CH 27: CQ 2, 10, PR 5, 9, 10, 19, 31, 37, 48
CH26: PR 9, 15, 23, 29, 31

CQ.

2. Use the photon model to explain why ultraviolet radiation is harmful to your skin while visible light is not.

IN THE PHOTON MODEL, ALL THE PHOTON'S ENERGY IS ABSORBED AT ONCE. HENCE, THE HIGHER FREQUENCY, HIGHER ENERGY UV PHOTONS DELIVER MORE ENERGY TO THE CELLS AND DO MORE DAMAGE. UV PHOTONS ALSO DELIVER ENOUGH ENERGY TO IONIZE ATOMS AND MOLECULES WHICH WILL CHANGE THE CHEMISTRY AND DISRUPT NORMAL CELL PROCESSES.

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10. If green light causes the ejection of electrons from a metal in a photoelectric effect experiment and yellow light does not, what would you expect to happen if red light were used to illuminate the same metal? Do you expect more intense yellow light to eject electrons? What about very faint violet light?

IT ALL DEPENDS ON THE PHOTON ENERGY WHICH DEPENDS ON THE FREQUENCY

$f_{GREEN} > f_{YELLOW} \Rightarrow E_G > E_Y$

SINCE $f_{RED} < f_{YELLOW} \Rightarrow E_{RED}$ IS TOO SMALL TO EJECT e^-'s

THE INTENSITY OF THE YELLOW LIGHT DOESN'T MATTER SINCE ITS FREQUENCY (& ENERGY) IS BELOW THE THRESHOLD FREQUENCY OF THE METAL

SINCE $f_{VIOLET} > f_{GREEN}$, VIOLET LIGHT, EVEN FAINT, WILL EJECT e^-'s. THERE MAY NOT BE MANY PHOTONS IN FAINT LIGHT, SO THERE WON'T BE A LOT OF e^- TO CREATE A LARGE CURRENT, BUT THERE WILL BE SOME.

PR.

5. A rubidium surface has a work function of 2.16 eV. (a) What is the maximum kinetic energy of ejected electrons if the incident radiation is of wavelength 413 nm? (b) What is the threshold wavelength for this surface?

$\phi_{Rb} = 2.16\ eV,\ \lambda = 413\,nm$

a) $K_{MAX} = hf - \phi = \frac{hc}{\lambda} - \phi$

SUBBING IN NUMBERS: $K_{MAX} = \frac{1240}{413} - 2.16 = \boxed{0.842\,eV = K_{MAX}}$

b) AT f_0, $K_{MAX} = 0$

$\Rightarrow 0 = \frac{hc}{\lambda_0} - \phi \Rightarrow \lambda_0 = \frac{hc}{\phi} = \frac{1240}{2.16} = \boxed{574\,nm = \lambda_0}$

9. Ultraviolet light of wavelength 220 nm illuminates a tungsten surface and electrons are ejected. A stopping potential of 1.1 V is able to just prevent any of the ejected electrons from reaching the opposite electrode. What is the work function for tungsten?

$\lambda = 220\,nm$, $V_{STOP} = 1.1\,V$

THE ENERGY DELIVERED BY THE PHOTON GOES INTO THE WORK FUNCTION AND COUNTERING THE STOPPING POT.

$$hf = \frac{hc}{\lambda} = \phi + eV_s \Rightarrow \phi = \frac{hc}{\lambda} - eV_s$$

$$\phi = \frac{1240}{220} - 1.1 = \boxed{4.53\,eV = \phi}$$

10. Photons with a wavelength of 400 nm are incident on an unknown metal, and electrons are ejected from the metal. However, when photons with a wavelength of 700 nm are incident on the metal, no electrons are ejected. (a) Could this metal be cesium with a work function of 1.8 eV? (b) Could this metal be tungsten with a work function of 4.6 eV? (c) Calculate the maximum kinetic energy of the ejected electrons for each possible metal when 200-nm photons are incident on it.

