PHYSICS OF BIONICS II. Final Exam 13th December 2012

Check the given (*a*, *b*, *c*, *d*, *e*) answers to the 20 questions. Are they TRUE =T (+), or FALSE=F (–) ? Note, more than one answer could be true!

Name:……..

	1	2	3	4	5	6	7	8	9	10
a)										
b)										
c)										
d)										
e)										
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	11	12	13	14	15	16	17	18	19	20
a)										
b)										
c)										
d)										
e)										

1. What do we know about the mechanical dynamics of a point-like body? Is it True or False that
   a. A point-like body under the influence of a given force moves always on a trajectory satisfying Newton's equation of motion, $m\ d\mathbf{v}/\mathrm{d}t = \mathbf{F}$;
   b. If the velocity is not negligible with respect to the velocity of light (c), the mass depends on the absolute value of the velocity as $m = m_0 / \sqrt{1 - v^2/c^2}$;
   c. The kinetic energy of a particle is always $E = 0.5 m_0 v^2$, where m_0 is the rest mass;
   d. If the particle moves in a potential force field, thus $\mathbf{F} = -q \cdot \mathrm{grad} U$, then $mc^2 - m_0 c^2 = qU$.
   e. If the particle moves in a potential force field, thus $\mathbf{F} = -q \cdot \mathrm{grad} U$, then $1/2\ mv^2 = qU$
2. What do we know about the Lorentz FORCE acting on a moving charge in electric (E) and magnetic (B) fields? Is it True or False that
   a. The Lorentz force is proportional to the charge (q) on which the fields act;
   b. The force component caused by the electric field (E) ia always parallel to the field vector (E);
   c. The trajectory of a charged particle in an electric field is always parabolic;
   d. The force component caused by the magnetic field (B) is always perpendicular to the magnetic field vector (B);
   e. The trajectory of a charged particle in a magnetic field is either circular or spiral.;
3. What do we know about the degrees of freedom of dynamical motion in classical mechanics? Is it True or False that
   a. The classical mechanical *degree of freedom* of a one-dimensional harmonic oscillator is 3;.

b. The classical mechanical *degree of freedom* of a plane double pendulum is 3.
c. The classical mechanical *degree of freedom* of a diatomic molecule is 6;
d. The *degree of freedom* of a spinning top is 5;
e. The classical mechanical *degree of freedom of n* freely moving particles is 3x*n;*

4. Is it True or False in a classical electromagnetic field that
   a. Electric charges are the sources (+) and sinks (-) of the E field;
   b. There are no whirls in the electric field ($\nabla\times\mathbf{E}=0$);
   c. There are no sources in the magnetic field ($\nabla\cdot\mathbf{B}=0$);
   d. Time-varying magnetic field generates whirls in the electric field as $\nabla\times\mathbf{E}=-\partial\mathbf{B}/\partial t$;
   e. Time-varying electric field generates whirls in the magnetic field as $\nabla\times\mathbf{B}=-\partial\mathbf{D}/\partial t$.
5. What do we know about the EMAG modes of an ideal cavity? Is it true or false that
   a. The state variable of the electromagnetic field in an ideal cavity is the electric field $\mathbf{E}(\mathbf{r},t)$;
   b. The state variable of the electromagnetic field in an ideal cavity is the vector-potential $\mathbf{A}(\mathbf{r},t)$;
   c. The eigenvalue problem $\Delta\mathbf{A}_k(\mathbf{r})=-k^2\mathbf{A}_k(\mathbf{r})$ defines the EMAG modes of a cavity, $k=k_1,k_2,\ldots\quad\mathbf{A_1}(\mathbf{r}),\mathbf{A}_2(\mathbf{r}),\ldots$;
   d. The general classical EMAG field in a cavity can be represented as a sum of eigenmodes $\mathbf{A}(\mathbf{r},t)=\sum_k f_k(t)\mathbf{A}_k(\mathbf{r})$;
   e. The eigen-values $k=k_1,k_2,\ldots$ are the frequencies of the modes as $\omega_k=k$
6. What do we know about the wave nature of the electron? Is it true or false that
   a. The frequency of an electron with 2 eV energy is 0.483 PHz;
   b. The velocity of the electron with energy 2 eV is about 1172 km/s;
   c. The absolute value of the momentum vector of an electron is $p=h/\lambda$;
   d. In case of an electron the wavelength in nanometers multiplied by the energy in eV is 1242 [eV.nm];
   e. The frequency and the wavelength of electron is related as $\lambda=c/\nu$;
7. What do we know about the particle nature of the photon? Is it true or false that
   a. In case of a collision between an electron and a photon, the energy and momentum are conserved;
   b. The energy of an infrared photon of wavelength 10 micron is 0.124 eV;
   c. The momentum of an infrared photon of wavelength 10 micron is $6.62\cdot10^{-29}\ \mathrm{kg\cdot m/s}$;
   d. The angular momentum of a circularly polarized plane-wave photon is about $6.625\cdot10^{34}\ \mathrm{VAs^2}$
   e. The Compton experiment proves the wave nature of the photon.
8. A monochromatic, 600 nm wavelength, coherent plane-wave stream of photons is moving into the positive *z* direction. The transmitted power is 1 pico-watt. Is it true or false that
   a. The energy of a photon is ~ 2.07 eV;
   b. The average number of photons are ~3.02 million photons/sec;

