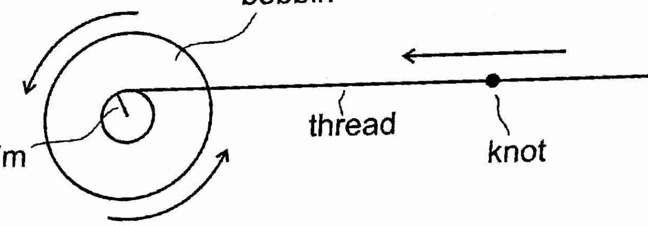
II. **Problems (30 points): Include correct units. In order to be eligible for partial credit, you must show your work.**

1. (4 pts) A sewing machine bobbin rotates, causing thread to wind around it. As the bobbin first begins to move, it accelerates from rest to 10 revolutions per second over a time of 1.4 seconds. During the winding process, the radius of the bobbin around which the thread is wrapped remains constant at 0.007m.



A. What is the bobbin's angular acceleration in rad/s^2?

$$\alpha = \frac{\Delta\omega}{\Delta t} = \frac{10\frac{rev}{s}\left(\frac{2\pi rad}{rev}\right)}{1.4s} = 44.9\,rad/s^2$$

B. What is the linear acceleration of a knot in the thread that is being pulled onto the bobbin? In other words, what is the linear ~~velocity~~ accel of the thread as it is being wound on to the bobbin?

$a = \alpha r$ $\quad a = 44.9\,rad/s^2\,(0.007\,\frac{m}{rad})$

$a = 0.314\,m/s^2$

4. (6pts) Platform diver

A. After jumping off of the diving platform, an olympic diver initially spins at a rate of 0.6 rev/s. Given that his moment of inertia (I) is 4.6 kg·m^2, calculate his angular momentum at this time.

$$L = I\omega = 4.6\,kgm^2\left(0.6\,\frac{rev}{s}\right)\left(\frac{2\pi\,rad}{rev}\right)$$

$$L = 17.3\,\frac{kgm^2}{s}$$

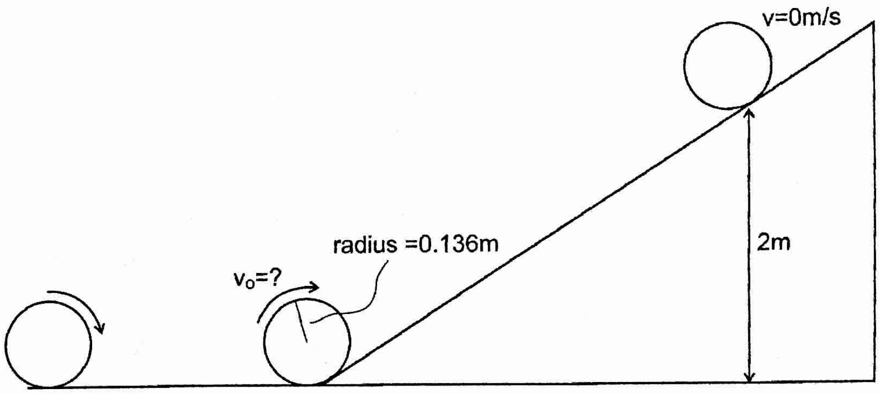
B. Before the diver hits the water, the diver's rotational speed increases to 2 rev/s. What is the diver's moment of inertia (I) at that point?

$$I = \frac{L}{\omega} = \frac{17.3\,kgm^2/s}{2\,rev/s\left(\frac{2\pi\,rad}{rev}\right)} = 1.38\,kgm^2$$

C. What does the diver do to cause this change in his moment of inertia?

He tucks in (decreases radius)

5. (4pts) A 0.175kg disc with a radius of 0.136m (same dimensions as a Discraft Ultrastar Sport Disc) rolls across level ground and then continues to roll up a ramp without slipping. The disc rolls to a point that is 2m higher than the base of the ramp before it stops and then rolls back down. For a disc, I= $\frac{1}{2}$ mr^2.



