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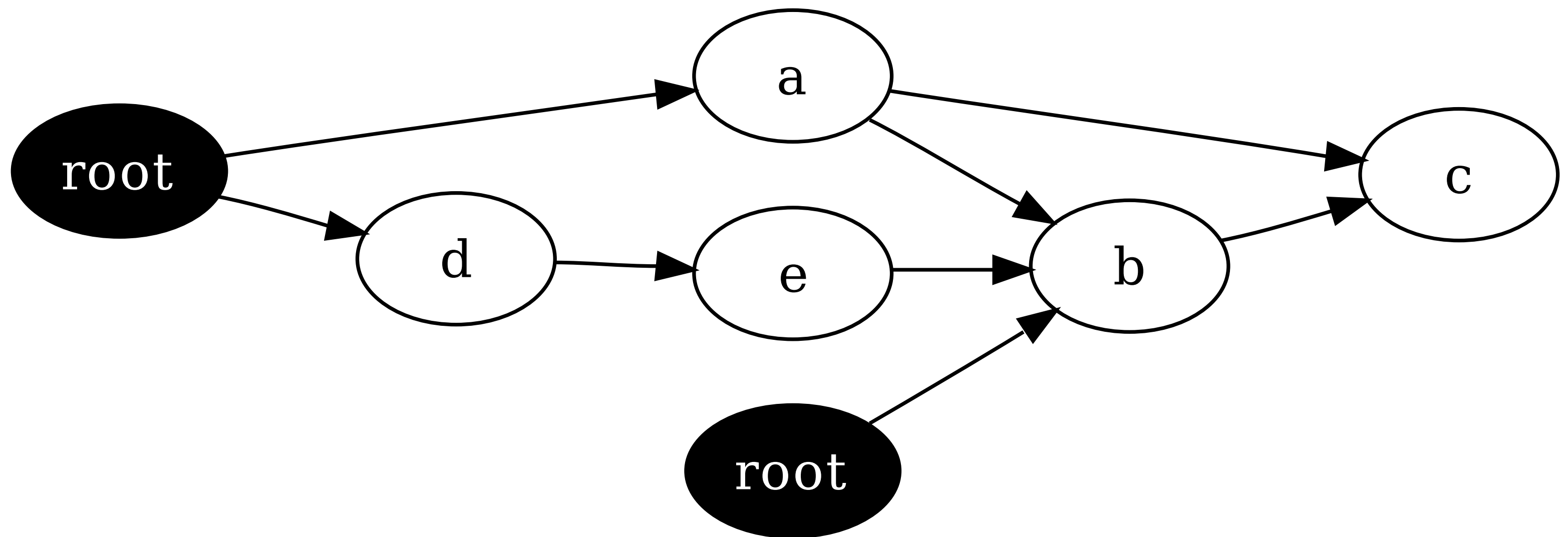
The Ghost in the Virtual Machine A Reference to References

Bob Lee
Google Inc.

