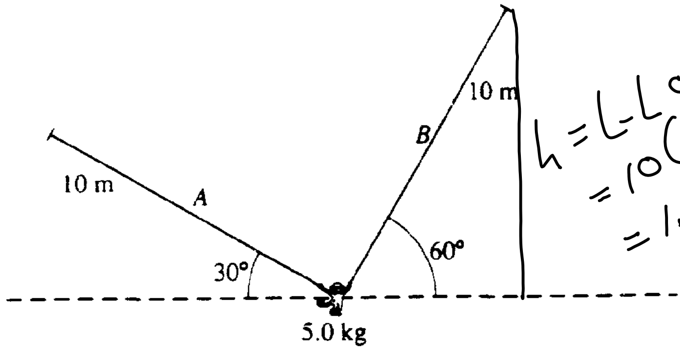
1991

AP Physics-B

Free-Response Questions



$h = L - L\cos\theta$

$= 10(1 - .87)$

$= 1.3$

sin 30° = 0.50	sin 60° = 0.87
cos 30° = 0.87	cos 60° = 0.50
tan 30° = 0.58	tan 60° = 1.73

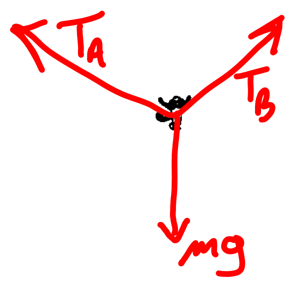
A 5.0-kilogram monkey hangs initially at rest from two vines, *A* and *B*, as shown above. Each of the vines has length 10 meters and negligible mass.

(a) On the figure below, draw and label all of the forces acting on the monkey. (Do not resolve the forces into components, but do indicate their directions.)

c) $v = \sqrt{2gh}$

$= \sqrt{20(1.3)}$

$\boxed{v = 5.1 \text{ m/s}}$



d) $\Sigma F = F_c = T - mg$

$T = F_c + mg$

$= \frac{mv^2}{r} + mg$

$= \frac{5(26)}{10} + 50$

$\boxed{T = 62N}$

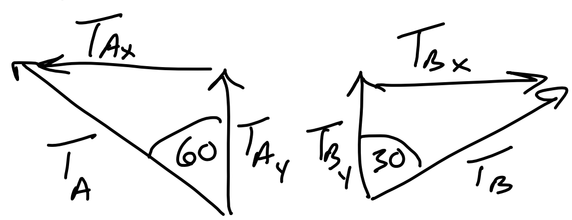
(b) Determine the tension in vine *B* while the monkey is at rest.

The monkey releases vine *A* and swings on vine *B*. Neglect air resistance.

(c) Determine the speed of the monkey as it passes through the lowest point of its first swing.

(d) Determine the tension in vine *B* as the monkey passes through the lowest point of its first swing.

b)



$T_{Ay} + T_{By} = mg$ $\qquad T_{Bx} = T_{Ax}$

$T_A \cos 60 + T_B \cos 30 = mg$

$T_A \sin 60 = T_B \sin 30$

$T_A = T_B \frac{\sin 30}{\sin 60}$

$T_B \frac{\sin 30}{\sin 60} \cos 60 + T_B \cos 30 = mg$

$T_B = \frac{mg}{\frac{\sin 30}{\sin 60}\cos 60 + \cos 30} = \frac{50}{\frac{.5}{.87}\,.5 + .87}$

$\boxed{T_B = 42N}$

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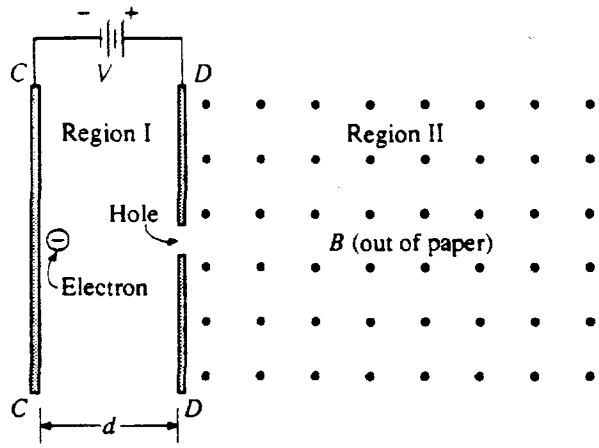