$\lambda = 400\,nm \Rightarrow e^-$ EJECTED

$\lambda = 700\,nm \Rightarrow$ NO e^- EJECTED

a) CAN IT BE Cs, $\phi_{Cs} = 1.8\,eV$?

$$\lambda_{0,Cs} = \frac{hc}{\phi} = \frac{1240}{1.8}$$

$$\lambda_{0,Cs} = 689\,nm$$

SO 400 nm WOULD EJECT PHOTONS & 700 nm WOULD NOT

$\Rightarrow$ YES, IT COULD BE CESIUM!

b) CAN IT BE Tn, $\phi_{Tn} = 4.6\,eV$?

$$\lambda_{0,Tn} = \frac{1240}{4.6} = 270\,nm \Rightarrow \text{No } e^- \text{ FOR 400 OR 700}$$

$\Rightarrow$ NO IT CAN'T BE TUNGSTEN

c) $$K_{MAX,Cs} = \frac{hc}{\lambda} - \phi_{Cs} = \frac{1240}{200} - 1.8 = \boxed{4.4\,eV = K_{MAX,Cs}}$$

$$K_{MAX,Tn} = \frac{hc}{\lambda} - \phi_{Tn} = \frac{1240}{200} - 4.6 = \boxed{1.6\,eV = K_{MAX,Tn}}$$

19. In a color TV tube, electrons are accelerated through a potential difference of 20.0 kV. Some of the electrons strike the metal mask (instead of the phosphor dots behind holes in the mask), causing x-rays to be emitted. What is the smallest wavelength of the x-rays emitted?

$V_{TV} = 20.0\,kV$

$$K = hf_{MAX} = \frac{hc}{\lambda_{MIN}}$$

$$\lambda_{MIN} = \frac{hc}{K} = \frac{hc}{eV}$$

$$\lambda_{MIN} = \frac{1240\,\cancel{e}V}{\cancel{e}(20\times10^3)} = 0.062\,nm = \boxed{62\,pm = \lambda_{MIN}}$$

31. What is the orbital radius of the electron in the $n = 3$ state of hydrogen?

$r = n^2 a_0$

$$\boxed{r_3 = 9(0.0529) = 0.476 \text{ nm} = r_3}$$

37. A hydrogen atom in its ground state absorbs a photon of energy 12.1 eV. To what energy level is the atom excited?

$E_{PHOTON} = 12.1\text{ eV}$

$$hf = E_f - E_i \Rightarrow E_f = hf + E_i = 12.1 - 13.6 = \boxed{-1.5\text{eV} = E_f}$$

$\Rightarrow e^-$ IS BUMPED UP TO $n = 3$, THE 3^{RD} STATE (SEE PAGE 1015)

48. The Bohr theory of the hydrogen atom ignores gravitational forces between the electron and the proton. Make a calculation to justify this omission. [*Hint:* Find the ratio of the gravitational and electrostatic forces acting on the electron due to the proton.]

$$F_{GRAV} = \frac{G M_{p^+} m_{e^-}}{r^2}$$

$$F_{ELEC} = \frac{k q_{p^+} q_{e^-}}{r^2}$$

TAKING THE RATIO:

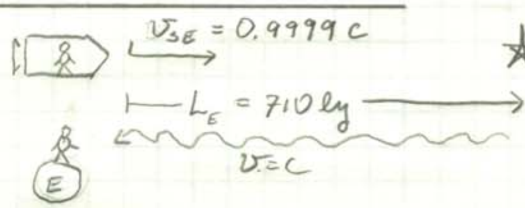
$$\frac{F_{GRAV}}{F_{ELEC}} = \frac{\frac{GM_p m_e}{r^2}}{\frac{ke^2}{r^2}} = \frac{G M_{p^+} m_{e^-}}{ke^2} = \frac{(6.67\times10^{-11})(1.67\times10^{-27})(9.11\times10^{-31})}{(8.99\times10^{9})(1.60\times10^{-19})}$$

$$\boxed{\frac{F_{GRAV}}{F_{ELEC}} = 4.41\times10^{-40}}$$

SO THE GRAVITATIONAL FORCE CAN SAFELY BE IGNORED!

