mass the crane can support 20.0m in front of the vertical support?

   1. We unfortunately threw out this question because we believed the parameters were set inappropriately. Therefore every test was graded for 92 points total and scaled to 50 points.

7. (8 points) Mission Possible

   Your Mission Possible teammates need help as well. Their device needs to easily lift golf balls a certain distance, but they're unsure what compound machine would be best.They need to convert rotational motion from a motor to vertical linear motion and have mechanical advantage, so you settle on a screw conveyor and inclined plane design, which can accommodate lifting many balls at once.

   For the screw conveyor, the screw has an overall radius of 10.0cm and a pitch (thread spacing) of 5.00 cm. The motor is directly coupled with this screw and can only output 1.79 mN m of torque. Your goal is to be able to lift five 45.9 gram golf balls at once at static equilibrium.

   1. What is the maximum angle for the inclined plane where this is possible?
   2. Find the mechanical advantage of the screw, the inclined plane, and the whole system.

   1. $F_{out} = \text{Compound MA} \cdot F_{in}$
      $0.0459 * 9.81 = \frac{0.20 \cdot \pi}{0.05} \frac{1}{\sin\theta} \frac{0.00179}{0.1}$
      $\sin\theta = 0.50$
      $\theta = \frac{\pi}{6} = 30.^\circ$
   2. Screw: 12.6
      Incline Plane: 2.00
      Whole System: 25.1