



### **To whom it may concern**

This letter supports Gagan's application for a joint Ph.D. at the University of Manchester, UK, and IIT Kharagpur. During the last two years, I closely interacted with Gagan as a teacher for several courses and as the research advisor for his master's thesis. I have complete clarity on Gagan's academic potential and research aptitude. I would have been more than happy to offer him a Ph.D. position; however, 5 Ph.D. students are currently working with me, which is the unofficial maximum that IIT Gandhinagar permits. I have no hesitation in saying that Gagan is one of the top 5% of students I interacted with globally, working in several labs at NUS Singapore, University of Manchester, and IIT Gandhinagar. Gagan is hardworking and an ardent listener who can articulate his thoughts very clearly. Gagan is undoubtedly an asset for any institution aspiring for talented students.

Let me first write about Gagan's research achievements. Research is not compulsory in the MSc program of IIT Gandhinagar as the program also has the option of course work only MSc. Most students are not very eager to do research during MSc programs, and the teaching (Course work) track is a natural choice. However, Gagan was an exception, and in his first semester of the program, he approached me with interest to work on two-dimensional materials. Seeing his enthusiasm, I readily offered a research project. He worked with me for one year on a project related to the transport of ions and water molecules through vermiculite membranes for nanofiltration applications. While deciding the research problem, I realized that Gagan is interested in graphene and related topics. Since much research has already been carried out in graphene, I thought a very similar material would be apt for his study, which ended up in 'layered vermiculite crystals'.

He has been very enthusiastic about the project and showed immense character in approaching the research problem. He has carried out a thorough literature review on the subject and gave several presentations on the topic, which was a revelation of the multiple cognitive abilities of Gagan in providing excellent oral presentations and provided a measure of the depth of knowledge. The clarity with which Gagan can communicate is incredible. The project aimed to synthesize H-intercalated vermiculite membranes by the liquid exfoliation method. As part of the project, Gagan expanded vermiculite crystals by exchanging several salt solutions at a temperature 100 Deg.C in a reflux system and then exfoliated using ultrasonication system. Thin flakes were isolated by performing centrifugation, and then a membrane was made on porous support using the vacuum filtration technique. Gagan performed X-ray diffraction measurements to characterize the vermiculite samples. He has learned to analyze the X-ray diffractometer patterns and estimated the interlayer spacing of H-vermiculite laminates, approximately 11.8 Å. Gagan also used techniques like contact angle measurements to understand the surface character of thus prepared vermiculites, which turned out to be hydrophilic. The membranes that are exchanged with several cations did not exhibit any tunable hydrophilicity, unlike a recent report in 'nature communications' raising serious questions. The well-characterized membranes were then examined using ion transport studies, and Gagan quickly learned these techniques. His curiosity and the dare to ask tough questions amazed me. His research resulted from his independent thinking and his ability to find solutions, even if it is a difficult situation. I should also mention here that there were several interruptions by Covid-related campus restrictions while carrying out his project. However, Gagan was always eager to find ways to do his research, which made him very different from others. During this process, he learned to use a reference manager like Zotero to write his thesis, read and understand papers, and provide a very good summary of the article. He is outstanding in articulating research problems and executing those with perfection.

Let me now write about Gagan's academic achievements. Gagan is distinctly different from his peers and has a positive attitude towards research and academic studies. He has outstanding academic credentials and is very consistent in performance. Gagan got into IIT Gandhinagar through the highly competitive JAM examination, which indicates the multiple abilities of a bright and highly motivated student. To sharpen research-related knowledge, Gagan has taken my course 'Physics of two-dimensional materials' and has performed well though letter grades were not given as decided by the academic senate because of Covid. He was in the top 5% among the class of 40 students. This course consists of topics from different branches of science and engineering. What amazed me was his ability to learn new topics, not in his comfort zone. I am sure he will be naturally good in engineering, materials, chemistry, and physics-related subjects.

In summary, I strongly support the application of Gagan at your estimated institute.  
Do not hesitate to contact me if you have any further queries.

Yours sincerely,



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