c. If the signal is the average number of photons, the coherent noise level is ~0.33 pico-watt, and the SNR is about 3.02;
d. The direction of the momentum vector is $-z$,
e. In case of a collision with a standing still hydrogen atom, the atom will gain a velocity of about 0.66 m/s.

9. In an X-ray cathode ray tube (CRT) an electron can give almost all of its kinetic energy to a single photon when it strikes the anode of the CRT. (This is something like the photoelectric effect, in reverse.). We calculate the maximum energy of an X-ray photon produced by electrons accelerated through a potential difference *U*. Is it true of false that
   a. If $U = 100\ \mathrm{kV}$ the energy of the electron hitting the anode is 10 keV ;
   b. In case of a) the frequency of the emitted photon is not higher than ~ 2.4 x 10^{19} Hz;
   c. If $U = 50\ \mathrm{kV}$ the frequency of the photon (of maximum energy) is ~ 1.2 x 10^{21} Hz;
   d. If $U = 50\ \mathrm{kV}$ the frequency of the photon (of maximum energy) is ~ 1.2 x 10^{19} Hz;
   e. The wavelength of the emitted photon in nm can be estimated as $1242/U^{[V]}$.
10. Is it true or false that in a closed ideal cavity
    a. The energy of each cavity mode is proportional to the frequency of the mode;
    b. If there were no photons in a mode the energy would be zero;
    c. If the number of photons in a mode was doubled the energy stored in that mode would double;
    d. If the ground-state energy of a cavity mode was E_0 eV, the energy of that mode could be E_0+2nE_0, where n is the number of photons in the cavity mode;
    e. If we increase the number of photons in a mode by one, the energy of the mode would increase by $2E_0$.
11. In an electron gas the distribution of electrons follows the Fermi-Dirac statistics. Is it true or false that according to FD statistics
    a. The number of electrons in a micro-state could be any number;
    b. Only one electron can populate a microstate; the Pauli principle always holds;
    c. The density of allowed states increase with the square-root of energy;
    d. The probability that an allowed state is populated is proportional to the Fermi function;
    e. The average energy of electrons is equal to the two-third power of the Fermi energy level.
12. In a photon gas (in thermal equilibrium) the distribution of photons follows the Bose-Einstein statistics. Is it true or false that
    a. The number of photons in a micro-state is limited to one, because of the Pauli principle;
    b. The distribution of photons follows Planck's blackbody radiation law;
    c. The total energy in a photon gas is always quantized;
    d. At a given temperature there is an frequency at which the density of photons is maximum, such as $\nu_{\max} T = 2.898\ \mathrm{x}\ 10^{-3}\ \mathrm{Hz}\cdot\ \mathrm{K}$;
    e. At room temperature (~300 K) the frequency mentioned in d) is close to 30 THz (~10 micron wavelength).
13. Stimulated emission is excited by a resonant photon absorbed by an atom at higher energy level. Is it true or false that
    a. In case of population inversion, the absorption of a photon can cause the emission of two coherent photons;

b. Stimulated emission can generate a chain reaction, and the emission of a laser beam;
c. The spontaneous emission is always present. It does not participate in the process of coherent amplification, it generates noise only;
d. In a three level laser the pumped electrons are collected spontaneously at a discrete higher energy level, and after that a photon excitation stimulates the coherent emission;
e. The color of a laser beam depends on the energy difference between the higher and the lower discrete energy levels.

