Machines C - Machines - Pearl City Invitational - 12-12-2020

Machines C

Pearl City Invitational

December 12, 2020

Welcome to Machines!

- You have 50 minutes to complete this exam.
- You are permitted a binder and a calculator of any type each. This binder may be digital. You are also permitted (and encouraged) to have a writing utensil and plenty of scratch paper handy.
- Consider acceleration by gravity on Earth to be $g = 9.81\text{m}/\text{s}^2$.
- Unless specified in the question, do not worry about significant figures. Use three or more regardless of how many are in the question.
- You do not need to justify your answers. However, if you do, you may receive partial credit on a question that you did correctly, but did not come to the correct final answer.
- Questions in Part D are arranged in tiebreaker order. The first six tiebreaker questions are specified next to the question.
- Written by Rio Sessions, Socorro High School. If you have any questions or feedback, feel free to email me at riverwalker088@gmail.com.

Good Luck! And may the force by *ever* in your favor!

Part A

Conceptual Multiple Choice

- There are 22 multiple choice questions in this section, each worth 1.5 points for a total of 31 points in this section.
- All questions in this section are conceptual. They will not require calculation.

1. (1.50 pts) What is a simple machine?

- A) One of several devices capable of modifying motion and force.
- B) A collection of machines arranged together in a particular fashion such that a task is completed.
- C) The most basic form of a machine, with the capability of changing the torque in a system.
- D) One of a handful of devices capable of measuring fluctuations in spacetime.

2. (1.50 pts) Which of the following is a simple machine capable of?

- A) Manipulating the distance objects are moved.
- B) Manipulating the total energy in a system.
- C) Decreasing entropy in a system.
- D) Completing the crab cycle.

3. (1.50 pts) When a system is in static equilibrium, which of the following is true (select all that apply)?

(Mark **ALL** correct answers)

- [ ] A) The system is moving at a constant velocity.
- [ ] B) There is acceleration in the system.
- [ ] C) The net force on the system is zero Newtons.
- [ ] D) There forces in the system are not balanced.
- [ ] E) The ratio of effort work to resistance work in the system is less than one.
- [ ] F) Static electricity exerts a force that keeps the system in thermal equilibrium.

4. (1.50 pts)
Consider a lever. On one side is an effort force. On the opposite side is a resistance force that has a lesser magnitude than the effort force in the opposite direction. Given that this lever is in static equilibrium, how do the distances compare?

- ○ A) The effort side is longer than the resistance side.
- ○ B) The effort side is shorter than the resistance side.
- ○ C) The effort side and resistance side are of equal length.
- ○ D) There is not enough information to compare the distances.

5. (1.50 pts) Which of the following mechanisms would become useless in an ideal world?

- ○ A) Seesaw
- ○ B) Doorstop
- ○ C) Three-Beam Balance
- ○ D) Axe Head

6. (1.50 pts)
You have made the journey to another planet! Congratulations! What is the effect on the amount of force you feel exerted on you by the planet, in comparison to the amount of force Earth exerts on you?

- ○ A) You feel an increase in force.
- ○ B) You feel an decrease in force.
- ○ C) You feel the same force.
- ○ D) There is not enough information to determine.

7. (1.50 pts) You have traveled to another planet! Congratulations! What is the effect on your mass, in comparison to your mass on Earth?

- ○ A) Your mass increases.
- ○ B) Your mass decreases.
- ○ C) Your mass stays the same.
- ○ D) There is not enough information to determine.

8. (1.50 pts) The typical formula for potential energy is $PE = mgh$. For this formula to be correct, which of the following must be satisfied?

- ○ A) Air resistance must be negligible or nonexistent when the object is falling.
- ○ B) The object must be dropped a short distance, so that the radius of the Earth does not have an effect on g.
- ○ C) This object must not be in motion, so that kinetic energy does not play a role in the object's mechanical energy.
- ○ D) This object must be in motion, so that kinetic energy plays a role in the object's mechanical energy, and the mechanical energy reflects more than just the potential energy.

9. (1.50 pts) A vehicle is traveling at a constant speed while taking a turn at a constant angle. During this turn, the vehicle experienced a change in

- A) speed.
- B) velocity.
- C) acceleration.
- D) force.

10. (1.50 pts)
A little astrophysics: The moon and Earth exert a force on each other. How does the force that the moon exerts on the earth compare to the force the Earth exerts on the moon?

