

2026 ICM Problem E: Passive Solar Shading

2026 ICM 题目 E: 被动式太阳能遮阳

Background

背景

Passive solar shading has become a common addition to both housing and commercial buildings as a part of a retrofit or in new construction. It is relatively inexpensive and creates cost savings in heating and cooling. The shades are designed to block summer sun from entering a building, while allowing winter sun to not only enter the building but to warm a thermal mass that can reradiate for many hours after. Strategies such as overhangs, vegetative shading, brise-soleil systems, and high-performance glazing can reduce heat gain in buildings during higher temperatures.

被动式太阳能遮阳已成为住宅与商业建筑在改造升级或新建工程中的常见措施之一。其成本相对较低，并能在供暖与制冷方面带来费用节省。遮阳构件的设计目标是在夏季阻挡阳光进入室内，同时在冬季允许阳光进入，不仅照入室内，还可加热热质体 (thermal mass)，使其在随后数小时内持续再辐射释放热量。诸如外挑檐口 (overhang)、植物遮阳、遮阳格栅/遮阳百叶 (brise-soleil) 系统以及高性能玻璃等策略，都能在高温时段降低建筑的太阳得热。

Passive solar shading is different depending on building orientation, window area distribution between the different faces of the building, and climate. It also requires the presence of an internal thermal mass that can be heated by the direct sun. This thermal mass can be concrete, stone, water, or other material that can store heat. The thermal mass not only stores heat but reduces temperature swings throughout the day.

被动式遮阳方案会因建筑朝向、各立面窗面积分布以及气候条件而不同。该策略还需要室内设置可被直射阳光加热的热质体。热质体可以是混凝土、石材、水体或其他能够储热的材料。热质体不仅能存储热量，还能减小昼夜温度波动。

These techniques use the predictable path of the sun (determined through the use of solar position calculators), materials, geometry, and natural environmental conditions to maintain comfort and reduce energy consumption. However, the typical calculations make use of the angle of the sun at solar noon on the Summer and Winter Solstices to calculate the optimal extension of a shade over a window as shown in Figure 1. This is a simplistic view of the problem, and future metrics must do better to account for change.

这些技术利用太阳可预测的运行轨迹 (可通过太阳位置计算器确定)，并结合材料、几何形态与自然环境条件，以维持舒适并降低能耗。然而，常见的计算方法通常仅使用夏至与冬至在当地太阳正午 (solar noon) 的太阳高度角，来计算窗上方遮阳构件的最优外伸长度 (如图 1 所示)。这是一种较为简化的处理方式；面向未来的指标与方法需要更好地刻画变化因素。