CH 26.

9. A spaceship travels at constant velocity from Earth to a point 710 ly away as measured in Earth's rest frame. The ship's speed relative to Earth is 0.9999*c*. A passenger is 20 yr old when departing from Earth. (a) How old is the passenger when the ship reaches its destination, as measured by the ship's clock? (b) If the spaceship sends a radio signal back to Earth as soon as it reaches its destination, in what year, by Earth's calendar, does the signal reach Earth? The spaceship left Earth in the year 2000.



a) TRAVEL TIME SEEN BY EARTH

$$x = vt \Rightarrow t = \frac{x}{v}$$

$$t_E = \frac{710\, c\cdot\text{YR}}{0.9999c} = 710.1 \text{ YR}$$

TIME SEEN ON SHIP IS Δt_0

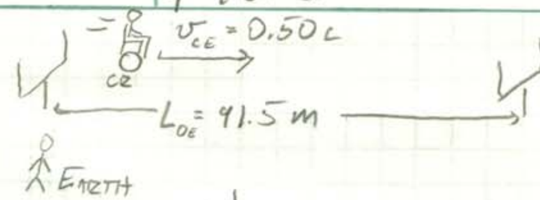
(PASSENGER DOES NOT SEE CLOCK MOVE)

$$\Delta t_0 = \frac{\Delta t}{\gamma} = \sqrt{1 - \frac{(0.9999)^2 c^2}{c^2}}\,(710.1) = 10 \text{ YR} \Rightarrow$$ TRAVELLER IS 30 YR. OLD

b) SIGNAL SENT OUT AFTER 710.1 YR, TAKE 710 YR TO ARRIVE

$$2000 + 1420.1 = \boxed{3420.1 \text{ CE}}$$ ARRIVAL YEAR

15. A cosmic ray particle travels directly over a football field, from one goal line to the other, at a speed of 0.50*c*. (a) If the length of the field between goal lines in the Earth frame is 91.5 m (100 yd), what length is measured in the rest frame of the particle? (b) How long does it take the particle to go from one goal line to the other according to Earth observers? (c) How long does it take in the rest frame of the particle?



$$\gamma = \frac{1}{\sqrt{1-\frac{(0.5)^2c^2}{c^2}}} = 1.15$$

a) $$L_{CR} = \frac{L_0}{\gamma} = \frac{91.5}{1.15} = \boxed{79.2\,m = L_{CR}}$$

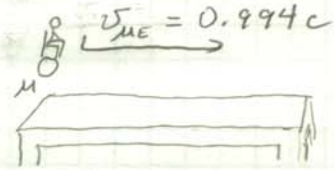
b) $$x_{EARTH} = v_{CE}\, t_{EARTH} \Rightarrow t_{EARTH} = \frac{x_E}{v_{CE}} = \frac{91.5}{(0.5)(3\times10^8)}$$

$$t_{EARTH} = 6.1\times10^{-7}\,s = \boxed{610\,ns = t_E}$$

c) TIME SEEN BY CR IS Δt_0 (CLOCK MOVES WITH CR)

$$\Delta t_0 = \frac{t_{EARTH}}{\gamma} = \frac{610}{1.15} = \boxed{530\,ns = \Delta t_{CR}}$$

23. The mean (average) lifetime of a muon in its rest frame is 2.2 μs. A beam of muons is moving through the lab with speed 0.994*c*. How far on average does a muon travel through the lab before it decays?