14. Are the following statements true or false?
    a. Every material body of temperature T > 0 emits photons (electromagnetic radiation), and the total radiated power is proportional to the fourth power of temperature (~ T^4);
    b. A blackbody radiates electromagnetic energy, and the frequency at which the radiation is maximum decreases linearly with the absolute temperature;
    c. If a metal surface is illuminated by light, and the photon energy is larger than the work function of the metal (the energy needed by an electron to escape), then electrons will be emitted. The kinetic energy of the emitted electrons increases with the frequency of radiation;
    d. During the collision of a photon with an electron or atom, the photon behaves similarly to particles, i.e. the total energy, momentum and angular momentum of the photon-atom system are conserved;
    e. Inside matter bounded electrons behave similarly to waves, i.e. their frequency is proportional to the energy of the electron, and their wavelength is inversely proportional to the momentum.
15. We compare electrons and photons. Is it true or false that
    a. The energy of a photon is proportional to its wave number;
    b. The energy of an electron is proportional to the square of its wave number;
    c. The momentum of an electron is proportional to its wave number;
    d. The momentum of a photon is proportional to the square of its wave number;
    e. The energy of a photon is proportional to the square of its wave number.
16. Generation and Detection of Light. Is it true or false that
    a. We can generate coherent light by incandescence (thermal heating);
    b. Quantum transitions generate material luminescence;
    c. Coherent light can be generated only by luminescence;
    d. If the decay time from an excited state if large, then the luminescence is called fluorescence;
    e. If the decay time from an excited state is short, then the luminescence is called phosphorescence;
17. Could be the results of the following measurements true, or the results are surely false?
    a. A metal with work-function $E_{W1} = 4.8\,\mathrm{eV}$ was contacted to another metal of work function $E_{W1} = 6.3\,\mathrm{eV}$, and the contact potential was measured. They found that the contact potential was 2.2 V;
    b. A metal with work-function $E_{W1} = 4.8\,\mathrm{eV}$ was contacted to another metal of work function $E_{W1} = 6.3\,\mathrm{eV}$, and the contact potential was measured. They found that the contact potential was 1.5 V;
    c. The color of a LED fabricated from silicon with band gap 1.1 eV was found blue;
    d. The color of a LED fabricated from a material with band gap 2 eV was found red;
    e. The color of a LED fabricated from a material with band gap 2.3 eV was found green

18. Absorption, spontaneous and stimulated emission. Is it true or false that
    a. In thermal equilibrium the number of emitted photons is equal to the number of absorbed photons (and no amplification in thermal equilibrium);
    b. Spontaneous emission does not depend on light input;
    c. Only population inversion (pumping) can enable light amplification;
    d. The light amplification coefficient of a LASER amplifier is equal to the ratio of emitted and absorbed photons;
    e. The amplification of a LASER amplifier can is equal to the number of stimulated photons devided by the number of absorbed photons (in an amplifier spontaneously emitted photons generate noise only);
19. Einstein coefficients of the rate of absorption, rate of spontaneous and stimulated emission are A, B_{12}, B_{21}. Is it true or false that
    a. Absorptions $B_{12}N_1\rho(\nu)$ are proportional to the population of the lower energy level (N_1) and the photon density ($\rho(\nu)=\frac{8\pi h\nu^3}{c^3}\frac{1}{e^{\frac{h\nu}{kT}}-1}$);
    b. Spontaneous emission AN_2 depends only on the population of the higher energy level (N_2);
    c. Stimulated emission is $B_{21}N_2\rho(\nu)$;
    d. The rate of absorption and stimulated emission are equal ($B_{12}=B_{21}=B$);
    e. In thermal equilibrium $AN_2+B_{21}N_2\rho(\nu)=B_{12}N_1\rho(\nu)$
20. Based on the relations in Problem 18, check whether the following Einstein coefficients are correct?
    a. $A=8\pi h\nu^3;\quad B=c^3$
    b. $A=\frac{8\pi h\nu^3}{c^3};\quad B=1$
    c. $\frac{A}{B}=\frac{8\pi h\nu^3}{c^3};\quad B=1;;$
    d. $A=\frac{8\pi}{c^3};\quad B=1/h\nu^3;$
    e. $A=1;\quad B=c^3;$