A19. In a fission reactor, the purpose of the moderator is to

D

(A) absorb neutrons and hence slow the reaction down.
(B) carry energy to the turbines that generate the electricity.
(C) prevent radioactive material from contaminating the fuel rods.
(D) increase the chance that neutrons will cause fission reactions.
(E) allow the reactor to be used as a fusion reactor if desired.

A20. Consider the following nuclear decay: ${}^{236}_{92}U \rightarrow {}^{232}_{90}Th + X$
If the uranium nucleus is at rest before its decay, which one of the following statements is true concerning the decay products:

C

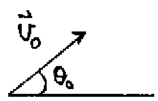
(A) They have equal kinetic energies and momenta of equal magnitudes.
(B) They have equal kinetic energies, but X has much more momentum.
(C) They have momenta of equal magnitudes, but X has much more kinetic energy.
(D) They have equal kinetic energies, but the thorium nucleus has much more momentum.
(E) They have momenta of equal magnitudes, but the thorium nucleus has much more kinetic energy.

PART B

FOR EACH OF THE FOLLOWING PROBLEMS, WORK OUT THE SOLUTION IN THE SPACE PROVIDED AND ENTER YOUR ANSWERS ON PAGE ~~6~~. 8

ONLY THE ANSWERS WILL BE MARKED. THE SOLUTIONS WILL NOT BE MARKED.

B1. Calculate the maximum height reached by a baseball projected from a flat surface on the earth with an initial speed of 45.0 m/s at angle of 35.0° to the horizontal. Neglect any effects due to air resistance.



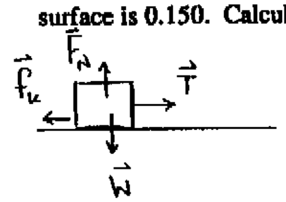
$v_{0y} = v_0 \sin\theta_0$; $v_y = 0$; $a_y = -9.81\,m/s^2$

$v_y^2 = v_{0y}^2 + 2ay$

$$y = \frac{0 - v_0^2 \sin^2\theta_0}{2a_y} = \frac{-(45.0\,m/s)^2 \sin^2 35.0°}{2(-9.81\,m/s^2)}$$

$$y = 34.0\,m$$

B2. A box of mass 2.00 kg is being pulled along a horizontal surface by a horizontal rope. The tension in the rope is 5.00 N and the coefficient of kinetic friction between the box and the surface is 0.150. Calculate the acceleration of the box.



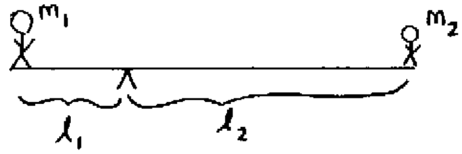
$\Sigma F_y = 0 \Rightarrow F_N = W = mg$

$\Sigma F_x = ma_x$

$$a_x = \frac{T - f_k}{m} = \frac{T}{m} - \frac{\mu_k F_N}{m} = \frac{T}{m} - \mu_k g$$

$$a_x = \frac{5.00\,N}{2.00\,kg} - (0.150)(9.81\,m/s^2) = 1.03\,m/s^2$$

B3. An 80.0 kg man and a boy stand on the ends of a balanced, massless teeter-totter. The fulcrum of the teeter-totter is located 1.50 m away from the man and 5.75 m away from the boy. If the teeter-totter remains balanced, calculate the mass of the boy.



$$\Sigma \tau = 0$$

$$m_1 g l_1 - m_2 g l_2 = 0$$

$$m_2 = \frac{m_1 l_1}{l_2} = \frac{(80.0\,kg)(1.50\,m)}{5.75\,m}$$

$$m_2 = 20.9\ kg$$

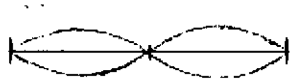
B4. A pipe of length 12.0 m and radius 0.150 m is used to carry water (density of 1000 kg/m^3, viscosity of 1.25×10^{-3} Pa·s). Calculate the pressure differential that must be applied across the ends of the pipe to obtain a volume flow rate of 0.140 m^3/s.

$$Q = \frac{\pi R^4 (P_2 - P_1)}{8 \eta L} \Rightarrow P_2 - P_1 = \frac{8 \eta L Q}{\pi R^4}$$

$$P_2 - P_1 = \frac{8(1.25\times10^{-3}\,Pa\cdot s)(12.0\,m)(0.140\,m^3/s)}{\pi\,(0.150\,m)^4}$$

$$P_2 - P_1 = 10.6\ Pa$$

B5. Transverse standing waves of frequency 60.0 Hz are generated along a stretched wire of mass 0.0250 kg and length 1.25 m that is fixed at both ends. Two antinodes are observed to exist between the fixed ends. Calculate the tension in the string.



