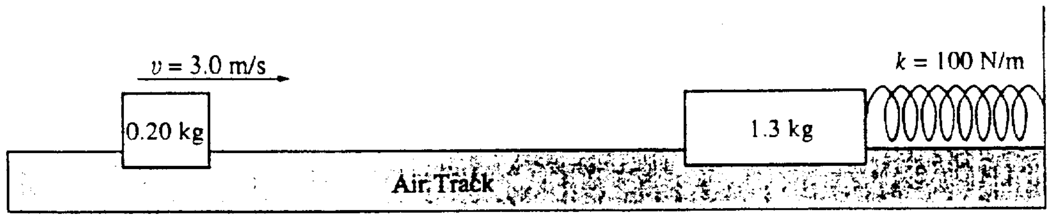
1995

AP Physics-B

Free-Response Questions



1. (15 points)
As shown above, a 0.20-kilogram mass is sliding on a horizontal, frictionless air track with a speed of 3.0 meters per second when it instantaneously hits and sticks to a 1.3-kilogram mass initially at rest on the track. The 1.3-kilogram mass is connected to one end of a massless spring, which has a spring constant of 100 newtons per meter. The other end of the spring is fixed.

(a) Determine the following for the 0.20-kilogram mass immediately before the impact.

i. Its linear momentum
ii. Its kinetic energy

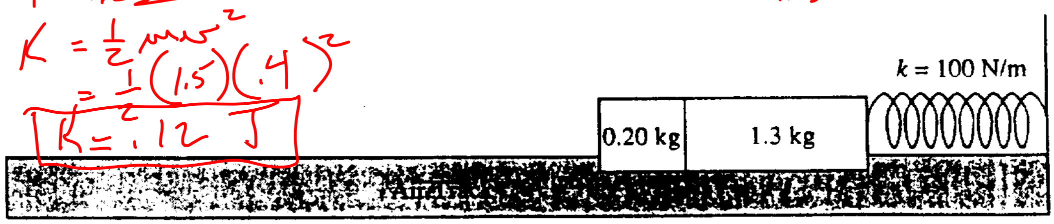
a i) $mv = (.2)(3)$
2 $P = 0.6\ kg\,m/s$
ii) $K = \frac{1}{2}mv^2 = \frac{1}{2}(.2)(3)^2$
2 $K = 0.9\ J$

(b) Determine the following for the combined masses immediately after the impact.

i. The linear momentum
ii. The kinetic energy

$mv = Mv_f \quad v_f = \frac{mv}{M} = \frac{.2(3)}{1.5}$

2 b i) $P_T = P_{.2} = 0.6\ kg\,m/s$
3 ii) $K = \frac{1}{2}mv^2 = \frac{1}{2}(1.5)(.4)^2$
$K = .12\ J$



After the collision, the two masses undergo simple harmonic motion about their position at impact.

(c) Determine the amplitude of the harmonic motion.

(d) Determine the period of the harmonic motion.

c) $K_m = P_s = \frac{1}{2}kx^2$
$x = \sqrt{\frac{2K_m}{k}} = \sqrt{\frac{2(.12)}{100}}$
3 $x = .049\ m$

