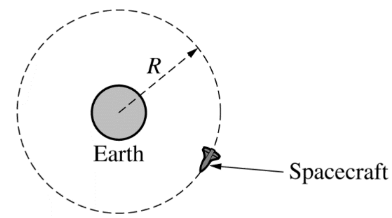
Greg Jacobs and Chris Becke solutions were used by me to check my answers.

2018 AP PHYSICS 1 Free Response Questions

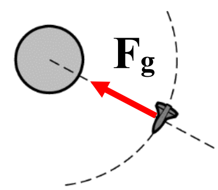
1. (7 points, suggested time 13 minutes)



Note: Figure not drawn to scale.

A spacecraft of mass m is in a clockwise circular orbit of radius R around Earth, as shown in the figure above. The mass of Earth is M_E.

(a) In the figure below, draw and label the forces (not components) that act on the spacecraft. Each force must be represented by a distinct arrow starting on, and pointing away from, the spacecraft.



Note: Figure not drawn to scale.

(b)

i. Derive an equation for the orbital period T of the spacecraft in terms of m, M_E, R, and physical constants, as appropriate. If you need to draw anything other than what you have shown in part (a) to assist in your solution, use the space below. Do NOT add anything to the figure in part (a).

$$\Sigma F_c = ma_c \qquad F_g = m\frac{V^2}{R} \qquad G\frac{M_E m}{R^2} = m\frac{\left(\frac{2\pi R}{T}\right)^2}{R}$$

$$G\frac{M_E m}{R^2} = m\frac{\frac{4\pi^2 R^{\cancel{2}}}{T^2}}{\cancel{R}} \qquad G\frac{M_E \cancel{m}}{R^2} = \cancel{m}\frac{4\pi^2 R}{T^2}$$

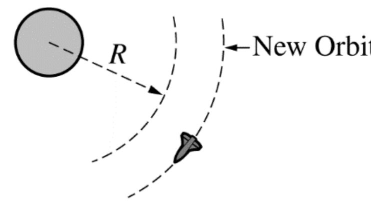
$$T^2 = \frac{4\pi^2}{GM_E}R^3 \qquad \boxed{T = \sqrt{\frac{4\pi^2}{GM_E}R^3}}$$

ii. A second spacecraft of mass $2m$ is placed in a circular orbit with the same radius R. Is the orbital period of the second spacecraft greater than, less than, or equal to the orbital period of the first spacecraft?

____ Greater than ____ Less than __X__ Equal to Briefly explain your reasoning.

Since the mass of the spacecraft drops out of the equation because Newton's Law of Universal Gravitation and Fg is the Centripetal Force so it is equal to ma.

(c) The first spacecraft is moved into a new circular orbit that has a radius greater than R, as shown in the figure below.



Note: Figure not drawn to scale.

Is the speed of the spacecraft in the new orbit greater than, less than, or equal to the original speed?

____ Greater than __X__ Less than ____ Equal to

Briefly explain your reasoning.

From part (B)i $G\frac{M_E m}{R^2} = m\frac{V^2}{R}$ $V = \sqrt{\frac{GM_E}{R}}$

If R goes up then V must go down because they are inversely related.

OR

Angular Momentum is $L = I\omega$ $L = mR^2\frac{V}{R}$ $L = mRV$

Momentum is conserved so if R goes up then V must go down.

2. (12 points, suggested time 25 minutes)

A group of students prepare a large batch of conductive dough (a soft substance that can conduct electricity) and then mold the dough into several cylinders with various cross-sectional areas A and lengths l. Each student applies a potential difference ΔV across the ends of a dough cylinder and determines the resistance R of the cylinder. The results of their experiments are shown in the table below.

