PhysicsGRE.com – Community Physics Problems (Version 1-4)

***Note:** The problems are not numbered but are instead identified by the username and date submitted. The first two problems are identical to the samples posted on the website. I included them in here to make sure nobody accidentally missed them. Please encourage your friends to submit problems so we can all benefit by them. PhysicsGRE.com reserves the right to modify submitted problems.*

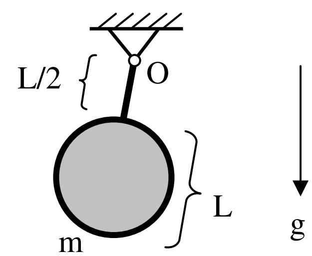
PROBLEM ID: Gman [8/9/03]

Initially, a small satellite is in a circular orbit about mars. Over a very small time interval, an external force accelerates the satellite in the direction of the satellite's velocity vector. After the impulse is applied, the satellite is in a new orbit (which is still bound). Which of the following statements is NOT true?

a) There was an increase in the angular momentum of the satellite about the center of mass of Mars.
b) The eccentricity of the new orbit is less than one.
c) After the impulse is applied, the speed of the satellite will change throughout the new orbit.
d) The period of the new orbit is shorter than the period of the original orbit.
e) The total energy of the satellite after the impulse is applied is larger than the initial total energy of the satellite.

PROBLEM ID: Gman [8/10/03]

As shown in the figure, a rigid massless rod of length ***L/2*** is rigidly attached to sphere with a mass of ***m*** and with a diameter that is of length ***L***. The system is free to pivot about point ***O***. What is the frequency of small oscillations about the equilibrium position?



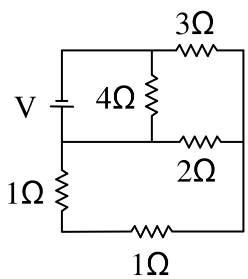
a) $\sqrt{g/2L}$
b) $\sqrt{2g/3L}$
c) $\sqrt{3g/4L}$
d) $\sqrt{10g/11L}$
e) $\sqrt{g/L}$

PROBLEM ID: forscher14 [8/17/03]

A hollow cylindrical barrel falls off the back of a truck traveling at speed v onto the road. Initially, the barrel has the same speed as the truck and isn't rotating; it's skidding due to friction between itself and the concrete. As soon as the barrel begins to roll, what will its speed be?

a) 1/4 * v
b) 1/3 * v
c) 1/2 * v
d) v
e) 1/10 * v

PROBLEM ID: Gman [8/19/03]



What is the current through the ***3Ω*** resistor?

a) $V/2\Omega$
b) $V/3\Omega$
c) $V/4\Omega$
d) $V/5\Omega$
e) $V/6\Omega$

PROBLEM ID: papucisse [9/12/03]

Mechanics: Consider a ball thrown vertically in the air (with air resistance). What is the condition for the ball to reach terminal velocity.

(a) When the ball reaches its highest height
(b) Immediately after it is thrown
(c) When the ball hits the ground
(d) When the weight and the air resistance are equal in magnitude and opposite in direction
(e) When the weight and the air resistance are equal in magnitude and direction

PROBLEM ID: vova [9/13/03]

A sphere of radius ***R*** carries a charge density proportional to the square of the distance from the center. What is the ratio of the magnitude of the electric field a distance ***2R*** from the center to the magnitude of the electric field a distance of ***R/2*** from the center (i.e. $E_{r=2R} / E_{r=R/2}$)?

a) 1
b) 2
c) 4
d) 8
e) 64

PROBLEM ID: Gman [9/28/03]

Consider an experiment where monochromatic light is incident perpendicularly from air on a thin, flat film of material that has an index of refraction ***n=1.2***. The thickness of the film is the minimum required for there to be constructive interference between the light that is reflected from the two surfaces of the film.

If the air in this experiment were replaced by water, with an index of refraction ***n=1.33***, then which of the following statements is true?

a) There would no longer be constructive interference because the wavelength of light in water is smaller than that in air.
b) The addition of water will induce a phase shift of the reflected light which will cause there to be destructive interference.
c) Light will no longer be reflected by the thin film and thus no form of interference will be observed.
d) There will still be constructive interference between the light that is reflected from the two surfaces of the film.
e) None of the above.