a) $V = \frac{EPE}{q} = \frac{EPE}{e}$

$EPE = KE = \frac{1}{2}mv^2$

i) $eV = \frac{1}{2}mv^2$

$\boxed{v_0 = \sqrt{\frac{2eV}{m}}}$

ii) $F = ma = eE = eV/d$

$\boxed{a = \frac{eV}{md}}$

In region I shown above, there is a potential difference V between two large, parallel plates separated by a distance d. In region II, to the right of plate D, there is a uniform magnetic field B pointing perpendicularly out of the paper. An electron, charge $-e$ and mass m, is released from rest at plate C as shown, and passes through a hole in plate D into region II. Neglect gravity.

(a) In terms of e, V, m, and d, determine the following.

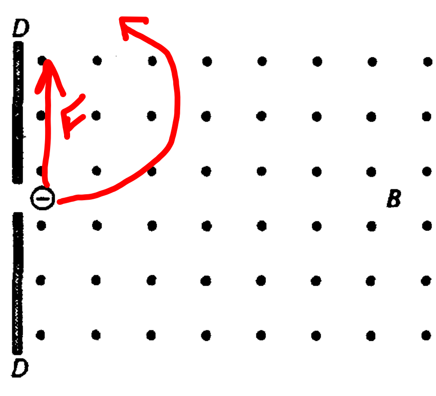
i. The speed v_0 of the electron as it emerges from the hole in plate D

ii. The acceleration of the electron in region I between the plates

(b) On the diagram below do the following.

i. Draw and label an arrow to indicate the direction of the magnetic force on the electron as it enters the constant magnetic field.

ii. Sketch the path that the electron follows in region II.



(c) In terms of e, B, V, and m, determine the magnitude of the acceleration of the electron in region II.

$\Sigma F = F_{MAG} = ma$

$evB = ma$

$a = \frac{evB}{m} = \frac{e\sqrt{\frac{2eV}{m}}B}{m} = \boxed{\frac{eB}{m}\sqrt{\frac{2eV}{m}}}$

A heat engine consists of an oil-fired steam turbine driving an electric power generator with a power output of 120 megawatts. The thermal efficiency of the heat engine is 40 percent.

(a) Determine the time rate at which heat is supplied to the engine.

(b) If the heat of combustion of oil is 4.4×10^7 joules per kilogram, determine the rate in kilograms per second at which oil is burned.

(c) Determine the time rate at which heat is discarded by the engine.

(d) If the discarded heat is continually and completely absorbed by the water in a full tank measuring 200 meters by 50 meters by 10 meters, determine the change in the temperature of the water in 1 hour. (Density of water is 1.0×10^3 kg/m^3; specific heat of water is $4.2 \times 10^3 \frac{\text{J}}{\text{kg}^\circ\text{C}}$.)

a) $eff = \frac{P_{OUT}}{P_{IN}}$ so $P_{IN} = \frac{120\,MW}{.4} = \boxed{300\,MW}$

b) $\frac{Kg}{s} = \frac{m}{t} = \frac{P}{L} = \frac{300 \times 10^6\,W}{4.4 \times 10^7\,J/Kg} = \boxed{6.82\,Kg/s}$

$(Q = mL = Pt)$

c) $P_H = P_C + P_{OUT}$ $\quad P_C = P_H - P_{OUT}$

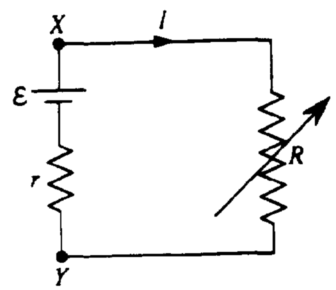
$(P_o = P_H - P_C)$

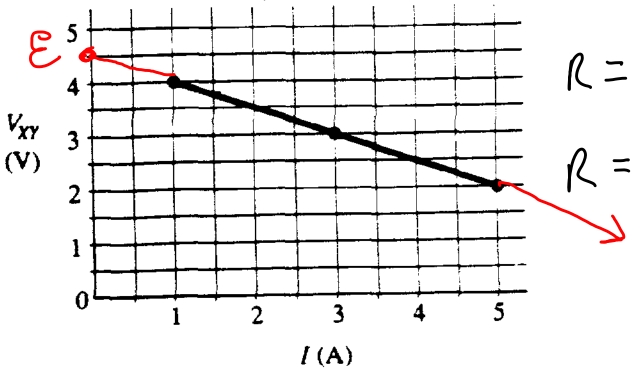
$= 300\,MW - 120\,MW = \boxed{180\,MW}$

d) $Q = Pt = mc\Delta T$

$\Delta T = \frac{Pt}{mc} = \frac{(180\,MW)(3600\,s)}{(200 \times 50 \times 10 \times 1000\,Kg)(4.2 \times 10^3\,J/Kg^\circ C)}$