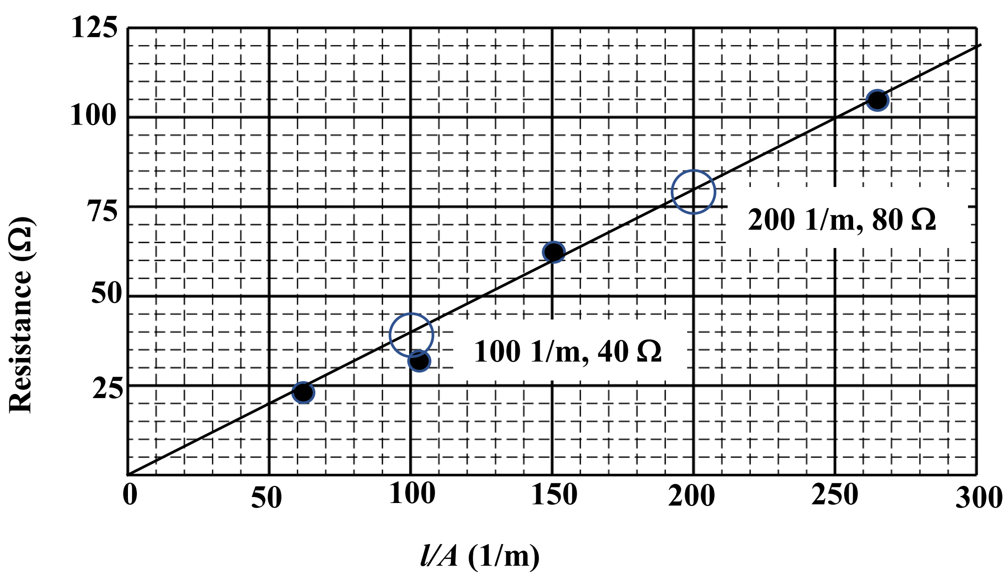
Dough Cylinder	A (m^2)	l (m)	ΔV (V)	R (Ω)	***l/A (1/m)***	
1	0.00049	0.030	1.02	23.6	**61.2**	
2	0.00049	0.050	2.34	31.5	**102**	
3	0.00053	0.080	3.58	61.2	**163**	
4	0.00057	0.150	6.21	105	**263**	

(a) The students want to determine the resistivity of the dough cylinders.

i. Indicate below which quantities could be graphed to determine a value for the resistivity of the dough cylinders. You may use the remaining columns in the table above, as needed, to record any quantities (including units) that are not already in the table.

Vertical Axis: **R resistance** Horizontal Axis: ***l/A***

ii. On the grid below, plot the appropriate quantities to determine the resistivity of the dough cylinders. Clearly scale and label all axes, including units as appropriate.



iii. Use the above graph to estimate a value for the resistivity of the dough cylinders.

$$R = \rho\left(\frac{l}{A}\right) \quad \rho = slope = \frac{\Delta R}{\Delta\left(\frac{l}{A}\right)} = \frac{(80\ \Omega - 40\ \Omega)}{\left(200\frac{1}{m} - 100\frac{1}{m}\right)} = 0.40\ \Omega * \text{m}$$

(b) Another group of students perform the experiment described in part (a) but shape the dough into long rectangular shapes instead of cylinders. Will this change affect the value of the resistivity determined by the second group of students?

____ Yes __**X**__ No

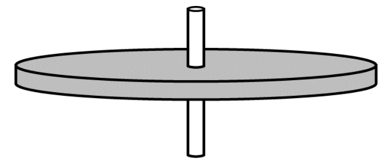
Briefly justify your reasoning.

Resistivity is a property of the material, since the dough has not changed it will have the same Resistivity

(c) Describe an experimental procedure to determine whether or not the resistivity of the dough cylinders depends on the temperature of the dough. Give enough detail so that another student could replicate the experiment. As needed, include a diagram of the experimental setup. Assume equipment usually found in a school physics laboratory is available.

Repeat the experiment you did above, chill some dough in a refrigerator for different amounts of time, and heat some in a toaster to get a wide range of temperatures, repeat multiple times each temperature and take an average at each temperature. Use a thermometer to measure the temperature of the dough. Find resistivity as stated above then graph resistivity versus temperature, if temperature affects the resistivity then the graph will have a non-zero slope. If it has a zero slope then there is no relationship between temperature and resistivity.

3. (12 points, suggested time 25 minutes)