PROBLEM ID: hansuiso [9/29/03]

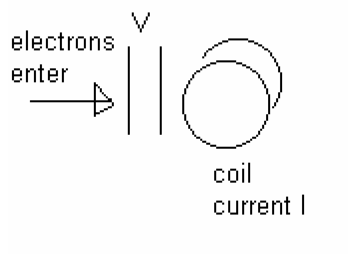
What is the (approximate) binding energy of a hydrogenic helium "atom".

a) 13.6 eV
b) 27.2 eV
c) 40.8 eV
d) 54.4 eV
e) 68.0 eV

PROBLEM ID: alovell [10/28/03]

The next two problems concern the following setup:

Electrons are accelerated across a potential difference V, and enter a vacuum tube parallel to two circular coils of wire with a flowing current I. The electrons will follow a circular path of radius r.



1) If the accelerating potential is doubled, what is the resulting radius of the path?

a) 2r
b) 0.5r
c) r
d) 0.71r
e) 1.4r

2) If the current to the coils is doubled, what is the resulting radius of the path?

a) 2r
b) 0.5r
c) r
d) 0.71r
e) 1.4r

PROBLEM ID: yevgeny [10/31/03]

A wave in water propagated from a region of depth h to a region of depth $4h$. How did its velocity v and wavelength λ change? Assume that the conditions in both regions are such that v does not depend on λ.
Hint: use dimensional analysis.

a) v increased to $2v$, λ increased to 2λ
b) v increased to $2v$, λ decreased to $\lambda/2$
c) v decreased to $v/4$, λ decreased to $\lambda/4$
d) v remained unchanged, λ decreased to $\lambda/2$
e) v remained unchanged, λ increased to 4λ

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PROBLEM ID: Miravek [11/5/03]

You have three energy levels in a system with at the temperature ***T***. The energies are ***0***, ***E***, and ***3E***. They have the degeneracies of ***1***, ***3*** and ***7*** respectively. What is the partition function for this system with ***k*** being the Boltzmann Constant?

a) $Z = 1 + 3e^{E/kT} + 7e^{3E/kT}$
b) $Z = 1 + 3e^{-E/kT} + 7e^{-3E/kT}$
c) $Z = 1 + e^{-E/kT} + e^{-3E/kT}$
d) $Z = 1 + e^{-3E/kT} + e^{-21E/kT}$
e) $Z = 1 + 3e^{E/kT} + 7e^{3E/kT}$

PROBLEM ID: Susan [11/18/03]

Two identical point charges are held a distance ***d*** apart by a non conducting string with tension ***T***. If a third identical point charge is fixed at a distance of ***d/2*** from both of the first two point charges then what will be the new tension in the string.

a) ***T*** b) ***2T*** c) ***3T*** d) ***4T*** e) ***5T***

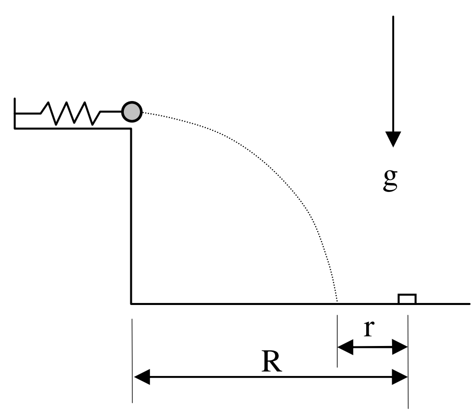
PROBLEM ID: hhegab [11/24/03]

A long glass tube is held vertically in water. A tuning fork is struck and held over the tube. Strong resonances are observed at two successive lengths ***0.50m*** and ***0.84m*** above the surface of water. If the velocity of sound is ***340m/s***, then the frequency of the tuning fork is:

a) 128 ***Hz*** b) 256 ***Hz*** c) 384 ***Hz*** d) 500 ***Hz*** e) 540 ***Hz***

PROBLEM ID: Susan [11/26/03]

You want to hit a small box on the floor with a marble fired from a spring-loaded gun that is mounted on a table. The target box is a distance ***R*** horizontally from the edge of the table; see the figure to the right. You compress the spring a distance ***d***, but the center of the marble falls short by a distance ***r*** of the center of the box. How far should you compress the spring to score a direct hit (neglect friction)?



