2010 Maryland Regional Tournament

PHYSICS LAB

Division C

Name(s): ______________________________ ______________________________

School Name: ______________________________________ **Team #:** ________

DO NOT open this test until you are told to do so by the event supervisor(s). Inside, you will find 5 questions with multiple parts each. Show all work when the question requires calculations and circle or place a box around your final answer. Partial credit for work will be given, but if you don't circle/box your answer, you won't get credit for your actual answer. Don't forget to keep track of significant figures.

The event supervisor(s) will call each team up one by one to test its blade assembly, so wait for your team to be called. When you are finished testing, you may return to the written test. You will have until 10 minutes before the hour to complete this test. When the event supervisor calls time, stop writing and place your writing instruments on the table. If you finish early and you've already tested your blade assembly, you're free to turn your test in and step out of the room.

If you need more paper, just let the event supervisor(s) know. Other than that, good luck to everyone!

Part 1	**Part 2**
Raw score =	Raw score =
Highest score =	
Percentage =	
Part 1 subscore = 50 × ( ) =	Part 2 subscore = ½ × ( ) =
Final Score =	

EQUATIONS AND CONSTANTS

Acceleration of gravity: $g = 9.81\ m \cdot s^{-2}$

Stefan-Boltzmann constant: $\sigma = 5.6704 \times 10^{-8}\ W \cdot m^{-2} \cdot K^{-4}$

Newton's Laws of force and motion:

$$\Delta x = v_0 t + \frac{1}{2} a t^2 \text{ and } \Delta\theta = \omega_0 t + \frac{1}{2}\alpha t^2$$

$$v = v_0 t + at \text{ and } \omega = \omega_0 + \alpha t$$

$$v^2 = v_0^2 + 2a\Delta x \text{ and } \omega^2 = \omega_0^2 + 2\alpha\Delta\theta$$

$$F = ma \text{ and } \tau = I\alpha = rF$$

$$F_{net} = F_1 + F_2 + F_3 + \cdots + F_n \text{ for however many } n$$

Work, energy, and power:

$$W = F\Delta x \text{ and } W = \tau\Delta\theta$$

$$KE = \frac{1}{2} m v^2 \text{ and } KE = \frac{1}{2} I \omega^2$$

$$PE_{grav} = mg\Delta h$$

$$P = \frac{\Delta W}{\Delta t} = Fv \text{ and } P = \frac{\Delta W}{\Delta t} = \tau\omega$$

Efficiency:

$$\eta = \frac{E_{out}}{E_{in}}$$

Heat transfer mechanisms:

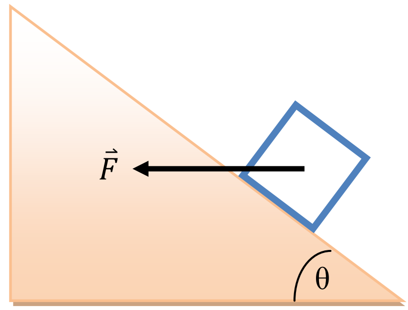
$$P = kA\left(\frac{T_H - T_C}{L}\right)$$

$$P = \sigma\varepsilon A T^4$$

Temperature scales:

$$T_F = \frac{9}{5} T_C + 32 \text{ and } T_K = T_C + 273$$

QUESTION A: A 5.0 kg block is sent sliding up a plane inclined at θ = 37° while a horizontal force $\vec{F}$ of magnitude 50. N acts on the block. The coefficient of kinetic friction between block and plane is 0.30, and the block has an initial velocity of 4.0 m/s.



(1) What is the magnitude and direction (up or down the plane) of the block's acceleration?

(2) How far up the plane does the block go?

(3) When the block reaches its highest point, does it remain at rest or slide back down the plane?

QUESTION B: Water passes over a 117-meter high waterfall at a volumetric rate of 1210 cubic meters per second. A hydroelectric plant is constructed over the waterfall to harness the energy of this moving water. Note that the mass of 1 m^3 of water is 1000 kg.

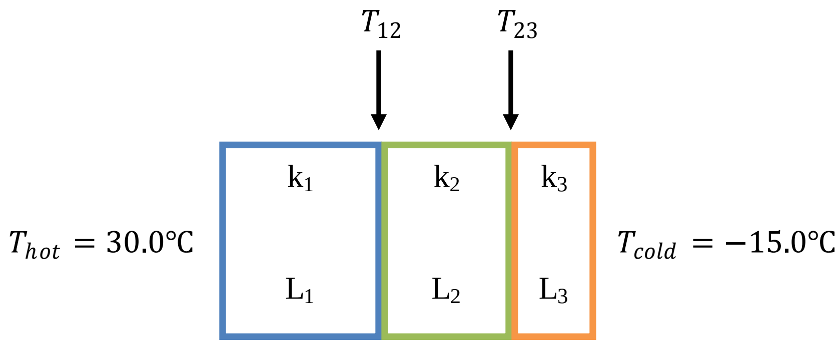
(1) What is the initial potential energy of water at the top of the waterfall?

(2) How much total kinetic energy is gained by the water from the entire fall?

(3) Suppose the turbines are able to harness roughly 88% of the kinetic energy gained by the water in falling. How much of the power is converted by the turbines?

(4) If the average power output of the plant is about 1100 MW (Megawatts), what is the efficiency of the generator?

QUESTION C: The wall in a building is made of three layers of different thicknesses and different thermal conductivities, as shown below. Thermal conduction is steady throughout.



$k_2 = 0.900k_1$ and $k_3 = 0.800k_1$
$L_2 = 0.700L_1$ and $L_3 = 0.350L_1$

(1) Describe the thermal conduction rate through layer 1 and layer 2 (give an equation).

(2) Describe the thermal conduction rate through layer 2 and layer 3 (give an equation).

(3) Find the temperature difference across layer 1, across layer 2, and across layer 3.

QUESTION D: Male emperor penguins must brave Antarctic winters every year in order to hatch their offspring. In order to survive, large numbers of penguins will actually huddle together to reduce the rate at which their bodies lose heat to the harsh environment. This helps them keep their body temperature at 39°C.

Consider each penguin a perfect cylinder with a height of $h = 1.1\ m$, a top surface area of $A = 0.34\ m^2$, and thermal emissivity $\varepsilon = 0.79$. Each penguin loses heat through radiation from the top and from the sides of its body.

(1) If there are 1000 penguins, calculate the total rate of energy loss if all the penguins are separated by a substantial distance.

(2) Now suppose the penguins are huddled together to form a "huddled cylinder" with top surface area $A_h = 1000A$ and the same height and emissivity. Calculate the total rate of energy loss for the penguins when they are huddled together.

(3) By what percentage does huddling close together reduce the total energy loss due to radiation?

QUESTION E: For a wind turbine, the total power in a single gust of wind is given by:

$$P = \frac{1}{2}\rho A V^3$$

Where ρ is the density of the air, A is the swept area of the turbine rotors, and V is the average velocity of the wind. On a windy day, the average velocity of the wind is $V = 15.3\ m/s$, and the air density is $\rho = 1.205\ kg/m^3$. The blade length on a certain 3-blade wind turbine situated to collect this energy is $L = 45.2\ m$.

(1) Determine the total power in a single gust of wind.

(2) If a single blade exerts a tangential force of 12.1 kN at the tip, determine the power in the rotation of the rotor with an average tip speed of 91.8 m/s.

(3) How efficient is the rotor of this wind turbine?

(4) Where did the rest of the energy calculated in part (1) go?