- A) The moon exerts a greater force on the Earth
- B) The Earth exerts a greater force on the moon
- C) They both exert an equal force on each other
- D) It is dependent in the rotation of other bodies, such as the Sun and the Milky Way

11. (1.50 pts) According to the laws of friction, what is the relationship between the force of friction and the area of the body?

- A) As the area over which a normal force is exerted increases, the force of friction increases.
- B) As the area over which a normal force is exerted increases, the force of friction decreases.
- C) Frictional force is independent of area.
- D) The relationship between area and frictional force is dependent on the material.

12. (1.50 pts) What is the relationship between the coefficient of static friction and the coefficient of kinetic friction?

- A) $\mu_{Static} > \mu_{Kinetic}$
- B) $\mu_{Static} < \mu_{Kinetic}$
- C) $\mu_{Static} = \mu_{Kinetic}$
- D) The relationship between the coefficient of static friction and the coefficient of kinetic friction is dependent on material.

13. (1.50 pts) Case 1: Two objects that have a low frictional force between them.
Case 2: Two objects that have a high frictional force between them.

How will the coefficient of friction in these two cases compare, assuming the same normal force in both cases?

A) The coefficient of friction in Case 1 will be closer to zero than Case 2.
B) The coefficient of friction in Case 1 will be closer to one than Case 2.
C) The coefficient of friction in Case 1 will be greater than Case 2.
D) There is not sufficient information to answer this question.

14. (1.50 pts) Force of friction encompasses which of the following (select all that apply):

(Mark **ALL** correct answers)
A) Inertia
B) Surface Contact
C) Air resistance
D) Gravitational Force
E) Normal Force
F) Resistance of motion in a fluid

15. (1.50 pts) For which of the following quantities does direction **not** have an impact?

A) Effort Force
B) Work
C) Momentum
D) Frictional Force

16. (1.50 pts)
Consider an object with mass (I know it's hard… just try). This object is experiencing a change in velocity for a set amount of time, until it reaches a final velocity. If you wanted to find the amount of time a force *F* was applied to get the object from the initial velocity to the final velocity, which of the following would be most useful to you?

A) Impulse
B) Kinetic Energy
C) Potential Energy
D) Mechanical Energy

17. (1.50 pts) Which of the following is a vector?

A) Kinetic Energy
B) Potential Energy

C) Mechanical Energy

D) Position

E) Impulse

18. (1.50 pts) Weight is dependent on which of the following?

A) Mass

B) The Universal Net

C) Incline Angle

D) All of the above

19. (1.50 pts) Which of the following is an SI base unit?

A) Kilogram

B) Centimeter

C) Volt

D) Watt

20. (1.50 pts) Which of the following is a measure of the same physical property as an SI base unit?

A) Newton

B) Inch

C) Watt/square meter

D) Ohm

21. (1.50 pts) A "Block and Tackle" is which of the following?

A) Atwood machine, with one mass resting on an inclined plane.

B) Lever system, where four levers are attached in a square formation and attached by flexible connections.

C) A compound pulley system.

D) A wheel and axle system where the axle of one wheel is connected to the outside of another.

22. (1.50 pts) What is a fulcrum?

A) The highest point on an inclined plane.

B) The point of a wedge.

C) The pivot point of a lever.

D) The point where a pulley attaches to the ceiling.

Part B

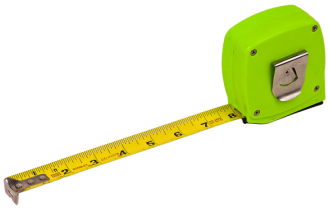
Conceptual Response

- There are 18 questions in this section, each worth 2-3 points, with a total of 44 points.
- All questions in this section are conceptual. No calculations will be required.

For questions 21-23, determine the simple machine that best fits the object in the photo. For levers, specify the class. For pulleys, specify if they are fixed or movable. For wheel & axles, specify whether the the effort force is applied to the wheel or the axle.
You will not need to justify your answer. However, you may receive credit for an answer not on the key if your answer has sufficient justification.

23. (2.00 pts) Identify this machine:

24. (2.00 pts) Identify this machine:



Note: *For this machine, I am looking for the machine that makes up the internal mechanism of the tape measure.*

25. (2.00 pts) Identify this machine:

Note: *I am looking for the simple machine that makes up the prongs (or the four end sticky things) of this fork.*

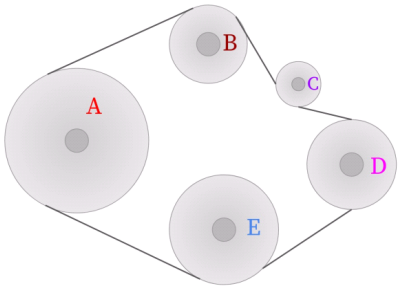
26. (3.00 pts) If I were to place a 2kg cylinder on a frictionless inclined plane in a vacuum, would the cylinder roll or slide down the plane? Why?