$\boxed{\Delta T = 1.5^\circ C}$





$R = \frac{V}{I} = \text{slope}$

$R =$

$V_{XY} = \mathcal{E} - Ir$

$4 = \mathcal{E} - 1r$ & $2 = \mathcal{E} - 5r$

A battery with emf $\mathcal{E}$ and internal resistance r is connected to a variable resistance R at points X and Y, as shown above on the left. Varying R changes both the current I and the terminal voltage V_{XY}. The quantities I and V_{XY} are measured for several values of R and the data are plotted in a graph, as shown above on the right.

(a) Determine the emf $\mathcal{E}$ of the battery.

(b) Determine the internal resistance r of the battery. $r = \text{slope} = \boxed{\frac{1}{2}\Omega}$

(c) Determine the value of the resistance R that will produce a current I of 3 amperes. $R = \frac{V}{I} = \frac{3}{3} = \boxed{1\Omega}$

(d) Determine the maximum current that the battery can produce.

(e) The current and voltage measurements were made with an ammeter and a voltmeter. On the diagram below, show a proper circuit for performing these measurements. Use —(A)— to represent the ammeter and —(V)— to represent the voltmeter.

$V_{XY} = \mathcal{E} - Ir$

a) $4 = \mathcal{E} - r$

$-(2 = \mathcal{E} - 5r)$

$2 = 4r$

$r = \frac{1}{2}\Omega$

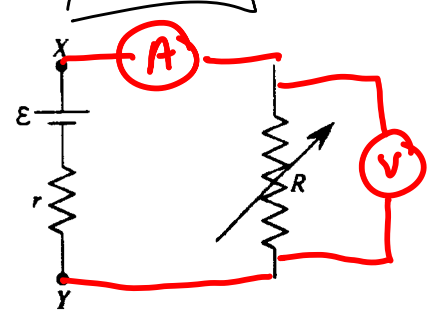
$\mathcal{E} = 4 + r = \boxed{4.5\Omega}$

-OR-

EXTEND GRAPH!

$V = -Ir + \mathcal{E}$

$y = mx + b$



d) $I_{MAX} \rightarrow R = 0$ OR $V_{XY} = 0$

$I_{MAX} = \frac{\mathcal{E}}{r} = \frac{4.5V}{.5\Omega}$

$\boxed{I_{MAX} = 9A}$

-OR-

FIND x-INT

A polonium nucleus of atomic number 84 and mass number 210 decays to a nucleus of lead by the emission of an alpha particle of mass 4.0026 atomic mass units and kinetic energy 5.5 MeV.
(1 atomic mass unit = 931.5 MeV/c^2 = 1.66 × 10^{-27}kg.)

$$Po^{210}_{84} \rightarrow Pb^{206}_{82} + He^{4}_{2}$$

(a) Determine each of the following.

i. The atomic number of the lead nucleus 82

ii. The mass number of the lead nucleus 206

(b) Determine the mass difference between the polonium nucleus and the lead nucleus, taking into account the kinetic energy of the alpha particle but ignoring the recoil energy of the lead nucleus.

(c) Determine the speed of the alpha particle. A classical (nonrelativistic) approximation is adequate.

(d) Determine the De Broglie wavelength of the alpha particle.

The alpha particle is scattered from a gold nucleus (atomic number 79) in a "head-on" collision.