$$L = 2\left(\frac{\lambda}{2}\right) = \lambda$$

$$v = f\lambda = \sqrt{\frac{F}{m/L}}$$

$$\frac{f^2 \lambda^2 \cdot m}{L} = F$$

$$f^2 L m = F$$

$$F = (60.0\,Hz)^2 (1.25\,m)(0.0250\,kg)$$

$$F = 113\ N$$

B6. **A proton is released from rest in an electric field of magnitude 1.30×10^3 N/C. Calculate the magnitude of the acceleration experienced by the proton.**

$$\vec{F} = q\vec{E} \quad (= m\vec{a})$$

$$a = \frac{qE}{m} = \frac{(1.60 \times 10^{-19} C)(1.30 \times 10^{3} N/C)}{1.67 \times 10^{-27} kg}$$

$$a = 1.25 \times 10^{11} \ m/s^2$$

B7. **An elderly man has perfect distance vision but can read a newspaper only when it is at least 60.0 cm from his eyes. Calculate the refractive power (in diopters) of the contact lenses that will enable him to read a newspaper held 25.0 cm from his eyes.**

$d_o = 25.0$ cm

$d_i = -60.0$ cm

$$\text{power} = \frac{1}{f} = \frac{1}{d_o} + \frac{1}{d_i} = \frac{1}{25.0 cm} + \frac{1}{(-60.0 cm)}$$

$$\text{power} = 0.0233 \ cm^{-1} = 2.33 \ m^{-1}$$

2.33 diopters

B8. **A diffraction grating has 6000 slits per cm and is illuminated with light of wavelength 628 nm. Calculate the angle, measured from the normal, at which the first order spectrum will be observed.**

$$N = \frac{6000}{cm}, \quad d = \frac{1}{N}$$

$$\theta = \arcsin\left(\frac{m\lambda}{d}\right) = \arcsin(m\lambda N)$$

$$\theta = \arcsin\left(1 \cdot 628 nm \cdot 6000 \ cm^{-1} \cdot \frac{1 cm}{10^7 nm}\right)$$

$$\theta = 22.1^\circ$$

B9. **The half-life of radioactive ^{14}C is 5730 years. An animal bone discovered in a cave is found to have only 70.0% of the number of ^{14}C atoms per gram of carbon in a living bone. Calculate the time since the death of the animal.**

$$N = 0.70 N_0 = N_0 e^{-\lambda t}$$

$$0.70 = e^{-\lambda t}$$

$$\ln(0.70) = -\lambda t$$

$$t = -\frac{\ln(0.70)}{\lambda} = -\frac{\ln(0.70)\, T_{1/2}}{0.693}$$

$$t = 2.95 \times 10^3\,y$$

B10. **Calculate the energy (in MeV) liberated in the fusion reaction $^2H + ^3H \rightarrow ^4He + n$ (Atomic masses: ^2H - 2.01410 u; ^3H - 3.01605 u; ^4He - 4.00260 u)**

$$Q = (\Delta m) c^2$$

$$Q = (2.01410u + 3.01605u - 4.00260u - 1.008665u)c^2$$

$$Q = 17.6\ \text{MeV}$$

C1. **The starship, *USS Enterprise*, is in a stable, circular, gravitational orbit around a newly discovered planet. The *Enterprise* completes 9.50 revolutions about the planet in 24.0 h when the ship is located 5.60×10^6 m above the planet's surface. Sensors show that the planet has a mass of 6.50×10^{25} kg.**

(a) Calculate the magnitude of the angular velocity of the *Enterprise* about the planet.

$$\omega = \frac{9.50\text{ rev}}{24.0\text{h}} \times \frac{2\pi\text{ rad}}{\text{rev}} \times \frac{1\text{ h}}{3600\text{s}} \qquad \boxed{6.91\times10^{-4}\text{ rad/s}}$$

(b) Calculate the radius of the planet.

$$\boxed{1.53\times10^{7}\text{ m}}$$

$$\sum \vec{F} = m\vec{a}$$

$$F_{grav} = ma_c \left(= \frac{mv^2}{r} = mr\omega^2\right)$$

$$\frac{GM\cancel{m}}{r^2} = \cancel{m}r\omega^2$$

$$\frac{GM}{\omega^2} = r^3 \Rightarrow r = \left[\frac{(6.67\times10^{-11}\text{ N}\cdot\text{m}^2/\text{kg}^2)(6.50\times10^{25}\text{ kg})}{(6.91\times10^{-4}\text{ rad/s})^2}\right]^{1/3}$$

$$r = 2.09\times10^{7}\text{m}$$

$$r_{planet} = 2.09\times10^{7}\text{m} - 5.60\times10^{6}\text{m} = 1.53\times10^{7}\text{m}$$

(c) Assuming that the planet is spherical and has a rotational period of 34.8 h, calculate the angular momentum of the planet about its rotation axis.