27. (2.00 pts) List two forms of potential energy.

28. (3.00 pts)
Gimea believes that she has built a machine capable of perpetual motion. When it doesn't work, she gets very disappointed, and quits being a physicist and moves into biology. Use any relationships between AMA and IMA to describe why it didn't work.

29. (3.00 pts)
Gimea never got over her perpetual motion machine not working. Later in her career, she challenged Conservation of Energy, saying that energy must have been destroyed for her machine not to have worked. Briefly (0.5-2 sentences) describe how Conservation of Energy still applies, even though her perpetual motion machine didn't work.

For questions 28-30, use the following image.

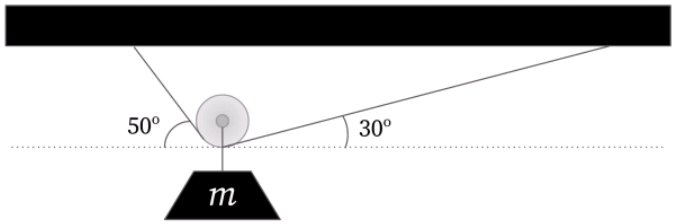


30. (2.00 pts) If wheel A spins in the counterclockwise direction, B spins ___ and C spins ___. (Use CW for clockwise, and CCW for counterclockwise).

31. (2.00 pts) Generally, what is the name of Gear C? You should answer with only a single word.

32. (2.00 pts) If I wanted to reduce slipping in the belt and pulley system, I could replace the belt with a ___ (singular, one word), and the pulleys with ___ (plural, one word).

33. (3.00 pts) If the efficiency of the machine below is 100%, describe the behavior of this machine.



34. (2.00 pts) If I experience a change in acceleration, what is the term for this? Answer with a single word.

35. (2.00 pts) In 2018, what base unit was redefined so that all SI base units were based on physical constants, instead of physical objects? Answer with the full name of the unit

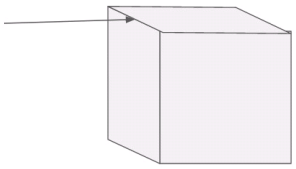
36. (2.00 pts)
Name any one other base SI unit that was affected by the redefinition of the unit you specified above. (I still can't get over that one unit was still in unit stone age until just a couple of years ago)

37. (2.00 pts)
A train traveling at a velocity of 100 km/hr takes a quite a bit of time to actually come to a stop, even with the train braking as hard as it can. This is due to the train's high ___. (Answer is one word)

38. (3.00 pts)
Consider an object suspended from a level ceiling with two ropes of equal length. In Case 1, these ropes are attached to the ceiling a far distance from each other. In Case 2, these ropes are attached to the ceiling closer to each other.

Consider the maximum weight of the object in both cases before the the ropes snapped. Would the object be able to be heavier in one case or the other? If so, give the case in which the suspended object could be heavier and briefly explain why. If both cases could hold the same weight suspended, briefly explain why.

39. (3.00 pts)
Consider a cube block sitting on a surface that has a coefficient of static friction of infinity. If I pushed on one of the top sides of it (as shown below), what would the block do?



40. (3.00 pts)

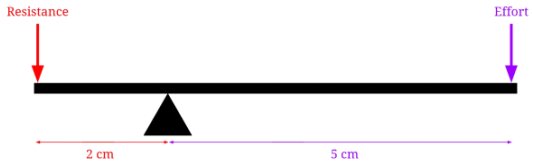
I use the disc brakes on my bicycle constantly for an extended period of time. I then reach down and touch them for no good reason and burn my hand. Use energy to describe wh my brakes got so hot.

Part C

Calculative Multiple Choice

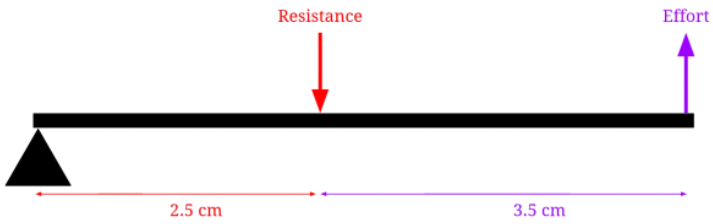
- There are 10 multiple choice questions in this section, each worth 2 points for a total of 20 points in this section.
- Questions in this section require calculations. Have your calculator ready! Answer choices do not necessarily contain proper significant figures.

