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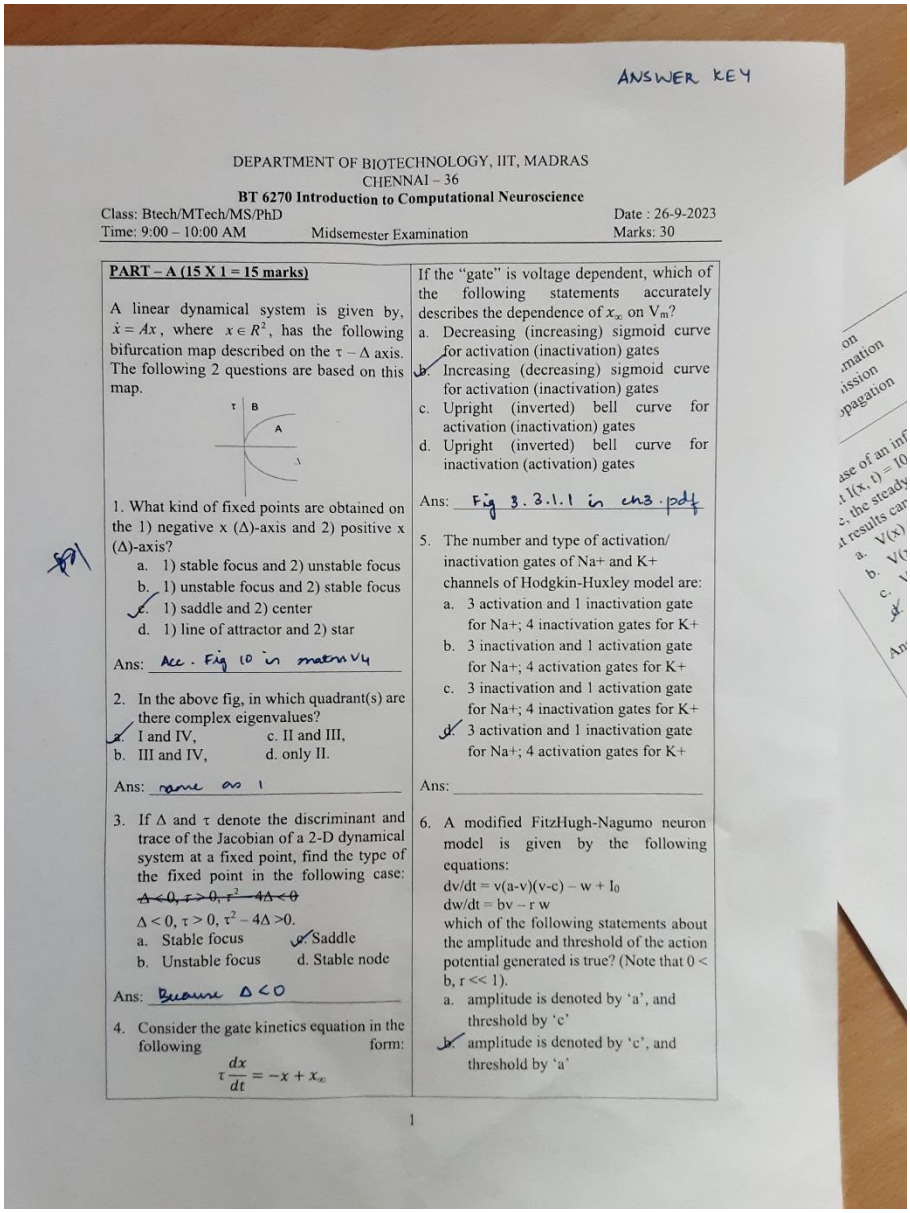
BT6270: Introduction to Computational Neuroscience | Jul-Nov 2023 Midsem |



ANSWER KEY

DEPARTMENT OF BIOTECHNOLOGY, IIT, MADRAS
CHENNAI – 36
BT 6270 Introduction to Computational Neuroscience

Class: Btech/MTech/MS/PhD — Date : 26-9-2023
Time: 9:00 – 10:00 AM — Midsemester Examination — Marks: 30

PART – A (15 X 1 = 15 marks)

A linear dynamical system is given by, $\dot{x} = Ax$, where $x \in R^2$, has the following bifurcation map described on the $\tau - \Delta$ axis. The following 2 questions are based on this map.

1. What kind of fixed points are obtained on the 1) negative x (Δ)-axis and 2) positive x (Δ)-axis?
   a. 1) stable focus and 2) unstable focus
   b. 1) unstable focus and 2) stable focus
   c. 1) saddle and 2) center
   d. 1) line of attractor and 2) star

Ans: Acc. Fig 10 in matrix V4

2. In the above fig, in which quadrant(s) are there complex eigenvalues?
   a. I and IV, c. II and III,
   b. III and IV, d. only II.

