SPH4U

Name: SOLUTIONS

UNIT 5 TEST – MODERN PHYSICS

Knowledge /45	Thinking /20	Application /15	Communication /5	Total /85

For full communication marks, show all of your work and be clear and organized in your solutions.

Communication ***[5]***

MULTIPLE CHOICE *[K30]*

1. Which scientist in the 17th century described the laws of motion that dominated physics until the 20th century?
    a. James Clerk Maxwell
    b. Galileo Galilei
    c. Isaac Newton
    d. Albert Einstein

2. An alien spaceship approaches Earth at .8c measured relative to Earth. The spaceship beams a laser at Earth. The speed of the laser light, when measured on Earth will be
    a. 1.6c
    b. 1.0c
    c. 0.2c
    d. 0.8c

3. The ether is a hypothetical medium through which electromagnetic waves were thought to propagate. Whose experiments failed to verify that there is an ether?
    a. Newton and Galileo
    b. Banting and Best
    c. Michelson and Morley
    d. Higgs and Boson

4. Which of the following are affected by relativity?
    a. length, simultaneity
    b. length simultaneity, momentum
    c. length, simultaneity, momentum, speed of light
    d. none of the above

5. Simultaneity is
    a. dilated
    b. absolute
    c. invariant
    d. relative

6. Two twins leave Earth at the same time in two different space ships. Jeremy travels twice as fast as Marnie. What will happen to them after they travel for one year of time back on Earth?

   a. They will age by the same amount.
   b. Jeremy will age more than Marnie.
   c. Marnie will age more than Jeremy.
   d. There is no way of knowing. Their ages will depend on the momentum of the spacecrafts.

7. What is proper length?
   a. the exact length of an object in from all frames of reference
   b. the length of a stationary object from a moving frame of reference
   c. a length unit that is suitable for a given measurement
   d. the length of an object measured by an observer who is stationary relative to the object

8. An object that is 50 cm long passes an observer who measures it as 51 cm. Which statement is most likely to be correct?
   a. The object is moving very quickly.
   b. The object is travelling backward.
   c. The object's length is dilated by relativity.
   d. The observer made an error in measurement.

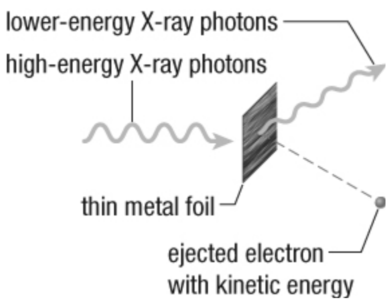
9. According to the principle of conservation of mass-energy, rest energy is equivalent to which of the following?
   a. rest mass
   b. relativistic mass
   c. relativistic mass plus rest mass
   d. relativistic mass minus rest mass

10. Which of these effects would be felt by an astronaut travelling at a constant speed of 0.5*c*?
   a. Her weight would increase.
   b. Her height would decrease.
   c. all of the above
   d. none of the above

11. Which of the following statements is correct?
   a. Particles show interference effects.
   b. Waves do not show interference effects.
   c. Particles deliver energy in discrete quantities.
   d. Particles deliver energy continuously over time.

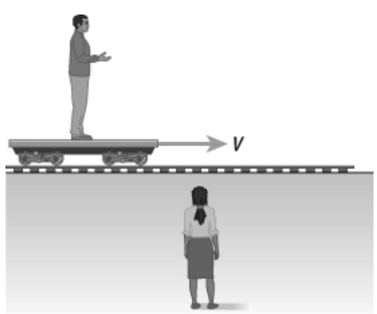
12. Which of the following definitions is correct?
    a. Photoelectric effect is the phenomenon of electrons being ejected from a material when exposed to electromagnetic radiation.
    b. Threshold frequency (f_o) is the maximum frequency at which electrons are ejected from a material.
    c. A photon is an object that absorbs all radiation reaching it.
    d. none of the above

13. What does the diagram represent?



    a. the Compton effect
    b. the photoelectric effect
    c. Wien's law
    d. none of the above

14. David travels on a high-speed railway past Zena, who is standing on Earth. Both are measuring time on identical clocks. What does Zena observe?



    a. David's clock seems to run slower than hers.
    b. David's clock seems to run faster than hers.
    c. The two clocks seem to keep exactly the same time.
    d. David's clock does not run properly.