41. (2.00 pts) Calculate the IMA of this machine.



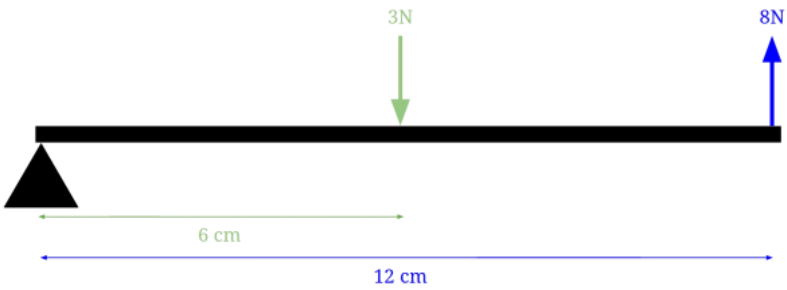
- A) 10
- B) 0.4
- C) 2.5
- D) 7

42. (0.00 pts) Calculate the IMA of *this* machine:



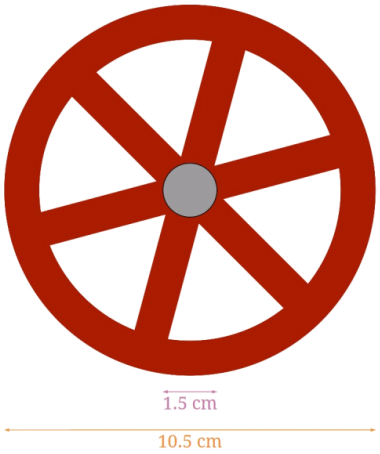
- A) 0.71
- B) 1.4
- C) 3
- D) 0.33

43. (2.00 pts) This machine is in static equilibrium. What is the efficiency of this machine?



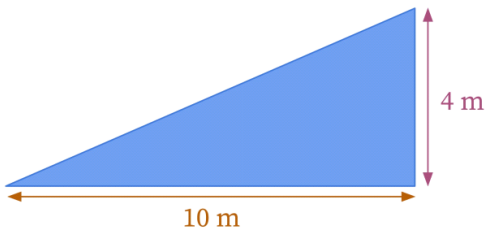
- A) 75%
- B) 13%
- C) 19%
- D) 67%

44. (2.00 pts) It takes 80N of force to turn this valve. Calculate the resistance force.



- A) 11N
- B) 1260N
- C) 560N
- D) 840N

45. (2.00 pts) This is a ramp. If I were to push a cart up it, what is the distance I would have pushed the cart (to the nearest whole number)?

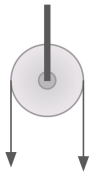


- A) 10m
- B) 14m
- C) 11m
- D) 39m

46. (2.00 pts) A ramp requires 2 lbs of force to push a 30 lb object up the ramp. What is the AMA of this ramp?

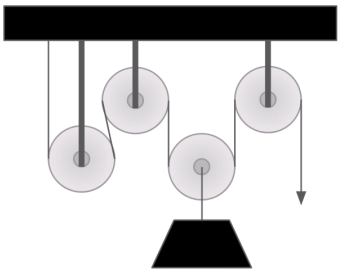
- A) 60
- B) 15
- C) 12
- D) 2

47. (2.00 pts) If I hang a 20N weight from one side of this system, how heavy must the weight on the opposite side be, for this system to be in static equilibrium?



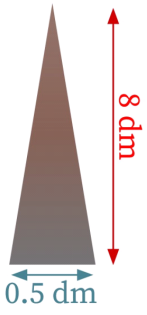
- A) 10N
- B) 20N
- C) 40N
- D) 0N

48. (2.00 pts) Calculate the IMA of this pulley system.



- A) 5
- B) 4
- C) 3
- D) 2

49. (2.00 pts) Calculate the IMA of this rusty axe blade that I got creative with the gradient of because I felt like wasting time.



A) 0.0625
B) 0.625
C) 16
D) 16.25

50. (2.00 pts) A screw has a pitch of 3 cm, and a head circumference of 8 m. What is the IMA of this... rather interesting screw?