Ans: same as 1

3. If Δ and τ denote the discriminant and trace of the Jacobian of a 2-D dynamical system at a fixed point, find the type of the fixed point in the following case: ~~$\Delta < 0, \tau > 0, \tau^2 - 4\Delta < 0$~~
   $\Delta < 0, \tau > 0, \tau^2 - 4\Delta > 0$.
   a. Stable focus c. Saddle
   b. Unstable focus d. Stable node

Ans: Because $\Delta < 0$

4. Consider the gate kinetics equation in the following form:

$$\tau \frac{dx}{dt} = -x + x_\infty$$

If the "gate" is voltage dependent, which of the following statements accurately describes the dependence of x_∞ on V_m?
   a. Decreasing (increasing) sigmoid curve for activation (inactivation) gates
   b. Increasing (decreasing) sigmoid curve for activation (inactivation) gates
   c. Upright (inverted) bell curve for activation (inactivation) gates
   d. Upright (inverted) bell curve for inactivation (activation) gates

Ans: Fig 3.3.1.1 in ch3.pdf

5. The number and type of activation/ inactivation gates of Na+ and K+ channels of Hodgkin-Huxley model are:
   a. 3 activation and 1 inactivation gate for Na+; 4 inactivation gates for K+
   b. 3 inactivation and 1 activation gate for Na+; 4 activation gates for K+
   c. 3 inactivation and 1 activation gate for Na+; 4 inactivation gates for K+
   d. 3 activation and 1 inactivation gate for Na+; 4 activation gates for K+

Ans:

6. A modified FitzHugh-Nagumo neuron model is given by the following equations:
   $dv/dt = v(a-v)(v-c) - w + I_0$
   $dw/dt = bv - r\,w$
   which of the following statements about the amplitude and threshold of the action potential generated is true? (Note that $0 < b, r << 1$).
   a. amplitude is denoted by 'a', and threshold by 'c'
   b. amplitude is denoted by 'c', and threshold by 'a'

c. amplitude is denoted by 'a', and threshold by 'b'
d. None of the above

Ans: _____

7. Put the following in correct temporal order
A) entry of Ca2+ ions into the presynaptic terminal
B) opening of ion channels on the postsynaptic terminal
C) arrival of an action potential on the presynaptic terminal
D) EPSP/IPSP
E) binding of neurotransmitter with receptors on the postsynaptic terminal
F) release of neurotransmitter

a. ACEFBD ✓c. CAFEBD
b. BDACFE d. FABECD

Ans: _____

8. How many **stable** limit cycles does the following system exhibit?

$$\dot{r} = r(1-r^2)(4-r^2)$$
$$\dot{\theta} = 2 - r^2$$

✓a. 1, b. 2, c. 3, d. 4

Ans: _____

9. The dynamics of Quadratic integrate and fire neuron is described as, $\frac{dV}{dt} = V^2 + I$;
Resetting mechanism: if $(V \geq V_{peak})$ V = V_{reset}.
If, I < 0 and $V_{reset} < -\sqrt{-I} < \sqrt{-I} < V_{peak}$, which of the following behaviors are exhibited by the model?

✓a. Excitability
b. bistability with 2 fixed points,
c. only oscillations
d. bistability – 1 fixed point and an oscillatory state

Ans: Fig 5.4.1.1, ch5.pdf

10. In the quadratic, integrate and fire model, described in q9, if, I < 0 and $\sqrt{-I} < V_{reset} < V_{peak}$, which of the following behaviors are exhibited by this model?

a. Excitability,
b. bistability with two fixed points,
✓c. only oscillations,
d. bistability – a fixed point and an oscillatory state

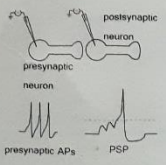
Ans: Fig 5.4.1.2, ch5.pdf

11. Which of the following about "shunting inhibition" is correct?

a. It occurs at synapses where presynaptic terminal can release both excitatory and inhibitory neurotransmitter.
b. It occurs at inhibitory synapses where on the post-synaptic side there is additional conductance (in addition to the synaptic conductance) whose Nernst potential roughly equals the membrane resting potential.
c. It occurs at inhibitory synapses where on the post-synaptic side has dual-gated channels, i.e., channels that are both ligand and voltage gated.
✓d. It occurs at excitatory synapses where on the post-synaptic side there is an additional conductance (in addition to the synaptic conductance) whose Nernst potential roughly equals the membrane resting potential.