What was the disc's linear velocity when it first reached the bottom of the ramp (just before it began to ascend)?

$$PE_0 + KE_{Rot,0} + KE_{Trans,0} = PE + KE$$

-2 only transl.

$$0 + \frac{1}{2}\left(\frac{1}{2}mr^2\right)\omega^2 + \frac{1}{2}mv^2 = mgh + 0$$

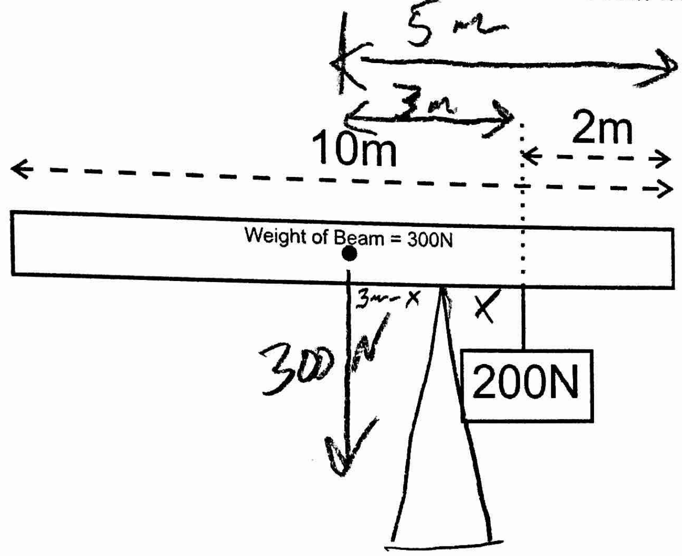
$$\frac{1}{4}mr^2\left(\frac{v^2}{r^2}\right) + \frac{1}{2}mv^2 = mgh$$

-1 for screwup somewhere but setup ok

$$\frac{3}{4}v^2 = gh \Rightarrow v = \sqrt{\frac{4}{3}gh} = \sqrt{\frac{4}{3}(9.8\,m/s^2)(2m)}$$

$$V_0 = 5.11\,m/s$$

(4pts) A 10m long beam of uniformly distributed mass has a weight of 300N. There is an additional weight of 200N hanging from the beam at a point 2m from the right end of the beam. Describe the location at which a fulcrum placed under the beam would cause the beam to balance horizontally.



-1 for extra mass

$$\tau_{ccw} = \tau_{cw}$$

$$300N(3m - x) = 200N(x)$$

$$900N\cdot m - 300Nx = 200Nx$$

$$900N\cdot m = 500Nx$$

$$x = \frac{9}{5}m = 1.8m$$

Fulcrum 1.8m left of the 200N weight

or

1.2m right of center

Electric Charge & Field

1. $F_E = k \frac{q_1 q_2}{r^2} = 8.99 \times 10^9 \frac{Nm^2}{C^2} \left(\frac{(40 \times 10^{-6} C)(40 \times 10^{-6} C)}{(0.22 m)^2} \right)$

$F_E = 297 N$

3. $E = \frac{F}{q} \Rightarrow 480 N/C = \frac{F}{3.3 \times 10^{-6} C} \Rightarrow F = 1.58 \times 10^{-3} N$ Leftward

negative charge is pushed opposite field direction

4. $E = \frac{kQ}{r^2} \Rightarrow 5.5 \times 10^4 \frac{N}{C} = 8.99 \times 10^9 \frac{Nm^2}{C^2} \left(\frac{Q}{(0.4 m)^2} \right)$

$Q = 9.79 \times 10^{-7} C$

III. Problems:

① — units 1/4, Answer 1/2

2 (units 1/2, Answer 1, Formula 1/2)

1. You have a 30-m-long piece of silver wire having a radius of 0.15 mm? (ρ_{Ag} = 1.59 x 10^{-8} Ω·m)

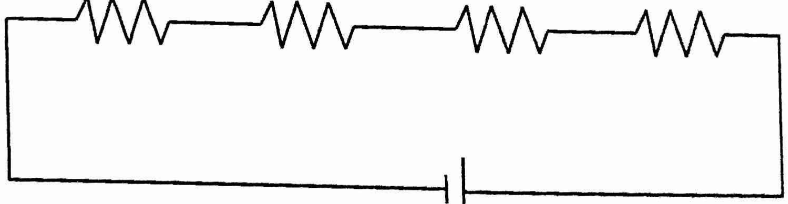
   A. What is the resistance of this wire?

   ② $$R = \frac{1.59\times10^{-8}(30\,m)}{\pi(1.5\times10^{-3}\,m)^2} = 6.75\times10^{-2}\,\Omega$$

   B. How much current will flow through the wire if there is a 9 V potential difference between the ends (i.e. if it is hooked up to a 12.0 V battery)?

