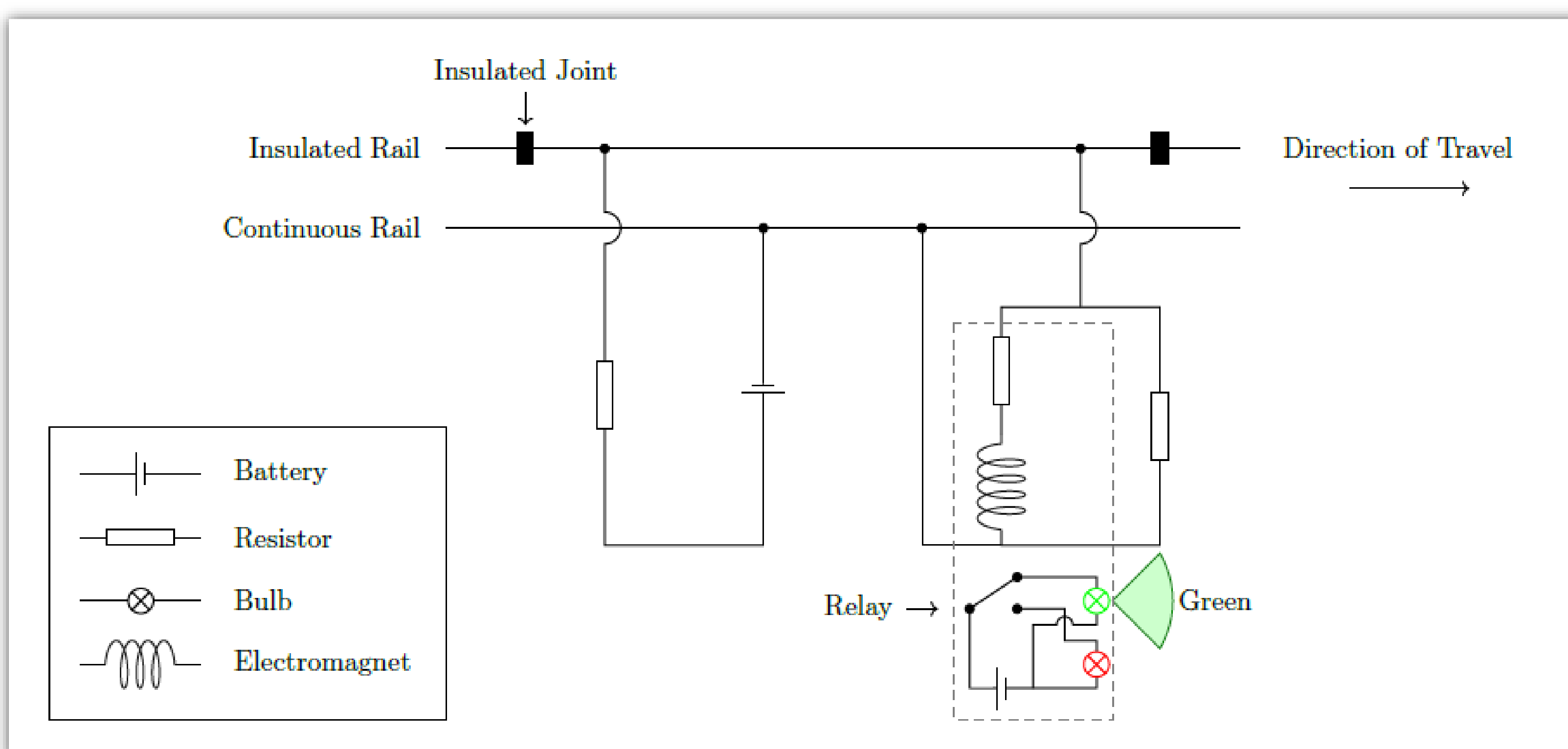


Space Weather Can Delay Your Trains

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1. Space weather impacts on railways

- **Signalling failures**
- Damage to locomotive on-board transformers
- Interference with GNSS and communications
- Interruption to power supply systems
- Potential hazard to track-side workers



2. Railway signalling

One of the most common signalling systems relies on **track circuits**, electrical circuits that detect the presence or absence of a train by the energising and de-energising of a relay.

- The train line is split into **blocks**, each one containing a power supply and a relay that controls red and green signal lamps
- In the **absence** of a train, the power supply keeps the relay **energised**, magnetically pulling the switch to the **green** position
- In the **presence** of a train, the power supply is short circuited, the relay becomes **de-energised**, dropping the switch to the **red** position
- As such, when external current sources such as **GICs** are introduced to the system, they can affect the balance of the system, leading to **false signals**.

3. Modelling the effects of GICs on track circuits

Using techniques developed by Boteler (2021), the impacts of GICs on a system of track circuits can be analysed.

What we need:

- Realistic track geometry and block lengths
- Electrical characteristics of the rail and infrastructure
- Localised geomagnetic and geoelectric field values

4. Results

Currently two sections of track are being studied, chosen for their differing underlying geological terrane and orientation. The results for the Preston to Lancaster section are shown here.

- Assuming the field is uniform across the area of the section and given the track's north-south orientation, electric field values of 2, 4, -2 and -4 V/km with geographic north direction (E_x) are applied
- For $E_x = 2, 4$ and -2 V/km, the GICs induced in the track circuits are **not strong enough** to cause signalling failures
- When $E_x = -4$ V/km, the GICs induced in the track circuits are sufficiently strong to cause several of the relays to be de-energised, thus displaying a false signal

The opposite effect is also possible, where a relay de-energised by a train could be re-energised by GICs, indicating a section is clear when it is occupied, in the worst case scenario this could lead to a collision.

