**Note:** This is a take-home style exam. Use of internet, textbooks, notes are allowed (with appropriate citations). You must submit your own work. Please familiarize yourself with the institute policy on plagiarism and unfair means. **You should work on this midsem exam independently (no discussion with anyone).**

**Submission:** You must enter your responses in this template and attach images of any (legible and neatly written) rough work/plots generated via programming/spreadsheet etc. in corresponding questions. You must submit only 1 file (this template in docx format) with all information self-contained. **Submission of multiple files will automatically disqualify you from the mid-semester exam (i.e. zero marks).**

**Attestation:** All photographs of hand-written material should contain your name, roll number written in your own handwriting on the sheets. Further you should sign with pen on each sheet (no digital signature).

**Please adhere to the submission deadline.** It is highly recommended that you create checkpoint submission(s) of your work in advance of the deadline. The previous file will be overwritten when you submit a new file. **You should not email your work to the instructor/TA after the deadline.**

By entering my name and roll number below, I declare that I have read the rules listed above and agree to abide by them. I understand that failure to comply with **one or more rules** above will result in zero marks being awarded for this exam.

Name:

Roll number:

1. You recently joined a start-up company, that has invented a revolutionary sensor (to measure concentration of pathogen ‘X’) which they claim is the ‘next big thing’ in the field. One of the engineers who worked with the company had made some measurements on these sensors before deciding to leave. One of the limitations in the method used to perform measurements is that each sensor can be used only for one measurement (use-n-throw mode). Therefore one cannot measure multiple concentrations using the same sensor, and has to rely on population statistics. The engineer had conducted 15 measurements for each concentration, using a new sensor for each measurement. The company is desperate to announce the revolutionary sensor in the market and want to publish a datasheet to attract potential customers. Since your transcript says that you have taken EE617 course at IIT Bombay, they entrust you with this critical task. The measurements are provided in the file ‘Q1-midsem2020-EE617.xlsx’ (same data in Sheet1 and Sheet2, use whichever or both sheets as per your convenience).
   1. Suggest a methodology for quantifying the sensitivity in units of [mV/pg/ml]. ([pg/ml] is the unit for measurement of pathogen concentration, and the sensor output is reported in [mV]). **[5pt]**

Ans. (Write your answer here. You may type your answer or attach images of legible and neatly written solution on paper – attested.)

* 1. Based on the measurements, suggest numbers to be used for min/max spec for sensitivity [mV/pg/ml]. Justify your answer.Attach screenshots of your code (adequately commented)/spreadsheet (with formulae shown clearly). **[10pt]**

Ans. Min = \_\_\_ [mV/pg/ml] Max = \_\_\_ [mV/pg/ml}

Justification: (Write your answer here. You may type your answer or attach images of legible and neatly written solution on paper – attested. Attach screenshots of your code/spreadsheet/calculations.)

1. In an alternate universe, instead of joining a cutting-edge science start-up, your friends convince you to abandon engineering and join a market research firm as a business analyst. Thankfully you joined the company after completing EE617 course, and your manager would like you to apply your knowledge of time/frequency stability analysis of data-series to monitor and analyse historical performance of key stock prices. Your manager has asked you to study five files that she downloaded from Yahoo Finance website (Reliance Industries [RELIANCE.BO], TATA Motors [TATAMOTORS.BO] and Infosys [INFY.BO] traded on Bombay Stock Exchange, as well as INR-USD conversion rate [USD-INR] and the BSE sensex index [BSESN]). Your manager is interested in knowing which among these five datasets validates the ‘efficient market hypothesis’ (<https://en.wikipedia.org/wiki/Efficient-market_hypothesis>). The efficient market hypothesis essentially implies that the natural logarithm of the stock price (log10S[j]) follows a random walk. Alternately, this can also be analysed using absolute value of the returns on the stock price, which should show white-noise like behaviour. Absolute value of the return at time index j is defined as . Please use the opening price (column labelled ‘Open’) in each dataset as the stock-price (S[j]). Please note that the files are downloaded as-is from Yahoo Finance and may have some rows with invalid entries (NaN/null) – please clean (manually or programmatically) the files before processing.