   ② $$I = \frac{V}{R} = \frac{9V}{6.75\times10^{-2}\,\Omega} = 133\,A$$

3. A. Calculate the total equivalent resistance of this circuit.



21Ω

(2)

B. Calculate the current flowing through this circuit.

$I = \frac{V}{R} = \frac{12V}{21\Omega} = 0.571A$

(2)

4. Bob spends 20 hours annually operating his hairdryer on a 120V circuit. Bob's hairdryer draws 12.5A of current. If Bob's electricity costs $0.15 per kilowatt-hour, what is the total cost of the electricity that he uses to run his hairdryer?

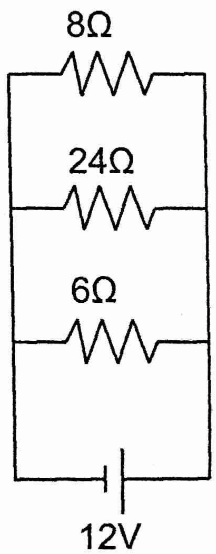
(2) $P = IV = 12A(120V) = 1{,}500W = 1.5kW$

$\frac{W}{h} = -1$ $(20\,hours)(1.5kW) = 30\,kW\cdot h$

$(30\,kW\cdot h)\left(\frac{\$0.15}{kW\cdot h}\right) = \$4.50$

5. A. Calculate the total equivalent resistance of this circuit.

(2) $\frac{1}{R_{eq}} = \frac{1}{8} + \frac{1}{24} + \frac{1}{6} = \frac{8}{24} = \frac{1}{3}$ $R_{eq} = 3\Omega$



B. Calculate the total current flowing through this circuit.

(2) $I = \frac{V}{R} = \frac{12V}{3\Omega} = 4A$

C. Calculate the current flowing through the 24-Ω resistor.

(2) $I = \frac{V}{R} = \frac{12V}{24\Omega} = 0.5A$

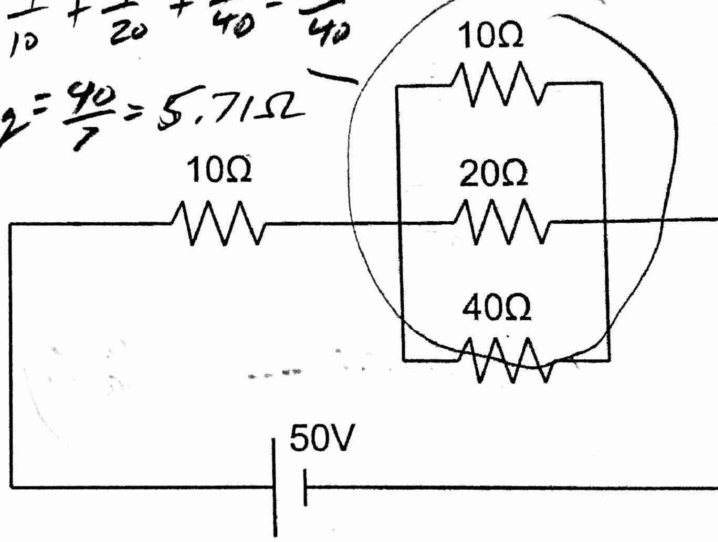
D. Calculate the power dissipated as heat through the 24-Ω resistor.

(2) $P = IV = (0.5A)(12V) = 6W$

6. A. Calculate the total equivalent resistance of this circuit.

$\frac{1}{R_{eq}} = \frac{1}{10} + \frac{1}{20} + \frac{1}{40} = \frac{7}{40}$

$R_{eq} = \frac{40}{7} = 5.71\Omega$



$R_{eq} = 10\Omega + 5.71\Omega = 15.71\Omega$

2

B. Calculate the total current flowing through this circuit.

$I = \frac{V}{R} = \frac{50V}{15.71\Omega} = 3.18A$

2

C. Calculate the potential difference across the (leftmost) 10-Ω resistor.

$V = IR = 3.18A(10\Omega) = 31.8V$

2

D. Calculate the current flowing through the 20.0-Ω resistor.

$I = \frac{V_{branch}}{R} = \frac{18.2V}{20\Omega} = 0.91A$

2

2.5A = -1

E. Calculate the total power dissipated as heat in this circuit.

$P = IV = (3.18A)(50V) = 159W$

2