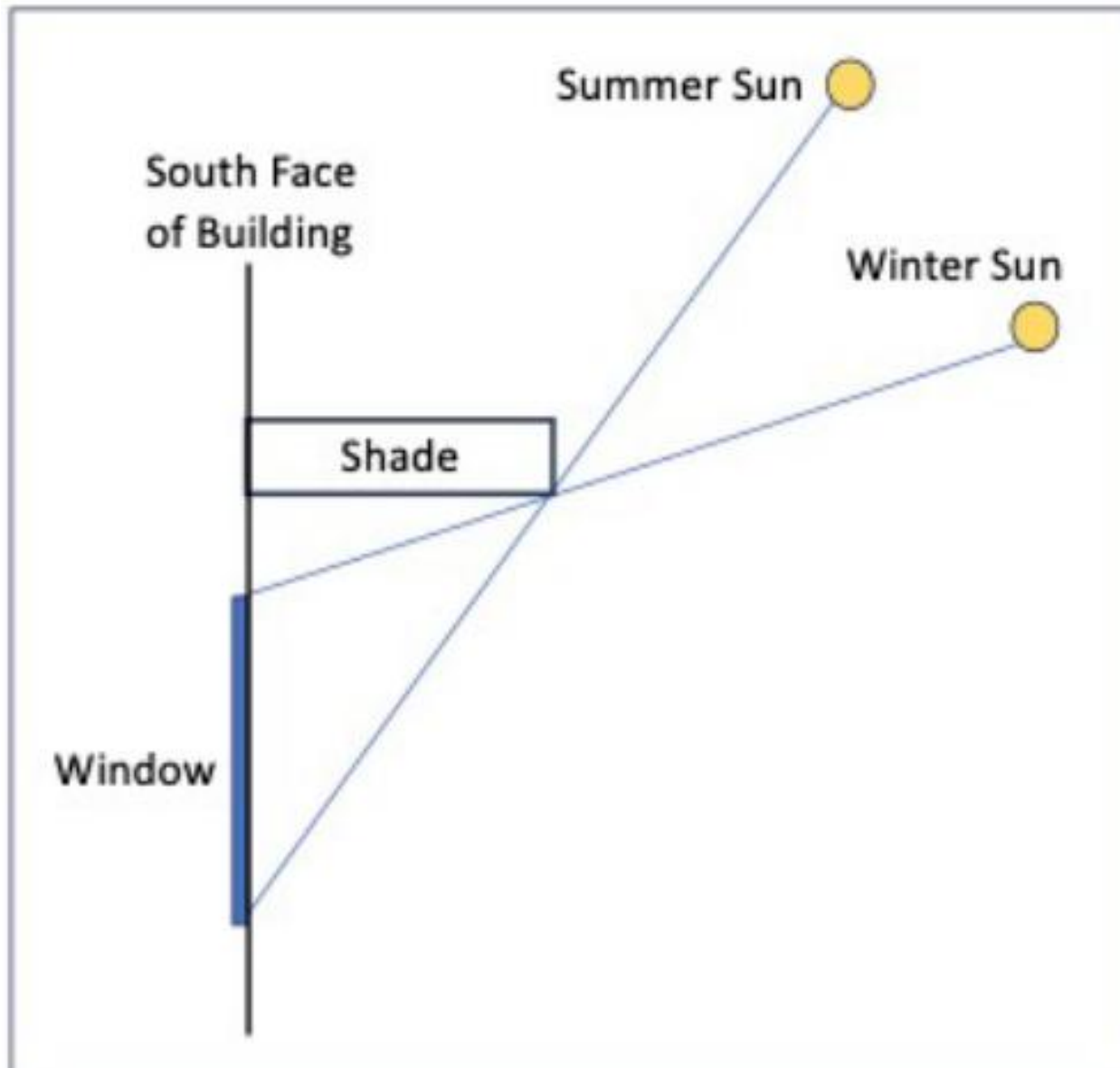


Figure 1: Passive Solar Shading - Winter and Summer Sun on Solstices

图 1: 被动式太阳能遮阳——冬至与夏至的冬季/夏季日照

Scenario

情景

You have been hired by the Collective Organizations Making Astrophysical Protections (COMAP) to innovate the next generation of solar shading strategies to be implemented at the notional Sungrove University and notional Borealis University.

你受雇于 Collective Organizations Making Astrophysical Protections (COMAP), 为设想的 Sungrove University 与设想的 Borealis University 创新并提出下一代太阳能遮阳策略, 以供实施。

The notional Sungrove University, located in a warm, low-latitude region with high solar exposure and increasingly frequent heat waves, is planning a major transformation of its main academic quad. The

campus currently suffers from excessive cooling costs and glare in the classrooms. The university leadership has decided to pursue a net-zero cooling initiative by 2040.

设想的 Sungrove University 位于温暖的低纬度地区，日照强、热浪发生频率不断上升，正计划对其主要教学四合院 (main academic quad) 进行重大改造。目前校园面临制冷成本过高以及教室眩光严重等问题。校方领导层已决定在 2040 年前推进“净零制冷” (net-zero cooling) 行动计划。

Notably, Sungrove University is planning to retrofit its Academic Hall North. It is a two-story classroom and office building. The interior layout combines perimeter offices and classrooms with interior corridors. The building has a rectangular footprint ($60\text{m} \times 24\text{m}$) with its long side aligned east-west as shown in Figure 2. The facade consists of double glazing and a brick veneer with an average window-to-wall ratio of 45% on the south facing side and 30% on the remaining sides. The building relies on mechanical cooling in the summer and hydronic heating in the winter with limited passive strategies in place. Additional features of this notional building are yours to imagine. Ensure you communicate these features in your writing to COMAP.

尤其值得注意的是，Sungrove University 计划对其 Academic Hall North 进行改造。该建筑为两层的教室与办公室综合楼，内部布局为外圈办公室与教室、内侧走廊的组合。建筑平面为矩形 ($60\text{m} \times 24\text{m}$)，长边如图 2 所示沿东西方向布置。其立面由双层玻璃与砖饰面构成：南向立面的平均窗墙比约为 45%，其余立面约为 30%。该建筑夏季依赖机械制冷，冬季采用热水供暖 (hydronic heating)，目前可用的被动式策略有限。该设想建筑的其他特征可由你自行设定，并务必在提交给 COMAP 的文字中清晰说明这些设定。