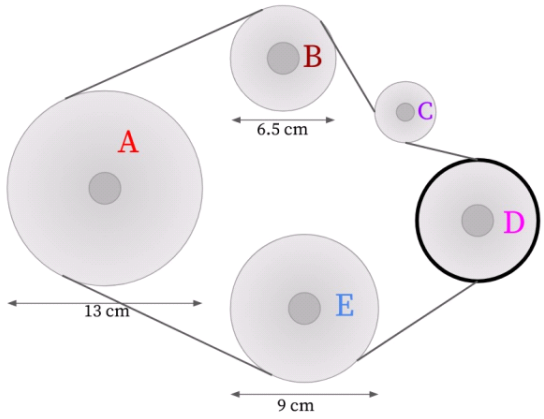
A) 2.67
B) 0.375
C) 267
D) 37.5

Part D

Calculative Response

- This is by far the longest section. There are 39 numerical questions (in 13 different scenarios), each worth 4 points. There is a single one-point freebie question, as well for a total of 156 points in this section.
- Questions in this section require calculations. Have your calculator ready!
- Use three significant figures in these questions.
- The unit your answer should be in is specified in brackets after each question. Be sure to have the right unit!
- You do not need to show work for any of these questions. However, you may receive partial credit for a question if you did it correctly, but punched it into your calculator wrong. Additionally, showing your work will help me find any errors that might be in the key

Questions 51-53 will utilize the following information.
The diameter of all axles (except axle c) in the following pulley system is 2cm. The axle of pulley A exerts a force of 65N on the system, and pulley A is spinning at 1500 rpm.



51. (4.00 pts) What is the output torque of pulley B?
[Unit: N*m]

52. (4.00 pts) What is the output force on the axle of pulley E?
[Unit: N]

53. (4.00 pts)
Pulley D has a diameter of 7cm. It has a 400kg ring on the outside of it, making the mass of the rest of the pulleys negligible. How long did it take, with the input force of pulley A, fo
pulley A to reach 1500 rpm, assuming no slip?
[Unit: s]

The following information will be used for questions 54-56.

I am riding my bicycle down a hill that is 50m tall. The mass of my bicycle and me combined is 82kg.

54. (4.00 pts) When I reach the bottom of the hill, how much work will have been done?
[Unit: J]

55. (4.00 pts) If I start at the top of the hill stopped, what will my velocity at the bottom be?
[Unit: m/s]

56. (4.00 pts)
I'm a little conservative about speed and not huge for crashing at high speeds, so I use my brakes on the hill. If my final velocity is 8 m/s, and all systems except my brakes have ar
efficiency of 100%, how hot did my brakes get, if they were originally 70ºC?

Hint: $Q = mc\Delta T$, where

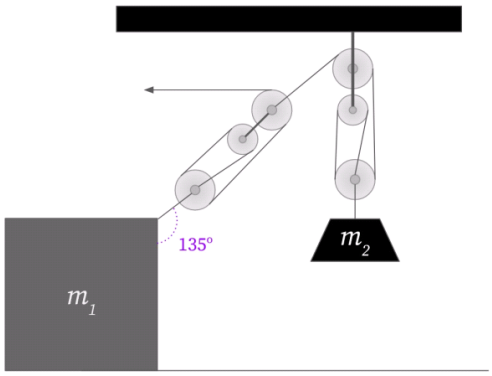
- *Q* is thermal energy (in J)
- *m* is mass (in Kg)
- *c* is the specific heat of the material (for my brakes, it's 1380 J/Kg ºC)
- ΔT is the change in temperature.

[Unit: ºC]

Answer to five significant figures for this question.

Questions 57-59 require the following information.

For all parts of this question, the following pulley system is in static equilibrium.



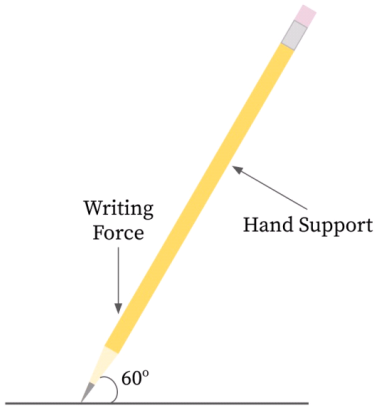
57. (4.00 pts) If the mass m_1 does not move, and the input force is 40N, what is the mass of m_2?
[Unit: N]

58. (4.00 pts) What is the minimum frictional force between m_1 and the ground in the previous question?
[Unit: N]

59. (4.00 pts) If the coefficient of static friction between m_1 and the ground is 1.2, what is the minimum weight of m_1?
[Unit: N]

Questions 60-62 will utilize the following information.

