


B2
Symmetry and Relativity
Lecture 5



Permutation group

	e	231	312	213	132	321
e	e	231	312	213	132	321
231	231	312	e	321	213	132
312	312	e	231	132	321	213
213	213	132	321	e	231	312
132	132	321	213	312	e	231
321	321	213	132	231	312	e

- Multiplication table: specifies where positions 123 end up
- Identity element: e takes 123 to 123
- Not commutative (“non-Abelian”)

Permutation group

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231	231	312	e	321	213	132
312	312	e	231	132	321	213
213	213	132	321	e	231	312
132	132	321	213	312	e	231
321	321	213	132	231	312	e

- Subgroup: e, 231, 312 multiply among selves
 - Cyclic permutations

Permutation group

	e	231	312	213	132	321
e	e	231	312	213	132	321
231	231	312	e	321	213	132
312	312	e	231	132	321	213
213	213	132	321	e	231	312
132	132	321	213	312	e	231
321	321	213	132	231	312	e

- Off-diagonal quadrants self-contained
 - 213, 132, 321 swap two positions, not cyclic
 - Not subgroups: no identity element

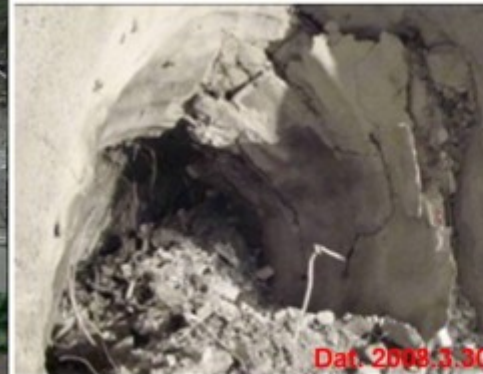
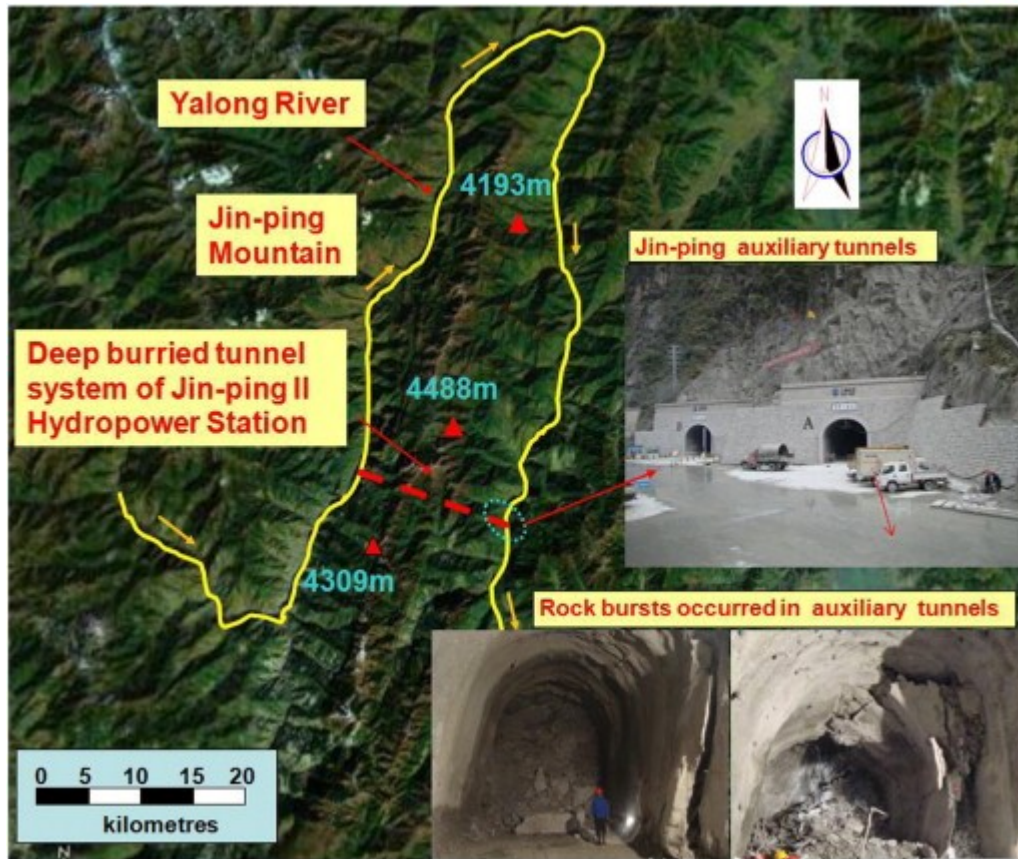
Permutation group

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321	321	213	132	231	312	e

- Don't need all elements to traverse group
 - Only need identity, permutation (231), swap (213)
 - “Generators”
 - Elements e, p, pp, s, sp, spp
 - Inverses: ppp = ss = e

Rockbursts

Jin-ping II Auxiliary Tunnels, 2015
(near China Jinping Underground Lab)

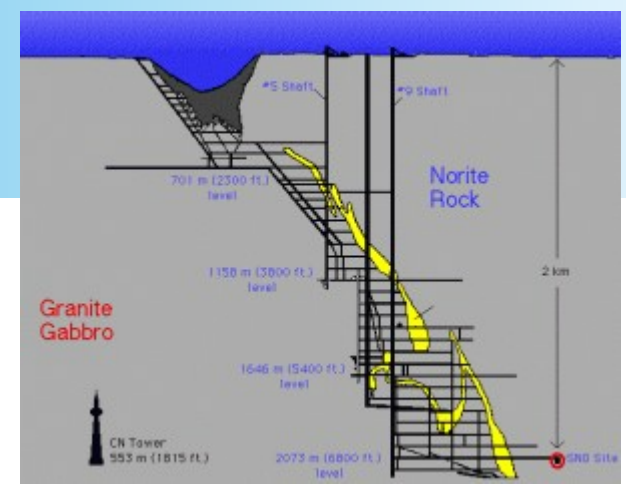


(a) Intensive rock burst of AK9+665-673m

(b) Intensive rock burst of AK9+685-690m

“Mitigation of rock burst events by blasting techniques during deep-tunnel excavation”,
P Yan et al., *Eng Geol*, 188 (2015), 126

Research underground



Surface facilities at Creighton Mine

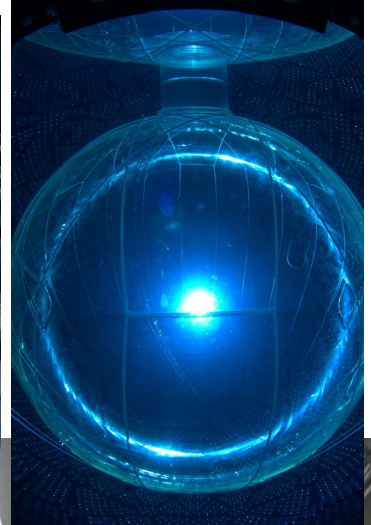
2 km

SNOLAB – Underground Laboratory

Tunnel

Photo by Rare

This block contains a 3D rendering of the surface facilities at the Creighton Mine, a vertical double-headed arrow indicating a 2 km depth, a schematic diagram of the SNOLAB underground laboratory layout, and a photograph of a tunnel interior with workers. The text 'Surface facilities at Creighton Mine' is at the top, '2 km' is in the middle, 'SNOLAB – Underground Laboratory' is on the left, 'Tunnel' is at the bottom left, and 'Photo by Rare' is at the bottom right.



SNO+



SNO+
August 9, 2022



Spherical harmonics

