Compound Machines Division C

School Name_____

Team Number _____

Directions: Answer the questions as they are written. DO NOT assume a question meant

something other than what it reads. All wording and numbers are deliberate.

Use the correct number of significant figures and keep track of all units.

Partial credit may be awarded for any question. Point values are listed, so prioritize your work.

You have **30 MINUTES**. Good ~~luck~~ skill!

Part 1: Matching (TIEBREAKER ONLY)

1) Work   e.   a. The force that a simple machine is attempting to overcome

2) Effort   g.   b. The ratio of output work to input work

3) IMA   l.   c. Not a simple machine: Can be used as a pulley wheel

4) Load   a.   d. The grooved wheel of a pulley

5) AMA   j.   e. The dot product of force and distance

6) Efficiency   b.   f. Last recognized simple machine

7) Windlass   k.   g. The force applied to a simple machine that gets multiplied

8) Inclined Plane   f.   h. Not a simple machine: Toothed wheels connected by a belt

9) Gear   m.   i. Two or more pulleys in blocks

10) Sprocket   h.   j. The ratio of output force to input force

11) Block and Tackle   i.   k. Type of wheel and axle using a cable and a crank

12) Deadeye   c.   l. Ratio of input distance to output distance

13) Sheave   d.   m. Not a simple machine: Toothed wheel

Part 2: Identification of Simple Machines
Directions: For each of the following devices, name one simple machine that is present within the device (1 point) and where it is found, if any (1 point). Name the class of any levers; "lever" alone will score no points. If the machine is wrong, you cannot earn the point for its location (EXCEPT: an incorrect class of lever loses one point for naming the machine but can still earn the point for location). There are many possible answers.
GENERAL: Check any answers for validity. Students may have correct responses not in key.

14) Bicycle
   a. Wheel and axle, wheels of the bike OR pedals
   b. 2nd class lever, brakes
   c. DO NOT SCORE: 3rd class lever (the load is the cable or hydraulic system right by the fulcrum), pulleys (it's a sprocket), sprockets (not a simple machine), gears (not a simple machine)
15) Stapler
   a. 2nd class lever, upper half (the bottom doesn't move)
   b. Wedge, the staples (this is not technically part of the device, but who uses a stapler without staples?)
   c. DO NOT SCORE: 3rd class lever (resistance force comes from a spring/pin at the fulcrum)
16) Mousetrap
   a. 2nd or 3rd class lever, spring-loaded part of the trap (can be either class depending on the trap)
17) Pencil Sharpener
   a. Wedge, blades
   b. Wheel and axle, crank (assuming not a handheld pencil sharpener)
   c. DO NOT SCORE: gears (not a simple machine)
   d. EXCEPTION: "planetary gear system" scores 1 point (no location point); although it isn't a simple machine, it demonstrates knowledge of related mechanical devices, which merits half-credit
18) Violin and bow
   a. Wheel and axle, tuning pegs (or fine tuners)
   b. 3rd class lever, bow (REQUIRES JUSTIFICATION)
   c. Screw, bow (the bow adjusts tightness via a screw)
   d. DO NOT SCORE: pulley (the strings are not pulled on one side to tighten the other, it's a wheel and axle)
19) Bicycle Pump
   a. 2nd class lever, seals the pump in place for use
   b. "None" can score 1 point IF a proper explanation why the main pump isn't a simple machine is provided; this demonstrates knowledge of simple machines, but does not consider the entirety of the device, which merits half-credit
20) Human Arm
   a. 3rd class levers, muscle/bone interactions
21) Grandfather Clock
   a. Wheel and axle (or windlass), the weight that falls rotates an axle, which turns the hands of the clock (the wheel)

b. "None" scores 2 points IF an explanation of why the pendulum AND gears are not simple machines is provided; this demonstrates knowledge of simple machines, and students should not be required to know the specific inner workings of a grandfather clock

c. DO NOT SCORE: gears (not a simple machine), pulley (the weight that falls to turn the clock's dials is attached to a string that is wrapped around the axle repeatedly; there is no other side of the string that gets pulled upwards with an equal force)

22) Castle Drawbridge

a. 2nd class lever, used to raise the bridge

Part 3: Free Response

23) Two physics students are holding opposite ends of a simple pulley. One has a mass of 65kg and is standing on a scale on the floor. The other has a mass of 55kg and is above the ground. If the 55kg student begins to climb up the pulley, will the scale read more, less, or the same weight? Why? (2 points)
   a. Less; Newton's third law of motion says that for every action there is an equal and opposite reaction. As the 55kg student climbs up the pulley, he pulls the rope down to pull himself up. Since the rope is being pulled down more on his end, there is more upward force on the 65kg student's end, so the scale reads less force (the net downward force is decreased).