When I write, I press directly downward 2cm from the end of the pencil. 9cm up the pencil, the pencil rests on my hand. I exert 4N of force directly downward.



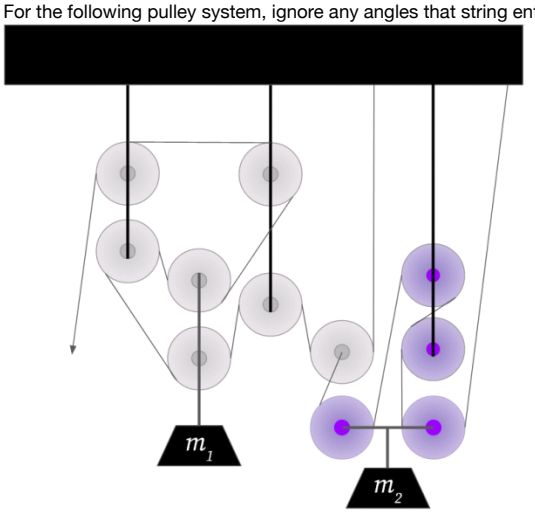
60. (4.00 pts) How much force does the my hand experience where the pencil rests on it?
[Unit: N]

61. (4.00 pts) If I have to exert 1N of horizontal force on the pencil in order to move it sideways, what is the coefficient of static friction between graphite and paper?

62. (4.00 pts)
If the pencil lead is cross-loaded with 2N of force perpendicular to it, it will break. How much more force will I have to push down with in order to break the lead at the end?
[Unit: N]

Questions 63-65 will utilize the following information.

For the following pulley system, ignore any angles that string enters the pulleys at. Assume all pulleys are ideal, massless pulleys.



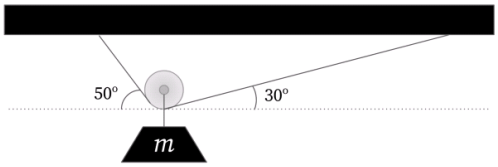
63. (4.00 pts) What is the IMA of the system made up of the four purple-colored pulleys (on the far right of the system)?

64. (4.00 pts) If the system is in static equilibrium, what is the mass ratio of m_1 to m_2?

65. (4.00 pts) If the system is in static equilibrium, and m_2 has a mass of 200N, how much force must be pulled on the end of the string?
[Unit: N]

Questions 66-68 will utilize the following information.

Consider the following pulley system (that you might recognize from earlier). The weight of m is 50N, the pulley is currently a distance of 0.5m from the ceiling.



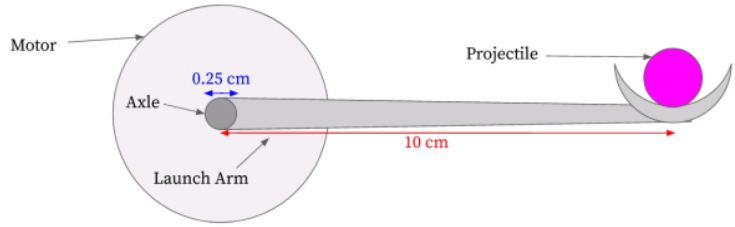
66. (4.00 pts)
What is the instantaneous force acting on the pulley system? Answer in vector form, or give magnitude and direction. Give your answer with respect to the dotted line being the x-axis.
[Unit: N]

67. (4.00 pts) If this pulley were released, what is the instantaneous acceleration of the system in the horizontal direction?
[Unit: m/s^2]

68. (4.00 pts) Assuming the efficiency of this system <100%, what will the change in gravitational potential energy have been from this point to the pulley's final resting point?
[Unit: J]

Questions 69-71 utilize the following information.

Below is a machine used to launch 1.4kg projectiles. It consists of a motor that drives a launch arm. This system is positioned 80m above the ground.



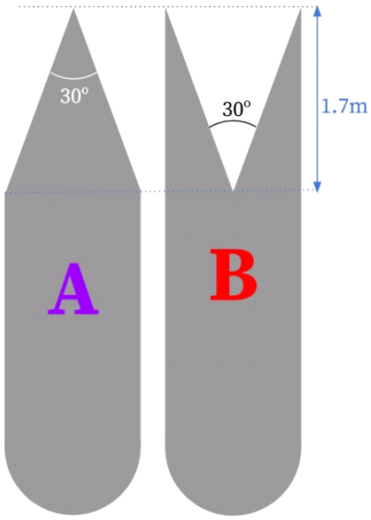
69. (4.00 pts) How much force must be exerted on the axle in order for the motor to hold the 1.4kg projectile?
[Unit: N]

70. (4.00 pts) If the motor exerts 10,000N of force on the axle until the projectile reaches 90^o, where the motor abruptly stops, what is the final velocity of the projectile?
[Unit: m/s]

71. (4.00 pts) At the above velocity, what is the horizontal distance it will travel before reaching the ground?
[Unit: m]

Questions 72-75 will utilize the following information.