d) $T = 2\pi\sqrt{\frac{m}{k}} = 2\pi\sqrt{\frac{1.5}{100}}$
2 $T = 0.77\ sec$

+1 UNITS

1995-B No. 2

a) $P = \frac{V^2}{R}$

$R = \frac{V^2}{P} = \frac{12^2}{6}$

$R = 24\,\Omega$

b) $\mathcal{E} = Pt$

$\mathcal{E} = (6\,W)(30 \times 24 \times 3600)$

$\mathcal{E} = 1.6 \times 10^7\,J$

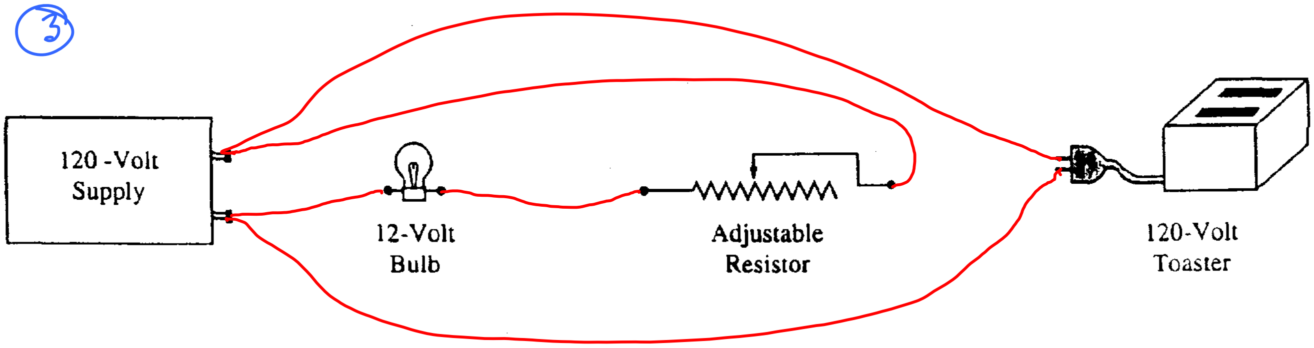
2. (15 points)
A certain light bulb is designed to dissipate 6 watts when it is connected to a 12-volt source.

(a) Calculate the resistance of the light bulb.

(b) If the light bulb functions as designed and is lit continuously for 30 days, how much energy is used? Be sure to indicate the units in your answer.

The 6-watt, 12-volt bulb is connected in a circuit with a 1,500-watt, 120-volt toaster; an adjustable resistor; and a 120-volt power supply. The circuit is designed such that the bulb and the toaster operate at the given values and, if the light bulb fails, the toaster will still function at these values.

(c) On the diagram below, draw in wires connecting the components shown to make a complete circuit that will function as described above.



(d) Determine the value of the adjustable resistor that must be used in order for the circuit to work as designed.

(e) If the resistance of the adjustable resistor is increased, what will happen to the following?

i. The brightness of the bulb. Briefly explain your reasoning.
ii. The power dissipated by the toaster. Briefly explain your reasoning.

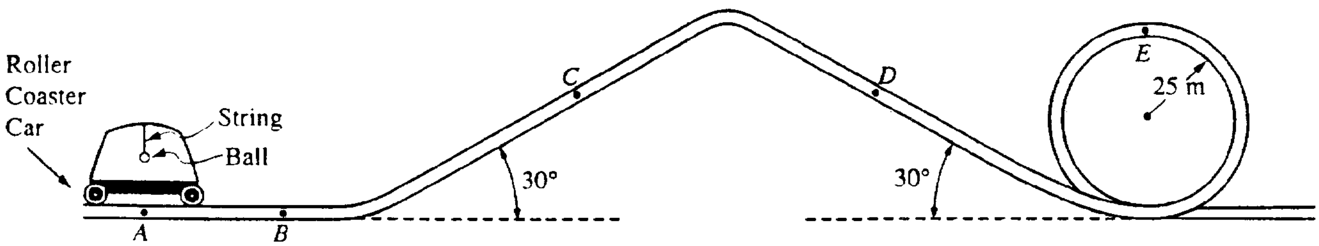
d) $V_{BULB} = 12$ so $V_R = 108$

$I_{BULB} = \frac{V_B}{R_B} = \frac{12\,V}{24\,\Omega} = \frac{1}{2}\,A$

$R = \frac{V_R}{I_R} = \frac{108\,V}{\frac{1}{2}\,A} = 216\,\Omega$

e) i. BRIGHTNESS DECREASES: $>R$ MEANS $<I$ SO $I^2R \downarrow$

ii. NO CHANGE. 2 SEP CIRCUITS; V & R CONST.



Note: Figure not drawn to scale.

3. (15 points)
Part of the track of an amusement park roller coaster is shaped as shown above. A safety bar is oriented lengthwise along the top of each car. In one roller coaster car, a small 0.10-kilogram ball is suspended from this bar by a short length of light, inextensible string.

(a) Initially, the car is at rest at point A.

i. On the diagram to the right, draw and label all the forces acting on the 0.10-kilogram ball.
ii. Calculate the tension in the string.

T, mg

$\Sigma F = ma = 0$
$T = mg$
$= (.1)(10)$
$T = 1N$

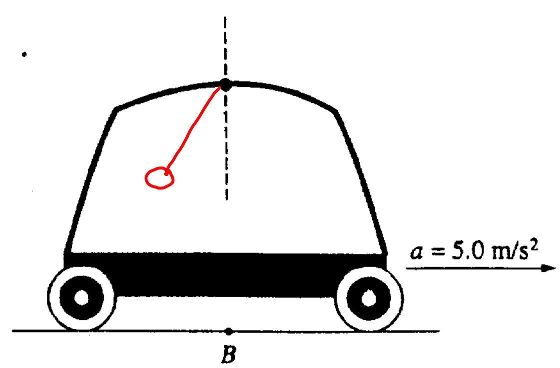
The car is then accelerated horizontally, goes up a 30° incline, goes down a 30° incline, and then goes around a vertical circular loop of radius 25 meters. For each of the four situations described in parts (b) to (e), do all three of the following. In each situation, assume that the ball has stopped swinging back and forth.