a) $x = \frac{d^2}{R-r}$ b) $x = \frac{d(R-r)}{R}$ c) $x = \frac{d^2}{R+r}$ d) $x = \frac{d(R-r)}{R+r}$ e) $x = \frac{Rd}{R-r}$

End of Practice Problems

Begin Solutions on the Next Page

SOLUTION: Gman [8/9/03]: ANSWER=D

The period of the new orbit will actually be longer than the period of the original orbit. The impulse will transform the circular orbit to a larger elliptical orbit which will have a larger period since period is proportional to the cube of the semimajor axis. This may sound counter intuitive since the speed increased but keep in mind that the path length traveled by satellite also increases. Also, as indicated in answer (e), the speed of the new orbit is no longer constant as it varies throughout the elliptical orbit in a manner such that angular momentum is constant.

Note about other answers: The angular momentum of the satellite about the center of mass of Mars and the energy clearly increase with the increase in velocity. The eccentricity of the original circular orbit was 0, and after the impulse the eccentricity of the bound elliptical orbit is somewhere between 0 and 1.

SOLUTION: Gman [8/10/03]: ANSWER=D

Find the equation of motion: $\Sigma\tau_0 = I_0\alpha$

Where $\Sigma\tau_O$ is the sum of torques about point ***O***, I_O is the moment of inertia about point ***O***, and α is the angular acceleration of the rigid system in motion. If you let θ be the angle between vertical and the rod (i.e. $\theta = 0$ when the mass is at its lowest position) then you find the equation of motion becomes.

$-mgL\sin\theta = \left(mL^2 + \frac{2}{5}m\left(\frac{L}{2}\right)^2\right)\ddot{\theta}$, where it is worth noting that the parallel axis theorem was used.

Assuming small oscillations (i.e. $\sin\theta \cong \theta$) and using some basic algebra, the equation of motion can simplify to become:

$\ddot{\theta} + \frac{10g}{11L}\theta = 0$, and therefore the angular frequency of small oscillation is: $\sqrt{\frac{10g}{11L}}$

Note: This problem could also have been solved just as easily using Lagrange's equations.

Note: You could have easily eliminated answers (a), (b), and (e) with knowledge of the simple pendulum by noting that the angular frequency must be between $\sqrt{g/L}$ and $\sqrt{2g/3L}$ as those would be the frequency if all the sphere's mass was concentrated at ***L*** and ***3L/2*** respectively. The only difference between this problem and the simple pendulum is that in this problem the moment of inertia about the center of mass of the sphere/bob is not negligible (i.e. you need to account for the fact that torque is required to actually rotate the "large" sphere back and forth during oscillations.)

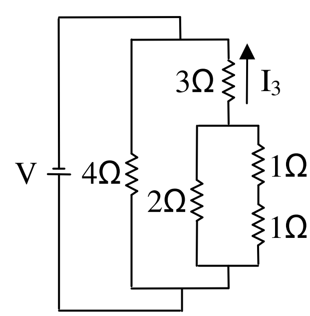
SOLUTION: forscher14 [8/17/03]: ANSWER=C

It appears as if there's not enough information to solve the problem, but who cares? The question's on the GRE, so it _has_ to be soluble. We can eliminate choice d) because it's entirely unreasonable--kinetic friction HAS to slow the barrel down.

Now let's get to work. Is there some way for us to cleverly apply angular momentum conservation to this problem? Yes. We consider the system immediately after the barrel has hit the road. Taking as our origin the point of contact between the road and the barrel, we find that the torque on the system is _always zero_--our position and frictional force vectors are always parallel! Neat, huh? Angular momentum about that point has to be conserved. Now we calculate angular momenta: as soon as the barrel hits the road, its angular momentum is M*v*R, where M is its mass and R is its radius. When it begins to roll, its angular momentum is (I)*omega + Angular momentum of CM about origin (where I is the moment of inertia of the barrel and omega is its angular velocity). We recall the condition for rolling motion: velocity of center of mass = R * omega . Omega must equal the final velocity vf of the barrel divided by R. In addition, I = MR^2 for a cylindrical shell and the L of the center of mass when it begins to roll is MR*vf. In the end, we have that MvR = MR^2*vf/R + MRvf, from which we surmise that vf = 1/2 v. We bubble in choice (c) and feel mighty proud of us selves.