Two people are racing to row upstream in a river in two differently shaped boats. One person has a negative IQ. The water current exerts 999.2N/m^2 on any object. Each boat is submerged 1 m into the water. Water has a density of 1000kg/m^3. Assume that water only exerts force in the direction opposite that that the boats are traveling, and will not slip underneath or around the back of the boat. Both boats have a mass of 212kg.



72. (4.00 pts) What is the force exerted by the current on Boat A?
[Answer Unit: N]

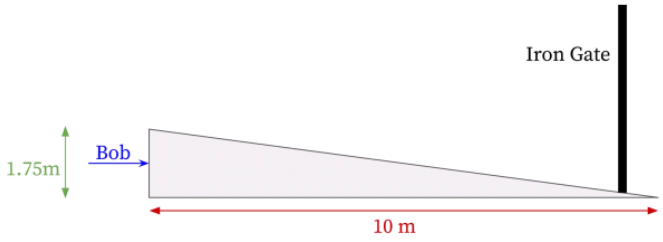
73. (4.00 pts) What is the force exerted by the current on Boat B?
[Unit: N]

74. (4.00 pts) The finish line is 50m upstream. If both boaters row with a force of 3000N, how much time will the winner win by?
[Unit: s]

75. (1.00 pts) *Freebie*: Which person has a negative IQ, the one rowing Boat A, or the one rowing Boat B? Answer with one letter, A or B.

Questions 76-78 utilize the following information.

Bob is trying to lift a gate made of solid iron. He wedges an inclined plane underneath the gate, and proceeds to push on the end of that inclined plane with a force of 6000N. The gate has a mass of 3208kg. His inclined plane has a mass of 200kg.



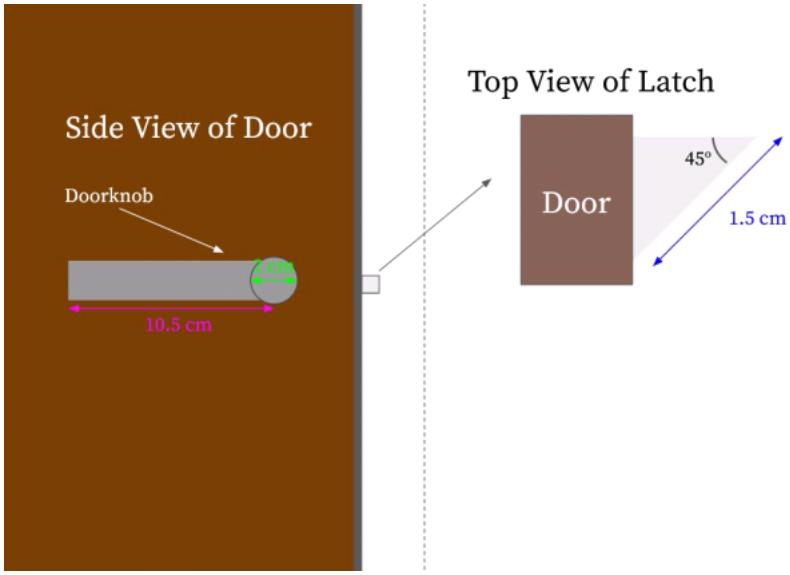
76. (4.00 pts) What is the upward acceleration of the gate?
[Unit: m/s^2]

77. (4.00 pts)
Given that Bob continues to push with this force until the gate reaches the end of the inclined plane, what will the final momentum of the gate in the upward direction be?
[Unit: N*s]

78. (4.00 pts)
Bob steps back three meters to admire his work. Unfortunately, he forgot that friction is negligible, and the gate starts closing. He freezes up with fear as his inclined plane starts accelerating back toward him. Given that when it hits Bob it stops, at what velocity is Bob knocked backwards? Assume the gate starts from a stop at the top of the ramp. Bob has a mass of 75kg.
[Unit: m/s]

Questions 79-81 utilize the following information.