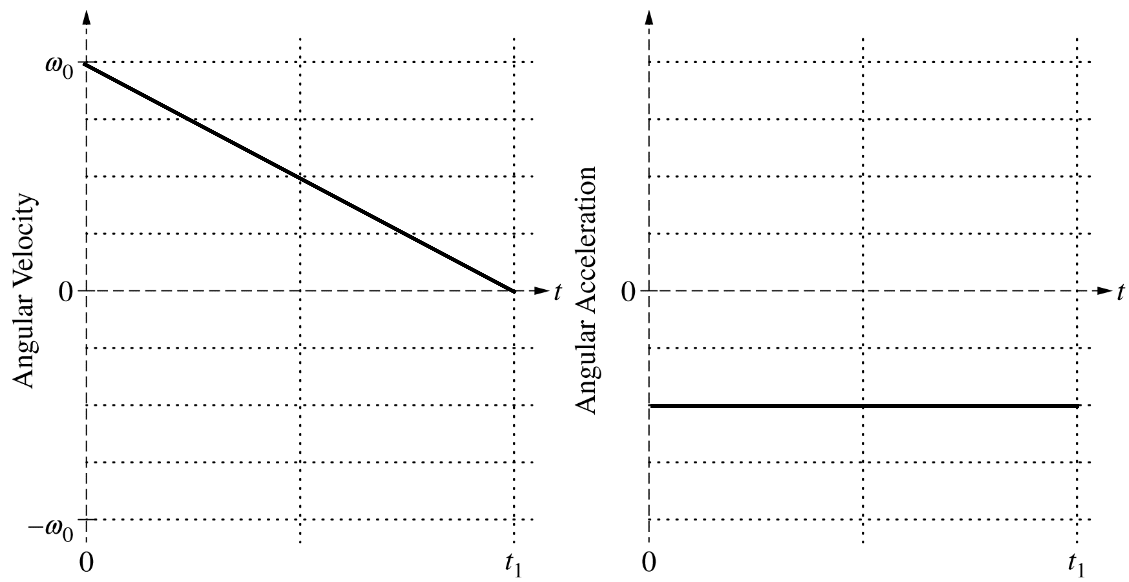


The disk shown above spins about the axle at its center. A student's experiments reveal that, while the disk is spinning, friction between the axle and the disk exerts a constant torque on the disk.

(a) At time $t = 0$ the disk has an initial counterclockwise (**positive**) angular velocity ω_0. The disk later comes **to rest** at time $t = t_1$.

i. On the grid at left below, sketch a graph that could represent the disk's angular velocity as a function of time, t from $t = 0$ until the disk comes to rest at time $t = t_1$.

ii. On the grid at right below, sketch the disk's angular acceleration as a function of time t from $t = 0$ until the disk comes to rest at time $t = t_1$.



(b) The magnitude of the frictional torque exerted on the disk is τ_0. Derive an equation for the rotational inertia I of the disk in terms of τ_0, ω_0, t_1, and physical constants, as appropriate.

$$\boldsymbol{\tau_{net} = I\alpha \qquad \tau_0 = I\alpha \qquad I = \frac{\tau_0}{\alpha}}$$

$$\textbf{slope of } \boldsymbol{\omega \ vs \ t \ graph \ \alpha = \frac{\Delta\omega}{\Delta t} = \frac{(\omega - \omega_0)}{(t_1 - 0)} \qquad \alpha = \frac{-\omega_0}{t_1}}$$

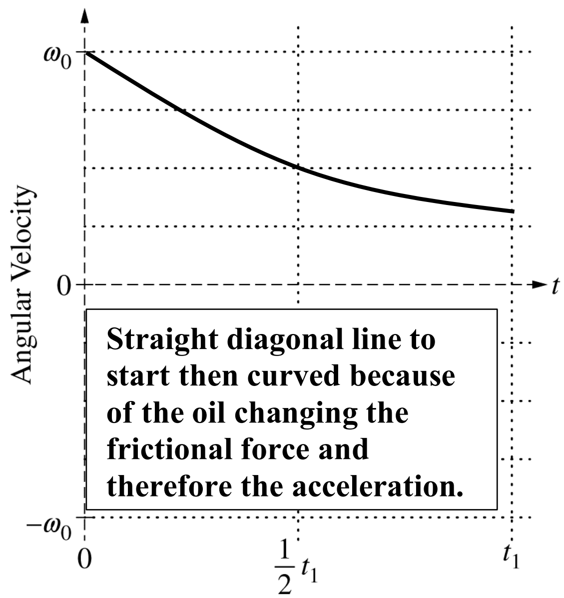
$$\boldsymbol{I = \frac{\tau_0}{\frac{\omega_0}{t_1}} \qquad I = \frac{\tau_0 t_1}{\omega_0}}$$

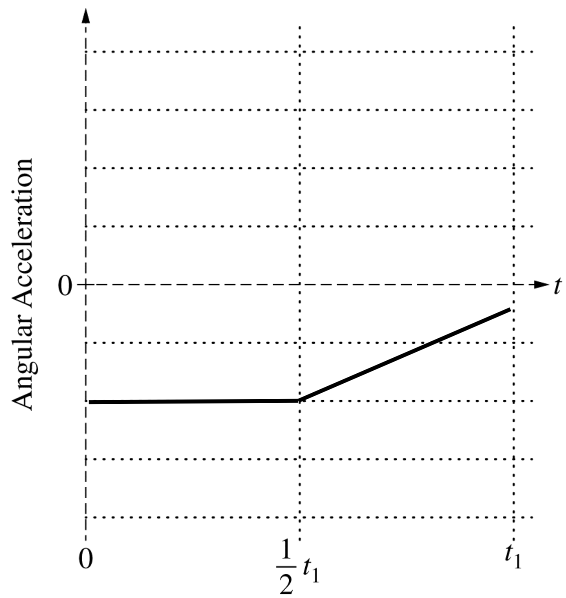
Question wants magnitude so the negative sign does not matter.