Please provide an answer to your manager’s question, along with appropriate justification for which of these five (mention all that apply) datasets validate the efficient market hypothesis, and which of these deviate from the hypothesis. **[15pt]**

Ans. (Write your answer here. You may type your answer or attach images of legible and neatly written solution on paper – attested. Attach screenshots of your code/spreadsheet/calculations.)

1. In this question, we operate in a universe where you decided to join ISRO and were involved in one of their previous projects. India launched a dedicated astronomy satellite named AstroSat in September 2015 (<http://astrosat.iucaa.in/>). This satellite has five different instruments for studying astrophysical objects. In this question, we will discuss three of these instruments, which are pointing in the same direction and observing astrophysical bodies emitting radiation at X-ray wavelengths.

**SXT**: Soft X-ray Telescope (SXT) observes the sky in the energy band 0.3-8.0keV. It is designed as a focussing X-ray telescope with 0.067m2 aperture and a CCD detector at its focus. It has photon detection efficiency (α) of 60% and can measure maximum of 15000 counts (saturation level) over the entire CCD.

**LAXPC**: Large Area X-ray Proportional Counter (LAXPC) is made of 3 side-by-side identical chambers filled with gas at high pressure. Each chamber has a cross-sectional area of 1m x 0.5m and photon detection efficiency of 40%. Its electronic circuits store the collected data in 8 different energy band counters, which are in ascending order of energy, but each has the same bandwidth. The energy bands of the counters are non-overlapping and together cover energy range from 3keV to 80keV. LAXPC reaches saturation if any one of the counters reaches a reading of 50000 or the combined reading of all the counters reaches 200000.

**CZTI**: The third instrument is a Cadmium Zinc Telluride Imager (CZTI) with a coded aperture mask that transmits 50% of light. It has photon detection efficiency of 100% and it operates in 10keV to 150keV energy range. It consists of 4 detectors each covering area of 0.15m x 0.15m. Each detector has 4096 pixels.



These instruments are used to observe an X-ray source (assumed to be a point source), whose

energy spectrum follows the power law:

[in units of counts/keV/m2/s]

where E is the energy (in keV), K is a constant of proportionality and F(E) is photon flux density at that energy. Photon flux density, by definition, is defined per unit collecting area (m2), per unit energy (keV) and per unit time (seconds). **From prior observations, we know that the astrophysical source that we want to study has a flux density of 10 counts/keV/m2/s at 1keV energy, when measured using a detector with 100% photon detection efficiency.** “Counts” denote number of photons reported by the detector.

As the source flux follows the power law given above, we know that for a given energy range from

E1 (lower energy) to E2 (higher energy) the total photon flux (FT) will be given by (obtained by integrating above equation):

[in units of counts/m2/s]

* 1. Estimate the incident flux density from the source at 5 keV and 100 keV. Also estimate the total count per unit energy recorded by each of the instruments at these energies for an integration time of 200 seconds. **[5pt]**

Ans. (Write your answer here. You may type your answer or attach images of legible and neatly written solution on paper – attested.)

* 1. Calculate the maximum exposure time (tsat), without suffering from saturation, for the CCD of SXT. **[5pt]**

Ans. (Write your answer here. You may type your answer or attach images of legible and neatly written solution on paper – attested.)

* 1. Assume that the counts reported by CZTI due to random fluctuations in electronics are about 0.00014 counts2 per pixel per keV per second at all energy levels. Any source is considered as “detected” when the SNR (signal to noise ratio) is at least 3. What is minimum integration time (tmin) needed for the source above to be detected in CZTI? **[5pt]**

Ans. (Write your answer here. You may type your answer or attach images of legible and neatly written solution on paper – attested.)

1. **Please paste a photograph of your laptop/computer used during midsem. [0pt/-2pt]**

**[No photo = 2 marks deducted from total in midsem]**