- Determine the horizontal component T_h of the tension in the string in newtons and record your answer in the space provided.
- Determine the vertical component T_v of the tension in the string in newtons and record your answer in the space provided.
- Show on the adjacent diagram the approximate direction of the string with respect to the vertical. The dashed line shows the vertical in each situation.

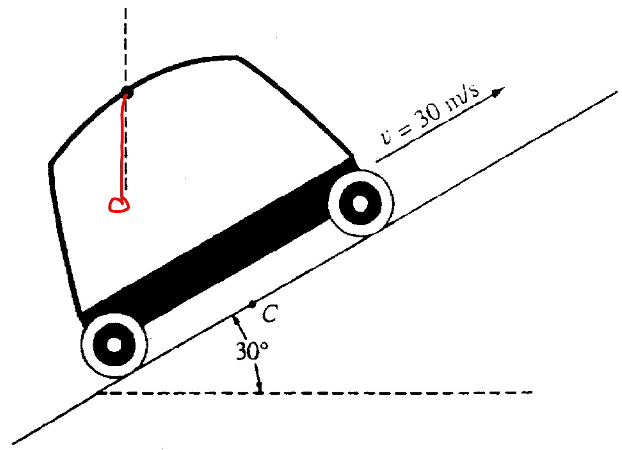
(b) The car is at point B moving horizontally to the right with an acceleration of 5.0 m/s^2.

T_h = 0.5N N T_v = 1N N

$T_H = ma = (.1)(5)$ $T_V = W = 1N$



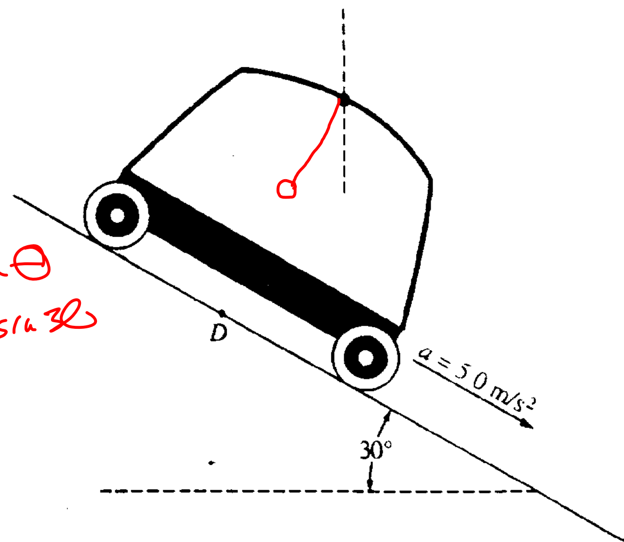
(c) The car is at point C and is being pulled up the 30° incline with a constant speed of 30 m/s.



T_h = __0__ N $\qquad$ T_v = __1 N__ N

$\Sigma F = 0$

(d) The car is at point D moving down the 30° incline with an acceleration of 5.0 m/s².

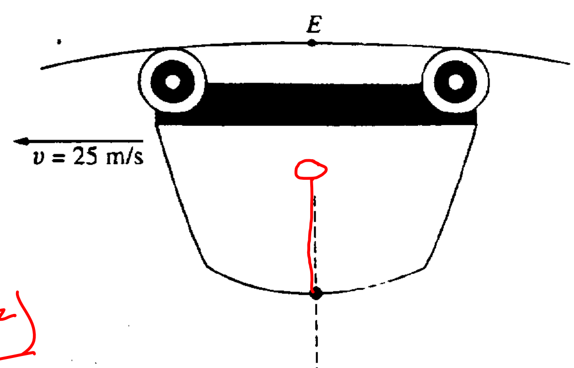


T_h = __0.43__ N $\qquad$ T_v = __0.75__ N

$T_H = ma\cos\theta = (.1)(5)\cos\theta$

$T_v = mg - ma\sin\theta = 1 - (.1)(5)\sin 30$

(e) The car is at point E moving upside down with an instantaneous speed of 25 m/s and no tangential acceleration at the top of the vertical loop of radius 25 meters.