15. Which statement about blackbody radiation is correct?
    a. A blackbody reflects all radiation reaching it.
    b. A blackbody absorbs all radiation reaching it
    c. A blackbody can be any colour except black.
    d. None of the above.

Answer TRUE or FALSE. If false, correct the statement. [K15]

T	1.	Scientists used to believe that light travelled through the *ether*, an invisible medium with no mass.
T	2.	A coordinate system relative to which motion is described is *a frame of reference*.
T	3.	A frame of reference that is at rest or moves with a constant velocity is *an inertial frame of reference*.
F - not	4.	The speed of light is *dependent* on whether the source of light is moving towards you or away from you.
F - same	5.	The speed of light is *different* for two observers moving in separate frames.
F - relativistic	6.	Time that changes relative to an observer is called *proper* time.
T	7.	Two events are either simultaneous or not simultaneous *for all observers*.
F – same frame of reference	8.	The rest mass of an object is its mass measured *only when it is stationary*.
F - less	9.	If the speed of an object with a rest mass of m is $0.5c$, its relativistic momentum is *greater* than Newtonian momentum.
T	10.	Mass measured in the same frame of reference will always be *the same*.
F - slower	11.	If two objects travelling at different speeds have the same momentum, the *faster* object has the greater mass.
F - same	12.	If you travelled at high speed to another galaxy, when you arrived your mass would be *greater than* it was on Earth.
F - quanta	13.	All quantum objects, including electromagnetic radiation and electrons, transfer energy in distinct, or discrete, amounts called *qubits*.
T	14.	The Compton effect is the *elastic scattering* of photons by high-energy photons.
F – de Broglie	15.	The wavelength associated with the motion of an electron with momentum p is called the *Heisenberg* wavelength.

SHORT ANSWER

1. A UFO streaks across a football field at 0.90c relative to the goal posts. Standing on the field, you measure the length of the UFO to be 228 m. The UFO later lands, allowing you to measure it with a meter stick. What length do you now obtain? ***[A4]***

$v = 0.90c$
$L_m = 228\text{ m}$
$L_s = ?$

$$L_s = \frac{L_m}{\sqrt{1-\frac{v^2}{c^2}}}$$

$$= \frac{228\text{ m}}{\sqrt{1-\frac{(0.90c)^2}{c^2}}}$$

$$L_s = 523\text{ m}$$

The length you now obtain is 523 m.

2. Calculate the longest wavelength of light that can eject electrons from a surface with a work function of 2.46 eV. ***[A3]***

$E = 2.46\text{ eV}$
$\lambda = ?$

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

$$\lambda = \frac{1.24\times10^3}{E}$$

$$= \frac{1.24\times10^3}{2.46\text{ eV}}$$

$$\lambda = 504\text{ nm}$$

The longest wavelength of light is 504 nm, or 5.04×10^{-7} m.

3. Calculate the momentum of a 4.10×10^2 nm photon of violet light. ***[A3]***

$\lambda = 410\text{ nm} = 4.10 \times 10^{-7}\text{ m}$
$p = ?$

$$p = \frac{h}{\lambda}$$

$$= \frac{6.63\times10^{-34}\text{ J}\cdot\text{s}}{4.10\times10^{-7}\text{ m}}$$

$$p = 1.62\times10^{-27}\text{ kg}\cdot\text{m/s}$$

The momentum is 1.62×10^{-27} kg·m/s.

4. A nuclear power reactor generates 3.00×10^9 W of power. In one year, what is the change in the mass of the nuclear fuel due to the energy conversion? (Hint: Recall that a 1-W power source delivers 1 J/s). ***[A5]***

$P = 3.00 \times 10^9\ \text{W} = 3.00 \times 10^9\ \text{J·s}$

$t = 1\ \text{a} = \left(\frac{365\ \text{d}}{\text{a}}\right)\left(\frac{24\ \text{h}}{\text{d}}\right)\left(\frac{3600\ \text{s}}{\text{h}}\right) = 3.15 \times 10^7\ \text{s}$

$\Delta m = ?$

$$P = \frac{E}{t}$$

$$3.00 \times 10^9\ \text{W} = 3.00 \times 10^9\ \text{J/s}$$

To calculate E_{total}:

$$E_{total} = \left(\frac{3.00 \times 10^9\ \text{J}}{\text{s}}\right)(3.15 \times 10^7\ \text{s})$$

$$E_{total} = 9.45 \times 10^{16}\ \text{J}$$

To calculate the change in mass:

$$\Delta m = \frac{\Delta E}{c^2}$$

$$= \frac{9.45 \times 10^{16}\ \text{J}}{(3.00 \times 10^8\ \text{m/s})^2}$$

$$\Delta m = 1.05\ \text{kg}$$

The change in mass is 1.05 kg.