(c) In another experiment, the disk again has an initial positive angular velocity ω_0 at time $t = 0$. At time $t = \frac{1}{2}t_1$, the student starts dripping oil on the contact surface between the axle and the disk to reduce the friction. As time passes, more and more oil reaches that contact surface, reducing the friction even further.

i. On the grid at left below, sketch a graph that could represent the disk's angular velocity as a function of time from $t = 0$ to $t = t_1$, which is the time at which the disk came to rest in part (a).

ii. On the grid at right below, sketch the disk's angular acceleration as a function of time from $t = 0$ to $t = t_1$.





(d) The student is trying to mathematically model the magnitude τ of the torque exerted by the axle on the disk when the oil is present at times $t > \frac{1}{2}t_1$. The student writes down the following two equations, each of which includes a positive constant $(C_1 \text{ or } C_2)$ with appropriate units.

(1) $\tau = C_1\left(t - \frac{1}{2}t_1\right) \quad \left(for\ t > \frac{1}{2}t_1\right)$

(2) $\tau = \dfrac{C_2}{\left(t + \frac{1}{2}t_1\right)} \quad \left(for\ t > \frac{1}{2}t_1\right)$

Which equation better mathematically models this experiment? ___ Equation (1) __X__ Equation (2)

Briefly explain why the equation you selected is plausible and why the other equation is not plausible.

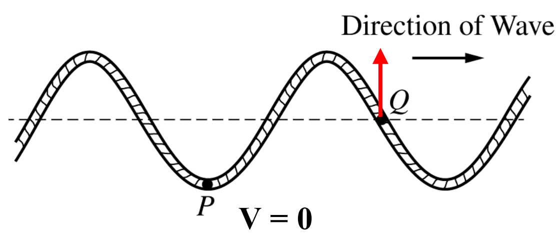
As time goes by equation 1 will have a larger and larger torque and since the torque is caused by friction which is decreasing so the torque should be getting smaller. Equation 2 has the time on the bottom of the fraction so as it gets larger the torque will get smaller.

4. (7 points, suggested time 13 minutes)

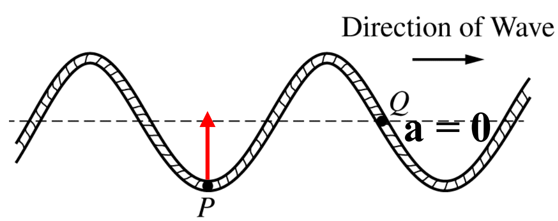
A transverse wave travels to the right along a string.

(a) Two dots have been painted on the string. In the diagrams below, those dots are labeled P and Q.

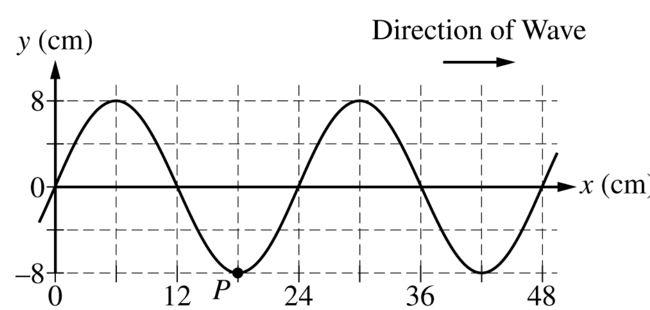
i. The figure below shows the string at an instant in time. At the instant shown, dot P has maximum displacement and dot Q has zero displacement from equilibrium. At each of the dots P and Q, draw an arrow indicating the direction of the instantaneous velocity of that dot. If either dot has zero velocity, write "$v = 0$" next to the dot.



ii. The figure below shows the string at the same instant as shown in part (a)i. At each of the dots P and Q, draw an arrow indicating the direction of the instantaneous acceleration of that dot. If either dot has zero acceleration, write "$a = 0$" next to the dot.

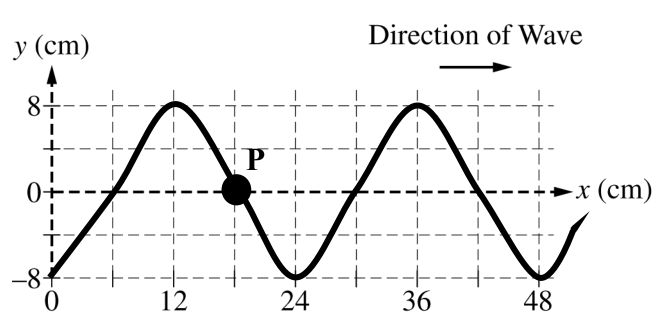


(b) The figure below represents the string at time $t = 0$, the same instant as shown in part (a) when dot P is at its maximum displacement from equilibrium. For simplicity, dot Q is not shown.



i. On the grid below, draw the string at a later time $t = T/4$, where T is the period of the wave.