T_h = __0__ N $\qquad$ T_v = __1.5__ N

$a_H = 0$

$\frac{mv^2}{r} = mg - T_v$

$T_v = 1 - \frac{(.1)(25^2)}{25}$

$T_v = -1.5\text{N}$ (Pulling DOWN on BALL...)

4. (15 points)
A free electron with negligible kinetic energy is captured by a stationary proton to form an excited state of the hydrogen atom. During this process a photon of energy E_a is emitted, followed shortly by another photon of energy 10.2 electron volts. No further photons are emitted. The ionization energy of hydrogen is 13.6 electron volts.

(a) Determine the wavelength of the 10.2-eV photon.

$a)\ \lambda = \frac{hc}{E} = \frac{(1.24\times10^{3}\ \text{eV nm})}{10.2\ \text{eV}}$

$\lambda = 1.22\times10^{-7}\ \text{m}$

(b) Determine the following for the first photon emitted.

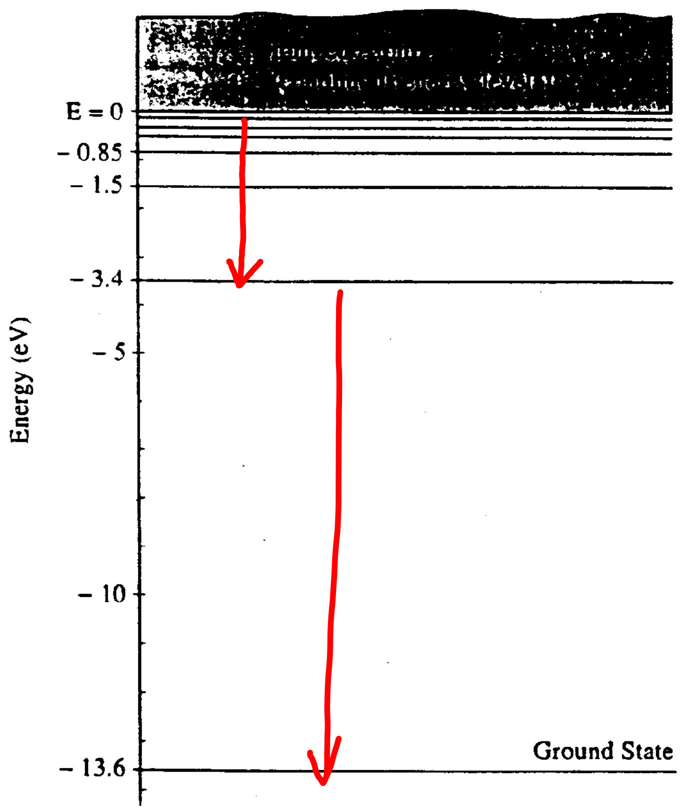
i. The energy E_a of the photon

ii. The frequency that corresponds to this energy

$b)\ i.\ E = 13.6 - 10.2 = 3.4\ \text{eV}$

$ii.\ f = E/h = \frac{3.4}{4.14\times10^{-15}} = 8.2\times10^{14}\ \text{Hz}$

(c) The following diagram shows some of the energy levels of the hydrogen atom, including those that are involved in the processes described above. Draw arrows on the diagram showing only the transitions involved in these processes.



(d) The atom is in its ground state when a 15-eV photon interacts with it. All the photon's energy is transferred to the electron, freeing it from the atom. Determine the following.

i. The kinetic energy of the ejected electron

ii. The de Broglie wavelength of the electron

$i.\ K = E - E_{ion}\ (\phi) = 15\ \text{eV} - 13.6\ \text{eV} = 1.4\ \text{eV}$

$ii.\ \lambda = \frac{h}{p} = \frac{h}{mv} = \frac{h}{m\sqrt{2K/m}} = \frac{h}{\sqrt{2mK}} = \frac{6.63\times10^{-34}}{\sqrt{2(9.11\times10^{-31})(1.4)(1.6\times10^{-19}\ \text{J/eV})}}$

$= 1\times10^{-9}\ \text{m}$

5. (10 points)
A heat engine operating between temperatures of 500 K and 300 K is used to lift a 10-kilogram mass vertically at a constant speed of 4 meters per second.

(a) Determine the power that the engine must supply to lift the mass.

(b) Determine the maximum possible efficiency at which the engine can operate.