5. The Big Bang, which is a theory predicting the origin of the universe, is estimated to have released 1.00×10^{68} J of energy. How many stars could half this energy create, assuming the average star's mass is 4.00×10^{30} kg? ***[T5]***

$E_{\text{total}} = 1.00 \times 10^{68}$ J

$\frac{1}{2}E_{\text{total}} = 5.00 \times 10^{67}$ J

$m = 4.00 \times 10^{30}$ kg

number of stars = ?

First we must calculate the change in mass:

$$\Delta m = \frac{\Delta E}{c^2}$$

$$= \frac{5.00\times10^{67}\text{ J}}{\left(3.00\times10^{8}\text{ m/s}\right)^2}$$

$$\Delta m = 5.56\times10^{50}\text{ kg}$$

To calculate the number of stars:

$$\text{number of stars} = \frac{5.56\times10^{50}\text{ kg}}{4.00\times10^{30}\text{ kg/star}}$$

$$\text{number of stars} = 1.39\times10^{20}\text{ stars}$$

The number of stars half of the energy could create is 1.39×10^{20} stars.

6. An electron is fired at a metal target, reaching a speed of 1.00×10^6 m/s. On impact, it rapidly decelerates to half that speed, emitting a photon in the process. Calculate the energy and the wavelength of the photon. ***[T7]***

$v_1 = 1.00 \times 10^6$ m/s
$v_2 = 0.50 \times 10^6$ m/s
$\lambda = ?$

First we must calculate the energy of the photon:

$$E_p = \Delta E_K = \frac{1}{2}mv_1^2 - \frac{1}{2}mv_2^2$$
$$= \frac{1}{2}m\left(v_1^2 - v_2^2\right)$$
$$= \frac{1}{2}\left(9.11\times10^{-31}\text{ kg}\right)\left[\left(1.00\times10^6\text{ m/s}\right)^2 - \left(0.50\times10^6\text{ m/s}\right)^2\right]$$
$$E_p = 3.42\times10^{-19}\text{ J}$$

To calculate wavelength:

$$\lambda = \frac{hc}{E_p}$$
$$= \frac{\left(6.63\times10^{-34}\text{ J}\cdot\text{s}\right)\left(3.00\times10^8\text{ m/s}\right)}{3.42\times10^{-19}\text{ J}}$$
$$\lambda = 5.82\times10^{-7}\text{ m}$$

The wavelength of the photon is 5.82×10^{-7} m, or 582 nm.

7. A supernova explosion of a star with a rest mass of 1.97×10^{31} kg, produces 1.02×10^{44} J of kinetic energy and radiation. ***[T8]***
   a. How many kilograms of mass are converted to energy in the explosion?
   b. Calculate the ratio of the mass destroyed to the original mass of the star.

$m = 1.97 \times 10^{31}$ kg
$E = 1.02 \times 10^{44}$ J

(a) $\Delta m = ?$

$$\Delta m = \frac{\Delta E}{c^2}$$
$$= \frac{1.02 \times 10^{44}\ \text{J}}{\left(3.00 \times 10^{8}\ \text{m/s}\right)^2}$$
$$\Delta m = 1.13 \times 10^{27}\ \text{kg}$$

1.13×10^{27} kg of mass are converted to energy in the explosion.

(b) $\dfrac{\Delta m}{m_{\text{star}}} = ?$

$$\frac{\Delta m}{m_{\text{star}}} = \frac{1.13 \times 10^{27}\ \text{kg}}{1.97 \times 10^{31}\ \text{kg}}$$
$$\frac{\Delta m}{m_{\text{star}}} = 5.75 \times 10^{-5}$$

The ratio of the mass destroyed to the mass of the star is 5.75×10^{-5}:1.