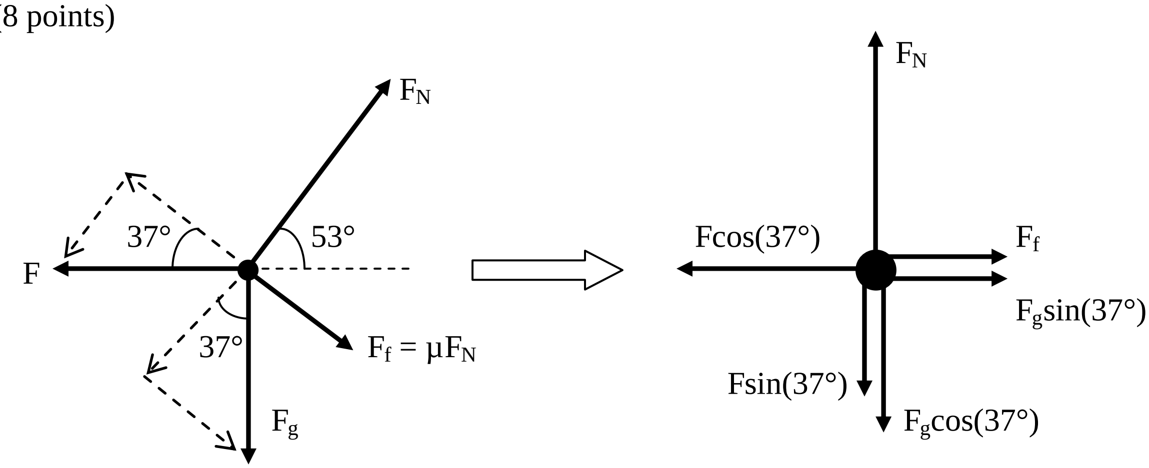
Physics Lab Answer Key

2010 Maryland Regional Tournament

NOTES:

1. A correct answer that has been circled/boxed-in and is accompanied by relevant work will receive full points.
2. A circled/boxed-in correct answer that is accompanied by irrelevant work will receive a maximum of half the points.
3. A wrong answer with relevant work can receive a maximum of half the points, left up to the discretion of the grader.
4. If there is no clearly circled or boxed-in answer, that question will be treated as if a wrong answer was provided.
5. Any answers that required work/calculations but show no work will receive zero points.
6. One point is deducted for incorrect significant figures in any answer.
7. All numeric answers are given 2 units of leniency in either direction in the last significant digit.

A.1) (8 points)



$$F_N = F\sin 37° + F_g\cos 37° = 30.1 + 39.2 = 69.3\ N$$
$$F_f = \mu F_N = (0.30)(69.3) = 20.8\ N$$

$$F_{net} = F\cos 37° - \left(F_f + F_g \sin 37°\right)$$
$$F_{net} = 39.9 - (20.8 + 29.5) = -10.4\ N$$
$$a = \frac{F_{net}}{m} = \frac{-10.4}{5.0} = -2.1\ m/s^2$$

In this case, the negative direction would be down the inclined plane.

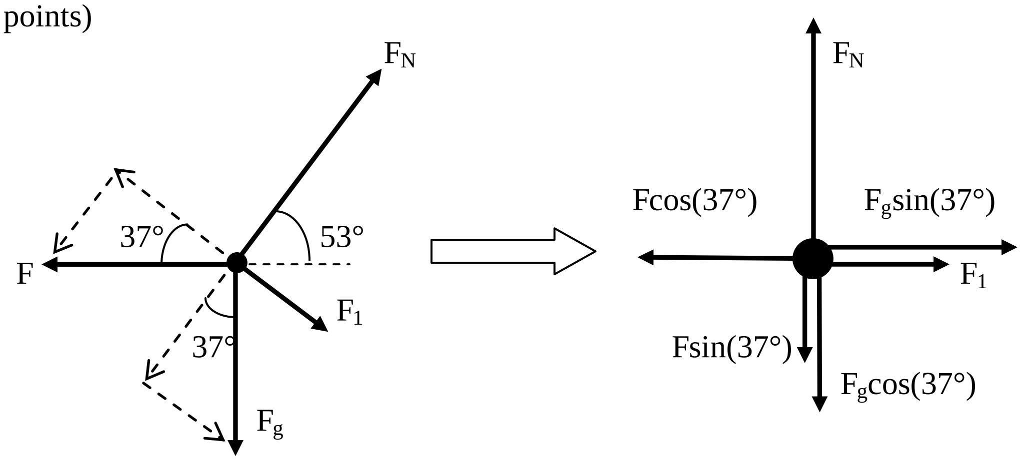
2.1 m/s^2 down the incline

A.2) (6 points)