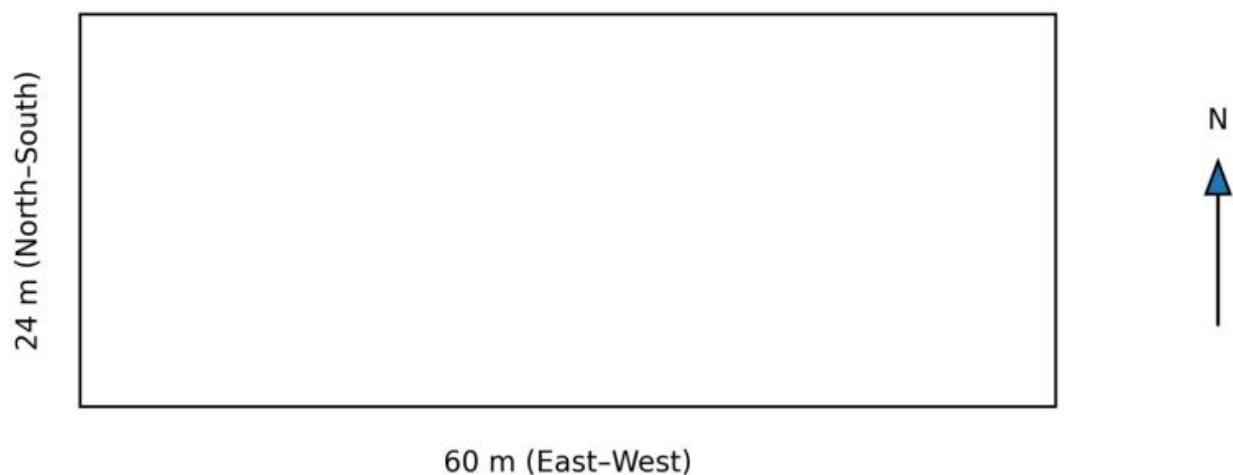


Figure 2: Academic Hall North footprint

图 2: Academic Hall North 建筑平面 (footprint)

Additionally, COMAP has been hired by the notional Borealis University, located at a high latitude where winter temperatures remain below freezing for months, sunlight hours are limited, and buildings experience heavy heating demands.

此外，COMAP 也受雇于设想的 Borealis University。该校位于高纬度地区，冬季气温常常连续数月低于冰点，日照时数有限，建筑供暖需求很高。

Sungrove University and Borealis University are also both planning a new student union that will serve as the hub of university activities. They have each mandated that their new student union building relies heavily on passive solar shading rather than mechanical cooling systems. The Universities want their student union building to serve as a prototype for future developments, meaning that their passive solar strategy design must perform well not only today, but under projected climate conditions well into the future.

Sungrove University 与 Borealis University 还都计划新建一座学生中心 (student union)，作为校园活动的枢纽。两校均要求新建学生中心应主要依赖被动式太阳能遮阳，而非机械制冷系统。校方希望该学生中心能成为未来开发建设的原型 (prototype)，这意味着其被动式太阳能策略不仅要在当下有效，也必须在未来气候情景预测条件下长期保持良好性能。

Beyond the standard approach to shading as outlined in the Background, to assist these notional universities, you should extend your ideas to include:

在背景部分所述的标准遮阳方法之外，为协助这些设想大学，你需要将构思扩展到包括：

- Shading needs throughout the day rather than just at solar noon.
- Windows of different sizes and shapes.
- Windows that do not face exactly south/north (depending on the hemisphere).
- Shades of different styles and materials that would match the architecture of the building.
- 不仅考虑太阳正午 (solar noon)，还要考虑全天各时段的遮阳需求。
- 不同尺寸与形状的窗。
- 并非严格朝南/朝北（取决于所在半球）的窗。
- 与建筑风格相匹配的不同样式与材料的遮阳构件。

As with any new strategy or model, you will not only need to describe your approach but also explain the advantages that your proposal holds over the previous standard. COMAP needs to know how your passive solar shading strategies can more effectively reduce heat gain in campus buildings during the summer while still admitting beneficial winter sun.

与任何新策略或新模型一样，你不仅需要描述你的方案，还需要说明其相较于既有标准方法的优势。COMAP 需要了解：你的被动式太阳能遮阳策略如何在夏季更有效地减少校园建筑的太阳得热，同时仍能引入冬季有益的日照。

Requirements

要求

Your team has been asked by COMAP to provide a model-based feasibility analysis that determines how Sungrove University can reduce its academic year cooling load with passive solar design in the retrofit of buildings on campus. To do so, design a retrofit for Sungrove University's Academic Hall North that optimizes heating and cooling throughout the academic year. What passive solar strategies and building features would you use, and how would you evaluate their performance?

COMAP 要求你的团队提供一份基于模型的可行性分析，以确定 Sungrove University 如何通过在校园建筑改造中采用被动式太阳能设计，降低学年期间的制冷负荷。为此，请为 Sungrove University 的 Academic Hall North 设计一套改造方案，使其在整个学年内的供暖与制冷达到优化。你将采用哪些被动式太阳能策略与建筑特征？又将如何评估其性能？

Borealis University has a building with a similar design to Sungrove University's Academic Hall North. How can extending your work for Sungrove University to include the crucial importance of the effective use of a thermal mass provide Borealis University with a plan to use passive solar shading? You may want to consider building geometry, material selection, glazing positioning, internal thermal mass, or other aspects to maximize winter heat gain while avoiding overheating in the warmer months.