Note: Do any scratch (practice) work on the grid at the bottom of the page. Only the sketch made on the grid immediately below will be graded.

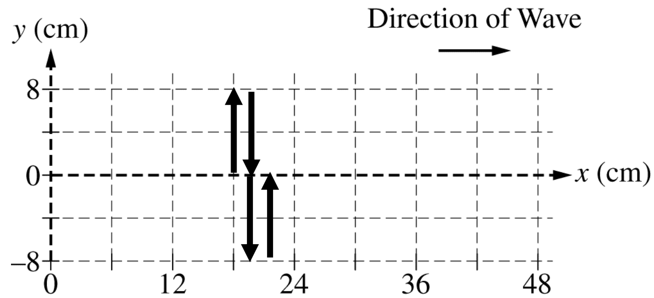


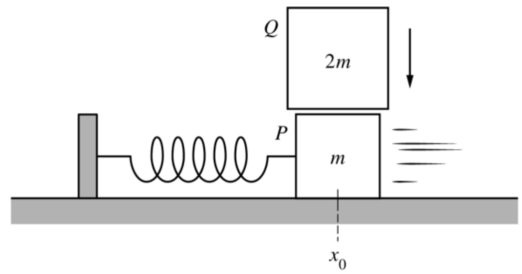
ii. On your drawing above, draw a dot to indicate the position of dot P on the string at time $t = T/4$ and clearly label the dot with the letter P.

(c) Now consider the wave at time $t = T$. Determine the distance traveled (not the displacement) by dot P between times $t = 0$ and $t = T$.

Travels 1 full cycle up 8 cm to max displacement, down 8 cm to equilibrium, down - 8 cm to max displacement, up 8 cm to equilibrium.
Distance travelled = 8 cm + 8 cm + 8 cm + 8 cm = 32 cm

The grid below is provided for scratch work only. Sketches made below will not be graded.

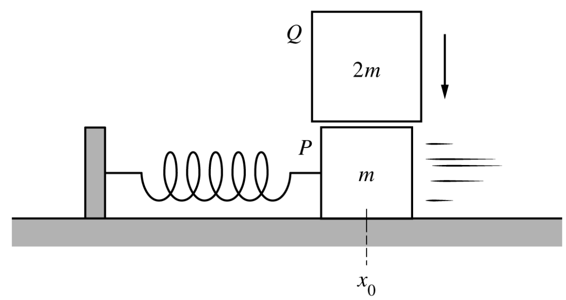




5. (7 points, suggested time 13 minutes)

Block P of mass m is on a horizontal, frictionless surface and is attached to a spring with spring constant k. The block is oscillating with period T_P and amplitude A_P about the spring's equilibrium position x_0. A second block Q of mass $2m$ is then dropped from rest and lands on block P at the instant it passes through the equilibrium position, as shown above. Block Q immediately sticks to the top of block P, and the two-block system oscillates with period T_{PQ} and amplitude A_{PQ}.

(a) Determine the numerical value of the ratio T_{PQ}/T_P.



$$T_P = 2\pi\sqrt{\frac{m}{k}} \qquad T_{PQ} = 2\pi\sqrt{\frac{3m}{k}}$$

$$\frac{T_{PQ}}{T_P} = \frac{2\pi}{2\pi}\sqrt{\frac{\frac{3m}{k}}{\frac{m}{k}}} \qquad \frac{T_{PQ}}{T_P} = \sqrt{3}$$

(b) The figure is reproduced above. How does the amplitude of oscillation A_{PQ} of the two-block system compare with the original amplitude A_P of block P alone?

__X_ $A_{PQ} < A_P$ ____ $A_{PQ} = A_P$ ____ $A_{PQ} > A_P$

In a clear, coherent paragraph-length response that may also contain diagrams and/or equations, explain your reasoning.

Block 2m and block m have an Inelastic collision in the horizontal direction. Mechanical energy is lost. Therefore, when the combined mass reaches maximum displacement, this will be less, as energy stored in the spring is less although equal to Kinetic Energy after collision since energy is conserved.

$$U_{s\,Before\,Collision} = K_{Before\,Collision} > K_{After\,Collision} = U_{s\,After\,Collision} = \frac{1}{2}kX^2$$

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