SOLUTION: Gman [8/19/03]: ANSWER=C

It may help some to redraw the circuit in form that makes it clear which resistors add in series and which add in parallel.



The effective resistance of this circuit can be found in the following manner (assuming you know how to add resistors in series and parallel). The ***1Ω*** and ***1Ω*** resistors add in series to effectively become a ***2Ω*** resistor which in adds in parallel with the ***2Ω*** resistor shown to the right to effectively become a ***1Ω*** resistor which adds in series with the ***3Ω*** resistor shown to the right to effectively become a ***4Ω*** resistor which adds in parallel with the ***4Ω*** resistor shown to the right to give the entire circuit an equivalent resistance of $R_{eq}=2\Omega$.

One way to find the current through the ***3Ω*** resistor is to subtract the current through the ***4Ω*** resistor from the total current through the entire circuit.

$$I_3 = V / R_{eq} - V / 4\Omega = V / 4\Omega$$

SOLUTION: papucisse [9/12/03]: ANSWER=D *(Note: Original problem was modified by PhysicsGRE.com)*

Answer: (d) When the weight and the air resistance are equal in magnitude and opposite in direction:
Discussion:

(a) is wrong, because the velocity at the highest height is zero and the ball is accelerating downward
(b) is wrong because the velocity immediately after the ball is thrown is the initial velocity and it is being accelerated downward both by gravity and air resistance
(c) is wrong because in some systems the ball may hit the ground without reaching terminal velocity
(d) is correct: when the gravitational and the air resistance forces cancel out, the ball will travel at a constant velocity; by definition this velocity is called "terminal velocity."
(e) Is wrong, because the net force on the ball will be positive and will cause acceleration.

Papu Cisse for PhysicsGRE.com

SOLUTION: vova [9/13/03]: ANSWER=B *(Note: Original problem was modified by PhysicsGRE.com)*

Hi guys !! This is a very simple problem which uses Gauss's Law. Gauss's Law states that the net electric flux passing out of closed surface is equal to the total charge within such surface.

For our spherical problem we know that: $E = \dfrac{q}{4\pi\varepsilon_o r^2}$

Where ***r*** is the radius of the Gaussian surface and ***q*** is the charge within surface.
The key to the problem is finding the enclosed charge at a distance of R/2 and 2R.
Note: $\rho(r) = Ar^2$ when $r \le R$ and 0 otherwise where A is a constant (i.e. we are given that the charge density of a sphere of radius R is proportional to the square of the distance from the center)

At $r = R/2$, $q = \int \rho(r) dV = \int_0^{R/2} r^2 4\pi r^2 dr = \dfrac{4\pi A R^5}{160}$

At $r = 2R$, $q = \int \rho(r) dV = \int_0^{R} r^2 4\pi r^2 dr = \dfrac{4\pi A R^5}{5}$ (Note: $\rho(r) = 0$ when $r > R$)

Using this information we can easily find the electric field.

At $r = R/2$, $E = \dfrac{AR^3}{40}$ and at $r = 2R$, $E = \dfrac{AR^3}{20}$

Therefore the ration of the magnitude of the electric field at a distance ***2R*** from the center to magnitude of the electric field a distance of ***R/2*** from the center is ***2*** and the answer is ***B***.

Any comments? Feel free to contact me at vova_ts@hotmail.com

SOLUTION: Gman [9/28/03]: ANSWER=D

d) is the correct answer. The addition of water instead of air will change which face the half-cycle phase shift of the reflected light takes place but the total number of phase shifts will be identical to the original experiment with just air (Note: This would not be the case if water had replaced the air on only one side of the thin film).

Note regarding answer a): It is true that the wavelength of light in water is smaller than that of air, but the wavelength in the medium where the difference in path length takes place is what is important.

SOLUTION: hansuiso [9/29/03]: ANSWER=D

There was no solution submitted with this problem but here is a quick discussion. The hydrogen atom has a binding energy of $E_1 = 13.6eV$ and the derivation of the binding energy of a hydrogenic helium atom is the same as the hydrogen atom except you note that $e^2 \to Ze^2$ and therefore $E = Z^2 E_1 = 54.4eV$.