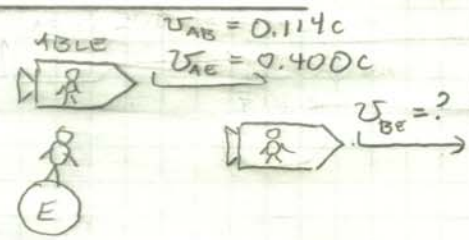


MUON'S CLOCK MOVES SO EARTH SEES Δt

$$\Delta t_{EARTH} = \gamma \Delta t_0 = \frac{1}{\sqrt{1-\frac{(0.994)^2c^2}{c^2}}}(2.2) = \underline{20.1\,\mu s = \Delta t_{EARTH}}$$

$$x_{EARTH} = v_{\mu E}\,\Delta t_E = (0.994)(3\times10^8)(20.1\times10^{-6}) = 6\times10^3 = \boxed{6.0\,km = x_E}$$

29. Rocket ship *Able* travels at 0.400*c* relative to an Earth observer. According to the same observer, rocket ship *Able* overtakes a slower moving rocket ship *Baker* that moves in the same direction. The captain of *Baker* sees *Able* pass her ship at 0.114*c*. Determine the speed of *Baker* relative to the Earth observer.



TRANSLATE PROBE, ABE, BEA TO → "PROBE" = ABLE
"BEA" = BAKER
"ABE" = EARTH

$$v_{PA} = \frac{v_{PB} + v_{BA}}{1 + \frac{v_{PB}\, v_{BA}}{c^2}}$$

$$\Rightarrow v_{ABLE,EARTH} = \frac{v_{ABLE,BAKER} + v_{BAKER,EARTH}}{1 + \frac{v_{ABLE,BAKER}\; v_{BAKER,EARTH}}{c^2}}$$

This problem is solved using GRR's method on the back page.

26.29 CONTINUED

WANT $v_{\text{BAKER, EARTH}}$ SO DO THE ALGEBRA

$$v_{AE}c^2 + v_{AE}v_{AB}v_{BE} = v_{AB}c^2 + v_{BE}c^2$$

$$(v_{AE} - v_{AB})c^2 = v_{BE}(c^2 - v_{AE}v_{AB})$$

$$v_{BE} = \frac{v_{AE} - v_{AB}}{1 - \frac{v_{AE}v_{AB}}{c^2}} \qquad \begin{cases} v_{AE} = 0.400c \\ v_{AB} = 0.114c \end{cases}$$

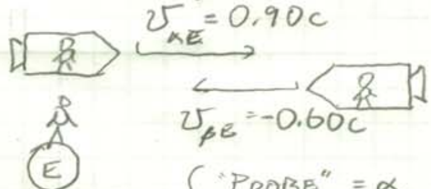
$$v_{BE} = \frac{(0.400 - 0.114)c}{1 - \frac{(0.400)(0.114)c^2}{c^2}} = \boxed{0.300c = v_{BE}}$$

---

31. As observed from Earth, rocket *Alpha* moves with speed 0.90*c* and rocket *Bravo* travels with a speed of 0.60*c*. They are moving along the same line toward a head-on collision. What is the speed of rocket *Alpha* as measured from rocket *Bravo*? (tutorial: adding velocities)

$v_{\alpha\beta} = ?$

$v_{\alpha E} = 0.90c$



$v_{\beta E} = -0.60c$

$$v_{PA} = \frac{v_{PB} + v_{BA}}{1 + \frac{v_{PB}v_{BA}}{c^2}} \rightarrow v_{\alpha E} = \frac{v_{\alpha\beta} + v_{\beta E}}{1 + \frac{v_{\alpha\beta}v_{\beta E}}{c^2}}$$

$$\begin{cases} \text{"PROBE"} = \alpha \\ \text{"BEA"} = \beta \\ \text{"ABE"} = E \end{cases}$$