24) When and why is IMA irrelevant? (3 points)
   a. Wedges and screws; friction is too great. Efficiency can be extremely low (like single digit low), so AMA means much more than IMA.
   b. Responses such as "When there is a lot of friction" with no reference to specific machines will score 2 point out of 3.

25) What is the unique advantage of a block and tackle system? (2 points)
   a. It allows for very large IMAs with only 2 sheaves (grooved wheels).

26) In as much detail as possible, what is torque? (1 point per distinct detail, up to 4)
   a. Cross product of force and distance
   b. Causes and caused by rotational motion
   c. Must be balanced for static equilibrium
   d. Measured in N·m
   e. Not a measure of energy; N·m ≠ J

27) When was the inclined plane recognized as a simple machine? (1 points)
   a. "Renaissance" scores 1 point

28) Who invented the first "vending machine"? How did it work? (2 points)
   a. Hero(n) of Alexandria
   b. Place a coin on a plate. The weight of the coin tips the plate, opening a gate that lets water out. When the coin slips off of the plate, the gate closes and water stops flowing.

29) What was Archimedes's famous quotation about levers? (2 points)
   a. "Give me a lever long enough and a place to stand and I will move the world."
   b. Full credit to any similar quotation; translations do not all agree
   c. One point may be awarded for quotes that are relevant but clearly incorrect

Part 4: Calculations

30) Calculate the IMA of each of the following devices (1 point each)

a.

b.
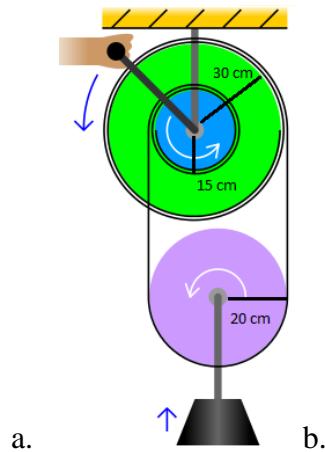
Differential Pulley:
IMA = (2R)/(R-r)
= 60/15 = 4
1 significant figure
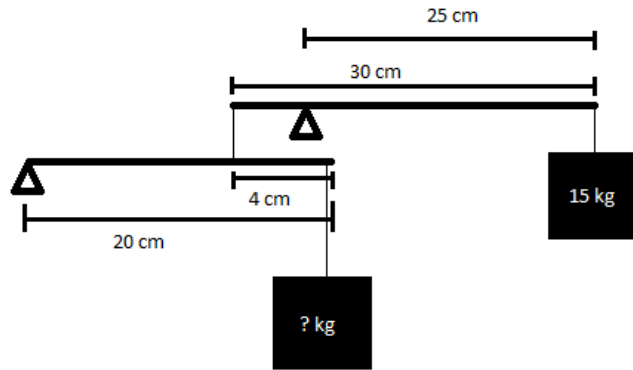
IMA = IMA$_1$ * IMA $_2$ = 25/5 * 16/20 =
5 * 4/5 = 4
1 significant figure, no units on IMA
DO NOT SCORE "60kg." The question
asks for IMA. Finding the unknown
mass does not answer the question.

31) The top of a triple start screw has a radius of 0.50 cm. Its pitch is 1.0 mm. A student
turns the screw with a screwdriver with a handle radius of 2 cm and a head radius of 0.40
cm. What is the IMA of the system? (2 points)
   a. IMA = handle circumference / lead, lead ≠ pitch (triple start screw; lead = 3 *
      pitch = 3 mm). IMA = 2π (20 mm) / 3 mm = 41.9 ≈ 40 (handle radius has 1
      significant figure, IMA has no units)
32) What is the IMA of a symmetrical wedge with an angle of separation of 15°? What is its
efficiency if its AMA is 1.4? (2 points)
   a. IMA of a wedge = (2 * tan(θ/2))$^{-1}$ = 0.5 * cot(θ/2) = 3.8
   b. Efficiency = 1.4/3.8 = 37%
33) Solid aluminum has a density of 2.70 g/cm³. A uniform square aluminum bar has side
lengths of 1.00 cm and a beam length of 50.0 cm. A fulcrum is attached 10.0 cm from
one end. If a 20 g mass is placed 30.0 cm from the same end as the fulcrum, what volume
of aluminum could be used to balance the beam and where? (4 points)
   a. Accept any combination of volume and location that gives a total torque of 2425
      N·m (automatic full credit)
   b. Preferred answer is 90 cm³ at the end of the bar (must be 1 significant figure due
      to the 20 g mass)
   c. 1 point for finding the mass of the bar to be 135 g
   d. 1 point for finding the total torque of the mass and center of gravity
   e. 1 point for finding a correct mass (not volume) of aluminum with location