$$v^2 = v_0^2 + 2a\Delta x$$
$$0 = (4.0)^2 + 2(-2.1)\Delta x$$
$$-16 = -4.2\Delta x$$
$$\Delta x = 3.8\ m$$

3.8 m

A.3) (6 points)



$$F_N = F_g \cos 37° = 39.2\ N$$

$F_1 = 10.4\ N$ (this is the F_{net} from A.1)

$$F_{net} = F \cos 37° - \left(F_g \sin 37° + F_1\right) = 39.9 - (29.5 + 10.4) = 0\ N$$

The block remains at rest.

B.1) (5 points)

$$\left(\frac{1210\ m^3}{s}\right)\left(\frac{1000\ kg}{m^3}\right) = 1.2 \times 10^6\ kg/s$$

$$PE = mg\Delta h = (1.21 \times 10^6)(9.81)(117) = 1.39 \times 10^9\ J$$ (per second)

1.39×10^9 J or 1.39×10^6 kJ or 1390 MJ

B.2) (5 points)

$$KE = PE = 1.39 \times 10^9\ J$$ (per second)

1.39×10^9 J or 1.39×10^6 kJ or 1390 MJ

B.3) (5 points)

$$P = \frac{\Delta W}{\Delta t} = \frac{\Delta KE}{\Delta t} = \frac{1.39 \times 10^9\ \text{J}}{1\ s} = 1.39 \times 10^9\ \text{W}$$

$$(0.88)P = 1.22 \times 10^9\ W$$

1.22×10^9 W or 1.22×10^6 kW or 1220 MW

B.4) (5 points)

$$\eta = \frac{1100}{1220} = 0.90$$

0.90 or 90. %

C.1) (4 points)

Since thermal conduction is steady through layers 1 and 2…

$$P_{12} = \frac{k_1 A(T_{hot} - T_{12})}{L_1} = \frac{k_2 A(T_{12} - T_{23})}{L_2}$$
$$\frac{k_1 A(T_{hot} - T_{12})}{L_1} = \frac{0.900 k_1 A(T_{12} - T_{23})}{0.700 L_1}$$

$$\boxed{\frac{k_1 A(T_{hot} - T_{12})}{L_1} = \frac{0.900 k_1 A(T_{12} - T_{23})}{0.700 L_1}}$$

It is also acceptable if the values for T_{hot} and T_{cold} are substituted above.

C.2) (4 points)

Since thermal conduction is steady through layers 2 and 3…

$$P_{12} = \frac{k_2 A(T_{12} - T_{23})}{L_2} = \frac{k_3 A(T_{23} - T_{cold})}{L_3}$$
$$\frac{0.900 k_1 A(T_{12} - T_{23})}{0.700 L_1} = \frac{0.800 k_1 A(T_{23} - T_{cold})}{0.350 L_1}$$

$$\boxed{\frac{0.900 k_1 A(T_{12} - T_{23})}{0.700 L_1} = \frac{0.800 k_1 A(T_{23} - T_{cold})}{0.350 L_1}}$$

It is also acceptable if the values for T_{hot} and T_{cold} are substituted above.

C.3) (12 points)

$$\frac{k_1 A(T_{hot} - T_{12})}{L_1} = \frac{0.900 k_1 A(T_{12} - T_{23})}{0.700 L_1} = \frac{0.800 k_1 A(T_{23} - T_{cold})}{0.350 L_1}$$
$$T_{hot} - T_{12} = \frac{9}{7}(T_{12} - T_{23}) = \frac{16}{7}(T_{23} - T_{cold})$$
$$7T_{hot} - 7T_{12} = 9(T_{12} - T_{23}) = 16(T_{23} - T_{cold})$$

$$7T_{hot} = 16T_{12} - 9T_{23} \text{ and } 9T_{12} - 25T_{23} = -16T_{cold}$$

$$210. = 16T_{12} - 9T_{23} \text{ and } 9T_{12} - 25T_{23} = 240.$$

Solve the system of two equations with two unknowns.