WANT $v_{\alpha\beta}$

$$v_{\alpha E}c^2 + v_{\alpha E}v_{\alpha\beta}v_{\beta E} = v_{\alpha\beta}c^2 + v_{\beta E}c^2$$

$$(v_{\alpha E} - v_{\beta E})c^2 = v_{\alpha\beta}(c^2 - v_{\alpha E}v_{\beta E})$$

$$v_{\alpha\beta} = \frac{v_{\alpha E} - v_{\beta E}}{1 - \frac{v_{\alpha E}v_{\beta E}}{c^2}} = \frac{[0.90 - (-0.60)]c}{1 - \frac{(0.90)(-0.60)c^2}{c^2}}$$

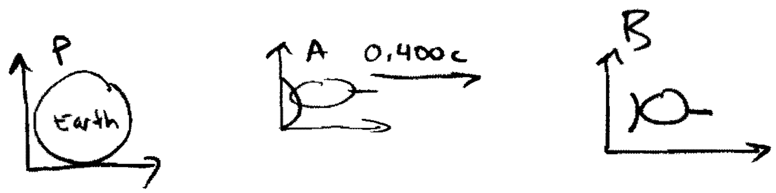
$$v_{\alpha\beta} = \frac{1.5c}{1.54} = \boxed{0.974c = v_{\alpha\beta}}$$

THEY APPROACH AT NEARLY THE SPEED OF LIGHT.

This problem is solved using GRR's method on the back page.

29 Rocket ship *Able* travels at 0.400*c* relative to an Earth observer. According to the same observer, rocket ship *Able* overtakes a slower moving rocket ship *Baker* that moves in the same direction. The captain of *Baker* sees *Able* pass her ship at 0.114*c*. Determine the speed of *Baker* relative to the Earth observer.

These solutions to Problems 29 & 31 in Chapter 26 use GRR's method for solving velocity addition problems.



V_{AP} = velocity of A relative to earth $= 0.400c$

V_{AB} = velocity of ABLE relative to Baker $= 0.114c$

$V_{BP} = ?$

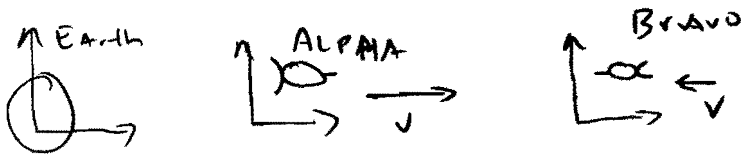
$$V_{BP} = \frac{V_{BA} + V_{AP}}{1 + \frac{V_{BA}V_{AP}}{c^2}}$$

$$V_{BA} = -V_{AB} = -0.114c$$

$$= \frac{-0.114c + 0.400c}{1 + \frac{(-0.114c)(0.400c)}{c^2}} = \frac{0.286c}{0.9544c} = \boxed{+0.3c}$$

31 As observed from Earth, rocket *Alpha* moves with speed 0.90*c* and rocket *Bravo* travels with a speed of 0.60*c*. They are moving along the same line toward a head-on collision. What is the speed of rocket *Alpha* as measured from rocket *Bravo*? (tutorial: adding velocities)

* You could have the direction of alpha + Bravo flipped since the question isn't clear. This will just flip the sign on all velocities



V_{AE} = velocity of ALPHA relative to earth $= 0.9c$

V_{BE} = velocity of Bravo relative to earth $= -0.6c$ $V_{EB} = -V_{BE} = +0.6c$

$V_{AB} = ?$

$$V_{AB} = \frac{V_{AE} + V_{EB}}{1 + \frac{V_{AE}V_{EB}}{c^2}} = \frac{0.9c + 0.6c}{1 + \frac{(0.9c)(0.6c)}{c^2}}$$

$$= \frac{1.5c}{1.54} = \boxed{0.974c = V_{AB}}$$

* If you flipped the direction of the space ships

$V_{AE} = -0.9c$

$V_{BE} = +0.6c$ $V_{EB} = -0.6c$

$$V_{AB} = \frac{(-0.9c) - 0.6c}{1 + \frac{(-0.9c)(-0.6c)}{c^2}} = \frac{-1.5c}{1.54} = \boxed{-0.974c}$$