SOLUTION: alovell [10/28/03] (Parts 1 and 2)

1) **ANSWER=E**
Here, we balance the magnetic force F = qvB with the circular motion mv^2/r. This yields a relation between r, m, v, q, and B. Many students will recognize this is an e/m experiment they conducted in lab. r = mv/(eB). Now this question is tricky, because the accelerating potential changes the ENERGY of the electron, and the radius depends on its VELOCITY.
Thus, there is a square-root relation between radius and potential V, giving a radius which goes UP by the square-root of two (this is 1.4, so answer (e) is the correct one).

2) **ANSWER=B**
In the same balance, we see that r is inversely proportional to B. Increasing the current to the coils is a LINEAR increase in magnetic field strength, so this is a LINEAR decrease in r, and answer (b) is the correct one.

In both of these problems, if you have a general understanding of the physics, you can eliminate the choices that are in the wrong direction. In changing the potential you SPEED up the electrons, and thus their path radius should increase, so (b)-(d) are eliminated. In changing the current you increase the magnetic field, which will TIGHTEN the spiral of the electrons, so you can eliminate values larger than r (a), (c) and (e).

SOLUTION: yevgeny [10/31/03]: ANSWER=A

Dimensional analysis of the relevant quantities (gravity acceleration g, depth h, density of water ρ) shows that the velocity must satisfy $v^2 \sim gh$. Therefore the velocity increased to $2v$.
The frequency f cannot change between the two regions. Therefore the relation $v = \lambda$ f implies that the wavelength becomes 2λ.

Note: The relation $v = \lambda f$ eliminates answers (b), (d), and (e) from the beginning, even without the need to use dimensional analysis.

SOLUTION: Miravek [11/5/03] ANSWER = B

The Partition function is written as $Z = \sum_n g_n e^{\frac{-E_n}{kT}}$ where g_n is the degeneracy of the level and T is the temperature. You simply plug in the values given and write the partition function.

About the other answers: A is the right setup, it is just missing the minus signs in the exponents and is meant to catch people who are trying to rush as they will see it first and say A. C would be the answer if they were non-degenerate energy levels. D puts the degeneracy up in the exponent and E is the non degenerate state without the minus sign in the exponent.

SOLUTION: Susan [11/18/03] ANSWER = E

If you use the principle of superposition and then sum the forces on one of the outside point charges you will see that there is a repulsive force of ***T*** from the other outside point charge and a repulsive force of ***4T*** from the point charge that was added in the center (i.e. identical charge at half the distance away would increase the force by a factor of ***4***). Therefore, to remain in static equilibrium the tension in the string would be ***5T***.

SOLUTION: hhegab [11/24/03] ANSWER = D

Successive resonances in the tube are separated by one half wavelength increments (***λ/2***).
Therefore the wavelength of the tuning fork is:
$\lambda = 2(0.84m - 0.50m) = 0.68m$ and therefore the frequency is:
$f = v/\lambda = 340(m/s)/0.68m = 500Hz$

SOLUTION: Susan [11/26/03] ANSWER = E

Perhaps the quickest way to solve this particular problem is to exploit the answers with the use of limits. You know that in the limit that $\boldsymbol{r \to 0}$ your answer should be $\boldsymbol{d}$. This leaves us with only answers b), d), and e). Also, in the limit that $\boldsymbol{r \to R}$ you expect the answer should become infinitely large and thus the only remaining answer choice is e). Note: This approach using limits doesn't always eliminate all four answers but it is often a quick way to eliminate some.

If you were to solve this problem without using the answers then it makes for a faster solution to note that the time required for the marble to fall is independent of the horizontal velocity and hence it is independent of the distance the spring is compressed. When the spring is initially compressed a distance $\boldsymbol{d}$, the marble travels a distance $(R-r)$ in the time required for it to fall. However, we want it to travel a distance $\boldsymbol{R}$ and therefore we want the initial velocity to be greater by a factor of $R/(R-r)$.

Using the conservation of energy we find that the initial horizontal velocity of the marble is related to the compression distance by: $\frac{1}{2}kd^2 = \frac{1}{2}mv^2$. Therefore, to increase the initial horizontal velocity by a factor of $R/(R-r)$ we would need to increase the distance the spring is compressed by a factor of $R/(R-r)$ as well. Therefore, the answer is e) $x = \frac{Rd}{R-r}$.