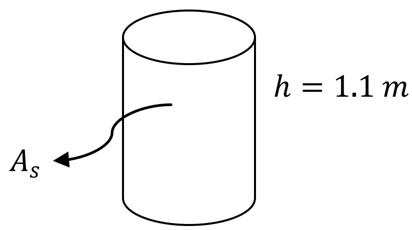
$$T_{12} = 9.69℃ \text{ and } T_{23} = -6.11℃$$
$$T_{hot} - T_{12} = 30.0 - 9.69 = 20.3℃$$
$$T_{12} - T_{23} = 9.69 - (-6.11) = 15.80℃$$
$$T_{23} - T_{cold} = -6.11 - (-15.0) = 8.9℃$$

C.3) (continued)

20.3°C across layer 1, 15.80°C across layer 2, 8.9°C across layer 3

D.1) (8 points)

$$A = 0.34\ m^2$$



$$A = \pi r^2$$

$$r = \sqrt{\frac{A}{\pi}} = \sqrt{\frac{0.34}{\pi}} = .33\ m$$

$$C = 2\pi r = 2\pi(.33) = 2.1\ m$$
$$A_s = C \cdot h = (2.1)(1.1) = 2.3\ m^2$$
$$A_{total} = A + A_s = 2.3 + 0.34 = 2.6\ m^2$$
$$T_K = T_C + 273 = 39 + 273 = 312\ K$$

$$P = \sigma \varepsilon A T^4 = (5.6704 \times 10^{-8})(0.79)(2.6)(312)^4 = 1100\ W$$

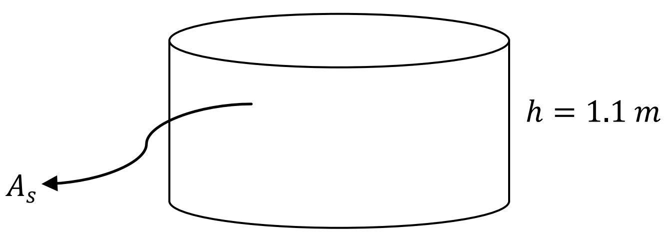
$1100\ W$ for each individual penguin.

$$1000P = 1.1 \times 10^6\ W = 1.1\ MW$$

1.1×10^6 W or 1.1×10^3 kW or 1.1 MW

D.2) (8 points)

$$A_h = 1000A = 340\ m^2$$



$$r = \sqrt{\frac{A_h}{\pi}} = \sqrt{\frac{340}{\pi}} = 10.4\ m$$

$$C = 2\pi r = 2\pi(10.4) = 65\ m$$
$$A_s = C \cdot h = (65)(1.1) = 72\ m$$

$$P = \sigma \varepsilon A T^4 = (5.6704 \times 10^{-8})(0.79)(72)(312)^4 = 31000\ W$$

D.2) (continued)

31000 W or 31 kW

D.3) (4 points)

$$\% \, reduction = \frac{1.1 \times 10^6 - 31000}{1.1 \times 10^6} = 0.97 = 97\%$$

0.97 or 97%

E.1) (7 points)

$$A = \pi(45.2)^2 = 6420 \, m^2$$
$$P = \frac{1}{2}(1.205)(6420)(15.3)^3 = 1.39 \times 10^7 \, W$$

1.39×10^7 W or 1.39×10^4 kW or 13.9 MW

E.2) (7 points)

$$F_{total} = 3(12.1) = 36.3 \, kN = 3.63 \times 10^4 \, N$$
$$\tau = (45.2)(3.63 \times 10^4) = 1.64 \times 10^6 \, N \cdot m$$
$$\omega = \frac{v}{r} = \frac{91.8}{45.2} = 2.03 \, s^{-1}$$
$$P = (1.64 \times 10^6)(2.03) = 3.33 \times 10^6 \, W$$

3.33×10^6 W or 3.33×10^3 W or 3.33 MW

E.3) (4 points)

$$\eta = \frac{3.33}{13.9} = .240$$

.240 or 24.0 %

E.4) (2 points)

A small portion of the original energy in the gust of wind is converted to unusable thermal energy (frictional losses), but most of it remains in the wind.