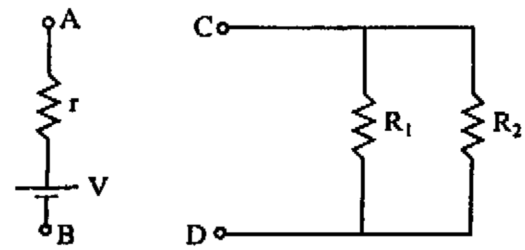
$$\boxed{3.05\times10^{35}\text{ kg}\cdot\text{m}^2/\text{s}}$$

$$L = I\omega$$

$$L = \frac{2}{5}MR^2 \cdot \frac{2\pi}{T}$$

$$L = \frac{2}{5}(6.50\times10^{25}\text{kg})(1.53\times10^{7}\text{m})^2 \frac{2\pi}{34.8\text{h}} \cdot \frac{1\text{h}}{3600\text{s}}$$

C2. The real battery shown has an emf, V, of 9.00 V and an internal resistance, r, of 5.00 Ω. It is to be connected to the network of resistors shown in the diagram. In this network, $R_1 = 35.0\ \Omega$ and $R_2 = 60.0\ \Omega$.



(a) Calculate the equivalent resistance between the terminals C and D of the resistor network.

$$R_{CD} = \left(\frac{1}{R_1} + \frac{1}{R_2}\right)^{-1}$$

$$R_{CD} = \left(\frac{1}{35.0\Omega} + \frac{1}{60.0\Omega}\right)^{-1}$$

$\boxed{22.1\ \Omega}$

(b) When the battery terminal A is connected to C, and the battery terminal B is connected to D, calculate the current drawn from the battery.

$$R_{tot} = r + R_{CD} = 5.00\Omega + 22.1\Omega$$

$$R_{tot} = 27.1\Omega$$

$$I = \frac{V}{R_{tot}} = \frac{9.00V}{27.1\Omega}$$

$\boxed{0.332\ A}$

(c) With the circuit connected as in (b) calculate the terminal potential difference of the battery (i.e. calculate the potential difference between A and B).

$$V_{AB} = I R_{CD} = (0.332A)(22.1\Omega)$$

or

$$V_{AB} = V - Ir = 9.00V - (0.332A)(5.00\Omega)$$

$\boxed{7.34\ V}$

(d) With the circuit connected as in (b) calculate the current passing through the resistor R_1.

$$I_1 = \frac{V_{CD}}{R_1} = \frac{V_{AB}}{R_1} = \frac{7.34V}{35.0\Omega}$$

$\boxed{0.210\ A}$

C3. When a surface is irradiated with light of wavelength 511 nm, electrons are ejected from the surface with a maximum kinetic energy of 0.600 eV. When a second source of light of unknown wavelength is used it is found that the emitted electrons have a maximum kinetic energy of 1.10 eV.

(a) Calculate the energy (in eV) in each photon of the light with wavelength 511 nm.

$\boxed{2.43\ \text{eV}}$

$$E = hf = \frac{hc}{\lambda}$$

$$E = \frac{(4.14 \times 10^{-15}\ \text{eV}\cdot\text{s})(3.00 \times 10^{8}\ \text{m/s})}{511 \times 10^{-9}\ \text{m}}$$

(b) Calculate the wavelength of the unknown light source.

$\boxed{424\ \text{nm}}$

1ST surface:

$$hf = KE_{max} + W_o$$

$$W_o = hf - KE_{max} = 2.43\ \text{eV} - 0.600\ \text{eV} = 1.83\ \text{eV}$$

2ND surface:

$$hf = \frac{hc}{\lambda} = KE_{max} + W_o$$

$$\lambda = \frac{hc}{KE_{max} + W_o} = \frac{(4.14 \times 10^{-15}\ \text{eV}\cdot\text{s})(3.00 \times 10^{8}\ \text{m/s})}{1.10\ \text{eV} + 1.83\ \text{eV}}$$

$$\lambda = 4.24 \times 10^{-7}\ \text{m}$$