(e) Write an equation that could be used to determine the distance of closest approach of the alpha particle to the gold nucleus. It is not necessary to actually solve this equation.

b) $m_{def} = \frac{E}{c^2} = \frac{5.5\,MeV}{c^2}\left(\frac{c^2}{931.5\,MeV}\right)(1\,u) = .0059\,u$

$\Delta m = m_{He} + m_{def}$

$= 4.0026 + 0.0059 = \boxed{4.0085\,u}$ $(6.65\times10^{-27}\,kg$ OR $3734\,\frac{MeV}{c^2})$

c) $K = \frac{1}{2}mv^2$

$v = \sqrt{\frac{2K}{m}} = \sqrt{\frac{2(5.5\times10^{6}\,eV)(1.6\times10^{-19}\,J/eV)}{(4.0026\,u)(1.66\times10^{-27}\,kg/u)}}$

$\boxed{v = 1.6\times10^{7}\,m/s}$ (OR $0.054c$)

d) $\lambda = \frac{h}{mv} = \frac{6.63\times10^{-34}}{(4.0026)(1.66\times10^{-27})(1.6\times10^{7})}$

$\boxed{\lambda = 6.2\times10^{-15}\,m}$

e) $W_{F_e} = K_{He}$

$\frac{k\,q_{He}\,q_{Au}}{d} = \frac{1}{2}m_{He}v^2$

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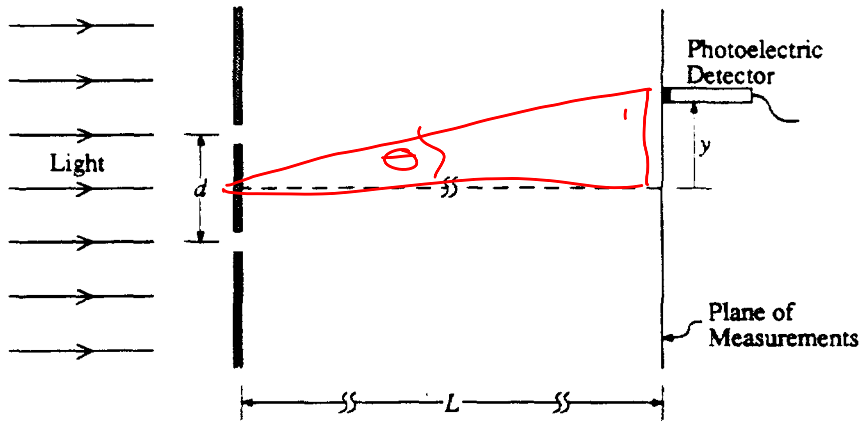

Note: Figure not drawn to scale.

Light consisting of two wavelengths, $\lambda_a = 4.4 \times 10^{-7}$ meter and $\lambda_b = 5.5 \times 10^{-7}$ meter, is incident normally on a barrier with two slits separated by a distance d. The intensity distribution is measured along a plane that is a distance $L = 0.85$ meter from the slits, as shown above. The movable detector contains a photoelectric cell whose position y is measured from the central maximum. The first-order maximum for the longer wavelength λ_b occurs at $y_b = 1.2 \times 10^{-2}$ meter.

a) $\lambda = d\sin\theta \rightarrow \lambda \, d\, y/L$

(a) Determine the slit separation d. $d = \frac{\lambda}{\sin\theta} = \frac{5.5\times10^{-7}}{1.2\times10^{-2}/.85} = 3.9\times10^{-5}\ m$

(b) At what position y_a does the first-order maximum occur for the shorter wavelength λ_a?

In a different experiment, light containing many wavelengths is incident on the slits. It is found that the photosensitive surface in the detector is insensitive to light with wavelengths longer than 6.0×10^{-7} m.

(c) Determine the work function of the photosensitive surface.

(d) Determine the maximum kinetic energy of electrons ejected from the photosensitive surface when exposed to light of wavelength $\lambda = 4.4 \times 10^{-7}$ m.

b) $\lambda = d\frac{y}{L}$

$y = \frac{\lambda L}{d} = \frac{(4.4\times10^{-7})(.85)}{3.9\times10^{-5}} = \boxed{0.0096\ m}$

c) $f_0 = \frac{c}{\lambda} = \frac{3\times10^{8}}{6\times10^{-7}} = 5\times10^{14}\ Hz$

$K_{MAX} = hf_0 - W$, $K_{MAX} = 0$ so

$hf_0 = W = (6.63\times10^{-34})(5\times10^{14})$

$\boxed{W = 3.315\times10^{-19}\ J}$

d) $K_{MAX} = hf - W = (6.63\times10^{-34})\frac{3\times10^{8}}{4.4\times10^{-7}} - 3.315\times10^{-19}$

$\boxed{K_{MAX} = 1.21\times10^{-19}\ J}$