(c) If the engine were to operate at the maximum possible efficiency, determine the following.

i. The rate at which the hot reservoir supplies heat to the engine
ii. The rate at which heat is exhausted to the cold reservoir

---

a) $P = Fv = mgv = (10)(10)(4)$

$P = 400\text{W}$

b) e_{MAX} FOLLOWS A CARNOT CYCLE:

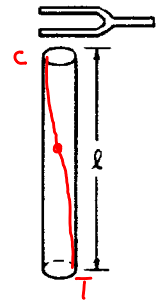
$e_{MAX} = \frac{T_H - T_c}{T_H} = \frac{500-300}{500}$

$e_{MAX} = 40\%$

c) i. $e = \frac{W}{Q_H} = \frac{Pt}{Q_H} = \frac{P}{Q_H/t}$

$\frac{Q_H}{t} = \frac{P}{e} = \frac{400}{.4} = 1{,}000\text{W}$

ii. $\frac{Q_c}{t} = 1000 - 400 = 600\text{W}$



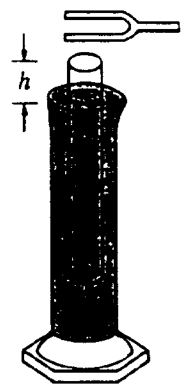
1995-B No. 6

6. (10 points)
A hollow tube of length ℓ, open at both ends as shown above, is held in midair. A tuning fork with a frequency f_0 vibrates at one end of the tube and causes the air in the tube to vibrate at its fundamental frequency. Express your answers in terms of ℓ and f_0.

(a) Determine the wavelength of the sound. $\boxed{\lambda = 2\ell}$

(b) Determine the speed of sound in the air inside the tube. $v = \lambda f = \boxed{2\ell f_0}$

(c) Determine the next higher frequency at which this air column would resonate. $\lambda = \ell,\ f = \frac{v}{\lambda} = \frac{v}{\ell} = \frac{2\ell f_0}{\ell}$ $\boxed{f = 2f_0}$



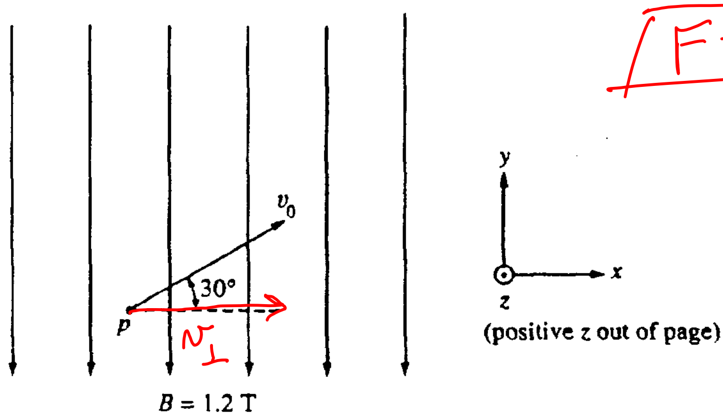
Note: Figure not drawn to scale.

The tube is submerged in a large, graduated cylinder filled with water. The tube is slowly raised out of the water and the same tuning fork, vibrating with frequency f_0, is held a fixed distance from the top of the tube.

(d) Determine the height h of the tube above the water when the air column resonates for the first time. Express your answer in terms of ℓ.

$h = \frac{\lambda}{4} = \frac{2\ell}{4} = \boxed{\frac{\ell}{2}}$

a) $F = q v_{\perp} B$
$= (1.6 \times 10^{-19})(4 \times 10^{7})(1.2)\sin 60$
$F = 6.7 \times 10^{-12}\ N$



7. (10 points)
A uniform magnetic field of magnitude $B = 1.2$ teslas is directed toward the bottom of the page in the $-y$ direction, as shown above. At time $t = 0$, a proton p in the field is moving in the plane of the page with a speed $v_0 = 4 \times 10^7$ meters per second in a direction 30° above the $+x$ axis.

(a) Calculate the magnetic force on the proton at $t = 0$.

(b) With reference to the coordinate system shown above on the right, state the direction of the force on the proton at $t = 0$. NEG z DIRECTION (RT-HND RULE...)

(c) How much work will the magnetic field do on the proton during the interval from $t = 0$ to $t = 0.5$ second?

(d) Describe (but do not calculate) the path of the proton in the field.

c) B DOES NO WORK SINCE $F_B \perp v$.

d) F_B CAUSES AN F_c SO P WILL SPIRAL UPWARD AROUND Y-AXIS...