Ans: _____

12. The following setup and recording in demonstrate which of the following phenomena?



a. Spatial summation
b. Temporal summation
c. Neurotransmission
d. Axonal propagation
Ans: _____

13. In case of an infinite dendritic cable, if a current I(x, t) = I0 u(t) is injected in the cable, the steady state voltage distribution that results can be described as:
   a. $V(x) = V_0 \exp(-x/\lambda)$
   b. $V(x) = V_0 \exp(-|x|/\lambda)$
   c. $V(x) = A \exp(x/\lambda) + B \exp(-x/\lambda)$
   d. V(x) = constant

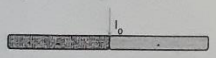
Ans: _____

14. In a supercritical Andronov-Hopf bifurcation, if μ is the bifurcation parameter and $\mu = 0$ is the bifurcation point, the radius of the limit cycle, R, grows as which of the following laws, near the bifurcation point?

a. $R \propto \sqrt{\mu}$, b. $R \propto \mu$,
c. $R \propto \mu^{2/3}$, d. $R \propto \mu^2$

Ans: _____

15. A constant current I_0 is injected into a composite dendrite with 2 semi-infinite segments joined as shown below:



For cable 1: $R_\infty = R_{\infty 1}$, and for cable 2: $R_\infty = R_{\infty 2}$. The steady state voltage, V_0, at the point of injection is:
   a. $V_0 = I_0 (R_{\infty 1} + R_{\infty 2})$
   b. $V_0 = I_0 (R_{\infty 1} R_{\infty 2}) / (R_{\infty 1} + R_{\infty 2})$
   c. $V_0 = I_0 (R_{\infty 1} - R_{\infty 2}) / (R_{\infty 1} + R_{\infty 2})$
   d. $V_0 = I_0 (R_{\infty 1} + R_{\infty 2})/2$

Ans: _____

PART – B (5 X 3 = 15 marks)

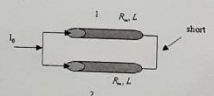
1. For the following 2D dynamical system, the number of fixed points are,
$$\dot{x} = x - x^3 - y$$
$$\dot{y} = x - 2y$$
   a. 1, b. 2, c. 3, d. 4

Ans: _____

2. For a dynamical system as given below, to be a Lienard system, the condition on f(x) is,
   a. f(x) must be an odd function, with the only root at the origin
   b. f(x) must be an even function, with indefinite integral F(x) having 3 roots.
   c. f(x) must be an even function, with indefinite integral F(x) having 1 root.
   d. f(x) must be an odd function, which must be positive for positive x.

Ans: _____

3. In the parallel two cable system shown below, DC current I_0 is injected from the left. The right ends of the two cables are shorted together. If the two cables are identical with properties, R_∞, L, what is the input impedance of the cable system?



a. $R_{in} = R_\infty \coth(L)$, b. $R_{in} = \tanh(L)$
c. $R_{in} = \frac{1}{2} R_\infty \coth(L)$, d. $R_{in} = 0$

Ans: _____

4. An extended form of Romeo and Juliet dynamics is given below,
$$\dot{R} = -R + J$$
$$\dot{J} = bR - J$$

The parameter 'b' represents the efforts of a friend of J, to push to couple towards marriage. If the range of b is [-1,2], determine for what values of b does J's friend succeed.

a. (1,2), b. (-1,1), c. (0,1), d. (-1,2)

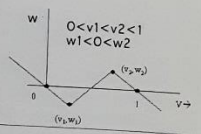
Ans: _____

5. A modified Fitzhugh-Nagumo model is given by the following equations:

$$\dot{v} = f(v) - w + I_a$$

$$\dot{w} = bv - w$$

Where f(v) is a piecewise linear approximation (see below) of the cubic nonlinearity given in the original model. Which of the following statements expresses condition for model to exhibit bistability (let b>0)



a. the v-nullcline and w-nullcline must intersect at a point where the slopes of both the nullclines are negative and the slope of w-n.c. > slope of v-n.c.

b. the v-nullcline and w-nullcline must intersect at a point where the slopes of both the nullclines are positive and the slope of w-n.c. < slope of v-n.c.

c. the v-nullcline and w-nullcline must intersect at a point where the slope of v-nc <0 and slope of w-nc >0, and slope of w-n.c. > slope of v-n.c.

d. the v-nullcline and w-nullcline must intersect at a point where the slopes of v-nc >0 and slope of w-nc < 0, and slope of w-n.c. > slope of v-n.c.

Ans: _____