A doorknob and latch mechanism is shown below. The latch has a mechanism attached to it such that it always exerts 25N of force horizontally. Between the doorknob and the latch is a mechanical system with an unknown mechanical advantage.



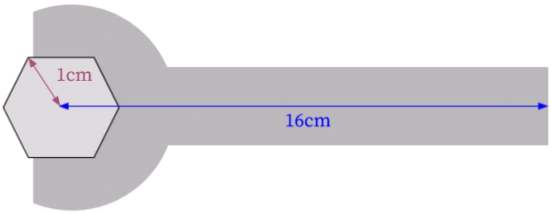
79. (4.00 pts)
I am closing this door. I come in contact with the doorjamb, where the latch now blocks the door from closing. How much force do I have to exert directly on the door (not on the doorknob) in order to force the latch to contract into the door so that I can close it fully? Assume that the force applied on the latch by the doorframe is directly perpendicular to the 1.5m long surface of the latch.
[Unit: N]

80. (4.00 pts)
If the end of the handle is pushed down 8cm and the latch contracts entirely into the door, what is the IMA of the internal mechanism that pulls the latch into the door?

81. (4.00 pts)
In order to overcome the 25N of force pushing the latch out of the door, I have to apply 8N of force. What is the efficiency of the internal mechanism? Assume the efficiency of the handle is 100%.
[Answer as a percentage]

Questions 82-84 utilize the following information.

A wrench is shown below, used to loosen a screw tightened against a material. The coefficient of static friction between the head of the screw and the material is 0.8.



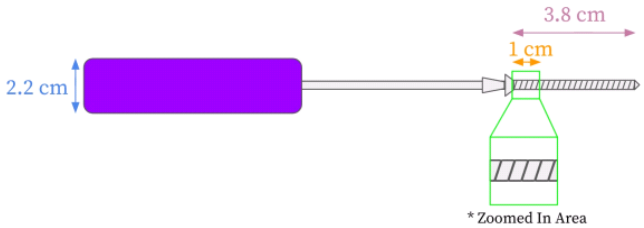
82. (4.00 pts) I have to apply 80N of force to the end of this wrench in order to get it to turn. What is the frictional force between the bolt and the material?
[Unit: N]

83. (4.00 pts) With how much force was the bolt head pushing on the material?
[Unit: N]

84. (4.00 pts) I vigorously rotate this wrench 20 times, only to see with dismay that the screw has only risen a single millimeter. What is the pitch of this screw?
[Unit: cm (Be careful!)]

Questions 85-87 will utilize the following information.

A screwdriver is screwing a screw into a material, shown below.



Note: *In the above image, ignore the threads on the actual screw itself. Look only at the threads in the zoomed in area. The threads on the actual screw image itself are not accurate.*

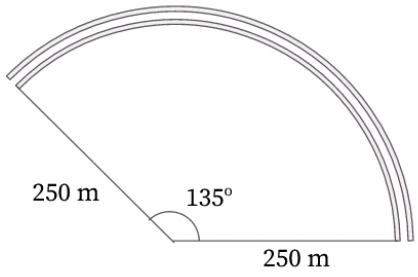
85. (4.00 pts)
Given that it takes 0.4 seconds to make a full rotation of the screw, how long will it take to fully screw this screw in? Take note of the note at the end of the information block.
[Unit: s]

86. (4.00 pts)
It takes 78N of force for the wedge on the end of the screw to split the material it is being screwed into. What force must be exerted on the handle of the screwdriver in order to overcome this?
[Unit: N]

87. (4.00 pts)
Let's take ourselves into a different world where this screw is being screwed into a different material. I have to exert 8N of force on screwdriver handle. The angle on the end of the wedge is 40º. What is the splitting force of the new material?
[Unit: N]

Questions 88-90 utilize the following information.

Shown below is a turn in a railroad track. The railroad ties are separated by four feet of space. A train with a mass of 113,000 kg traveling at 30km/hr begins to take the turn.



88. (4.00 pts) How much must the outside wheels speed up in order to make this turn?
[Unit: m/s]

89. (4.00 pts) The engineer takes 15 seconds to speed up the outside wheels of the train. What is the combined force exerted by all of the wheels in order to pull this feat off?
[Unit: N]

90. (4.00 pts) What is the centripetal force that this train experiences from this turn?
[Unit: N]

Congratulations! You made it!

If you have any questions or feedback, feel free to email me at riverwalker088@gmail.com (mailto:riverwalker088@gmail.com).