Borealis University 有一栋与 Sungrove University 的 Academic Hall North 设计相近的建筑。若将你在 Sungrove University 的工作扩展到强调并纳入“有效利用热质体”的关键作用，如何为 Borealis University 提供一套使用被动式太阳能遮阳的方案？你可以考虑建筑几何形态、材料选择、玻璃布置、室内热质体设置等因素，以在最大化冬季得热的同时，避免在较温暖月份出现过热。

The retrofit design models at both Sungrove and Borealis Universities are helpful for only those notional sites. Adapt your model and discuss the design considerations for other locations including the different heating and cooling needs at places that might have similar latitudes.

针对 Sungrove 与 Borealis 两校的改造设计模型仅适用于这两个设想场址。请对模型进行调整，并讨论适用于其他地点的设计考量，包括：在纬度相近但供暖与制冷需求不同的地区，你将如何改动与应用你的模型。

Design a passive solar shading strategy for the new student union building at either Sungrove University or Borealis University that keeps the building temperate. Describe the strategies, building features, and modeling approaches you would use to evaluate performance over time. You may wish to address some of the following in your analysis:

为 Sungrove University 或 Borealis University (二者择一) 的新学生中心设计一套被动式太阳能遮阳策略，使建筑保持适宜的室内热环境。请描述你将采用的策略、建筑特征与建模方法，以及如何随时间评估其性能。你的分析可考虑 (但不限于) 以下方面：

- Predicting solar heat gain
- Estimating heating and/or cooling load reductions
- Accounting for seasonal variations
- Evaluating the tradeoffs between daylighting needs and shading effectiveness
- 预测太阳得热
- 估算供暖与/或制冷负荷的降低幅度
- 纳入季节变化因素
- 评估采光需求与遮阳效果之间的权衡

Write a one-to-two-page letter to either Sungrove University or Borealis University (not both) outlining the steps they should take to include passive solar shading in both their retrofit and new building plans.

给 Sungrove University 或 Borealis University (仅选其一) 撰写一封 1-2 页的信件，概述他们在既有建筑改造与新建项目中纳入被动式太阳能遮阳应采取的步骤。

Your PDF solution of no more than 25 total pages should include:

你的 PDF 解答总页数不超过 25 页，应包括：

One-page Summary Sheet.

Table of Contents.

- Your complete solution.

One-to-Two-Page Letter.

- References List.

AI Use Report (If used does not count toward the 25-page limit.)

1 页摘要页 (Summary Sheet)。

目录。

- 完整解答。

1-2 页信件。

- 参考文献列表。

AI 使用报告 (如使用；不计入 25 页总页数限制。)

Note: There is no specific required minimum page length for a complete ICM submission. You may use up to 25 total pages for all your solution work and any additional information you want to include (for example: drawings, diagrams, calculations, tables). Partial solutions are accepted. We permit the careful use of AI such as ChatGPT, although it is not necessary to create a solution to this problem. If you choose to utilize a generative AI, you must follow the COMAP AI use policy. This will result in an additional AI use report that you must add to the end of your PDF solution file and does not count toward the 25 total page limit for your solution.

注：完整的 ICM 提交稿没有规定最低页数要求。你的全部解题内容及任何补充信息（例如：图示、示意图、计算、表格）最多可使用 25 页。允许提交部分解答。竞赛允许谨慎使用 ChatGPT 等 AI 工具，但完成本题并不依赖 AI。如你选择使用生成式 AI，必须遵循 COMAP 的 AI 使用政策；这将要求你在 PDF 解答文件末尾附加一份 AI 使用报告，该报告不计入 25 页总页数限制。

Glossary

术语表

Solar noon is the moment during the day when the Sun is at its highest point in the sky for a given location.

Solar noon（太阳正午）是指在某一地点的一天中，太阳在天空中达到最高点的时刻。

Winter Solstice is the day with the least daylight of the year, caused by Earth's tilt.

Winter Solstice（冬至）是指一年中白昼最短的一天，其成因与地轴倾角有关。

Summer Solstice is the day with the most daylight of the year, caused by Earth's tilt.

Summer Solstice（夏至）是指一年中白昼最长的一天，其成因与地轴倾角有关。

Notional means theoretical or fictitious. The universities in this problem are not real, but only theoretical case studies.

Notional 意为“设想的/虚拟的/理论上的”。本题中的两所大学并非真实存在，仅为理论案例研究。

Net-zero cooling means providing cooling without adding greenhouse gases to the atmosphere.

Net-zero cooling（净零制冷）是指在实现制冷的同时，不向大气增加温室气体排放（实现净零增量排放）。