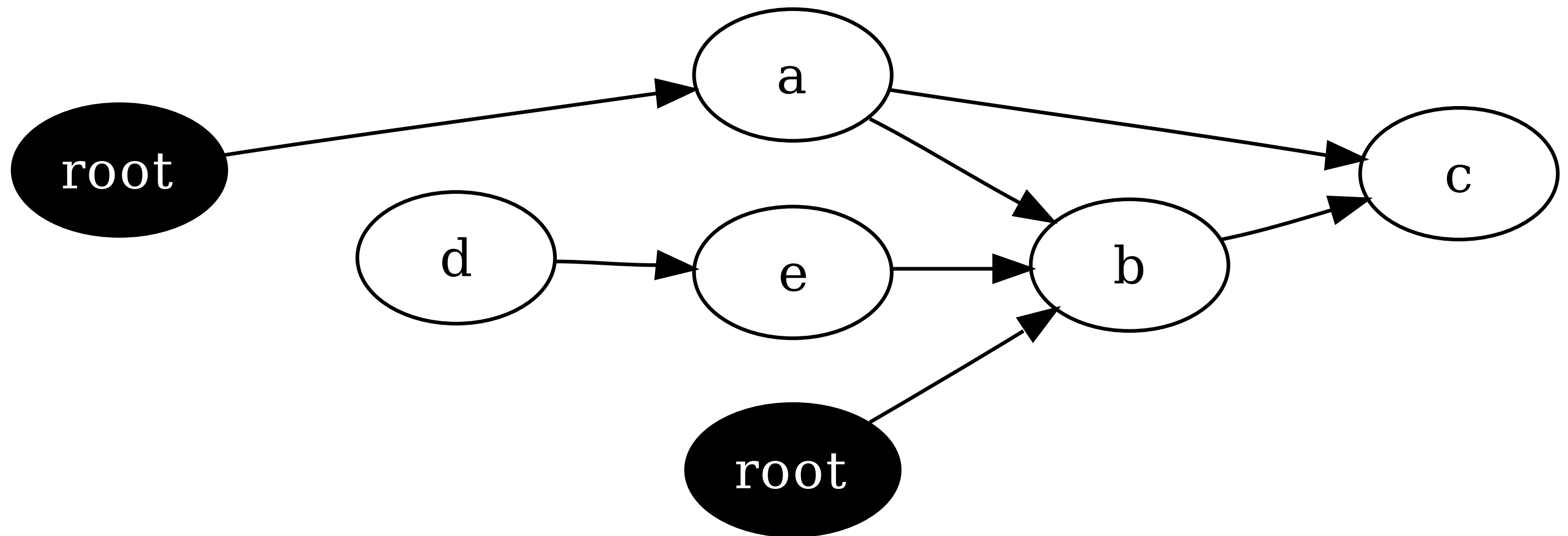
Goals

- > Take the mystery out of garbage collection.
- > Perform manual cleanup the Right way.
- > Become honorary VM sanitation engineers.

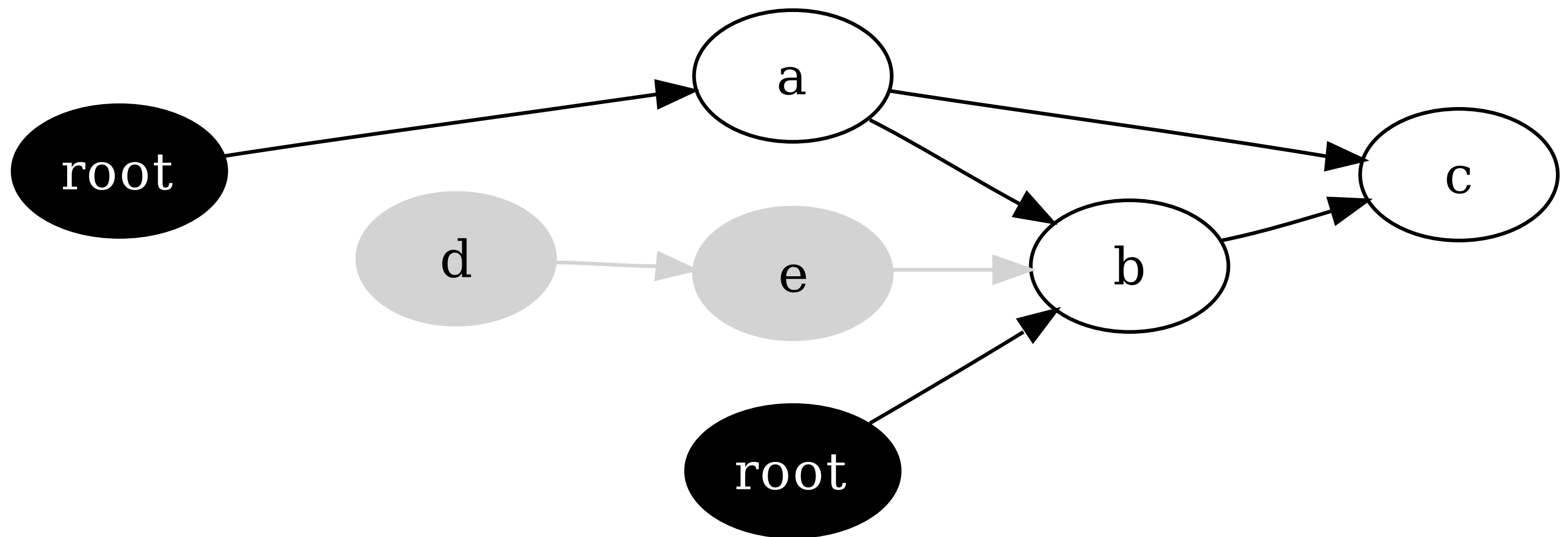
How does garbage collection work?



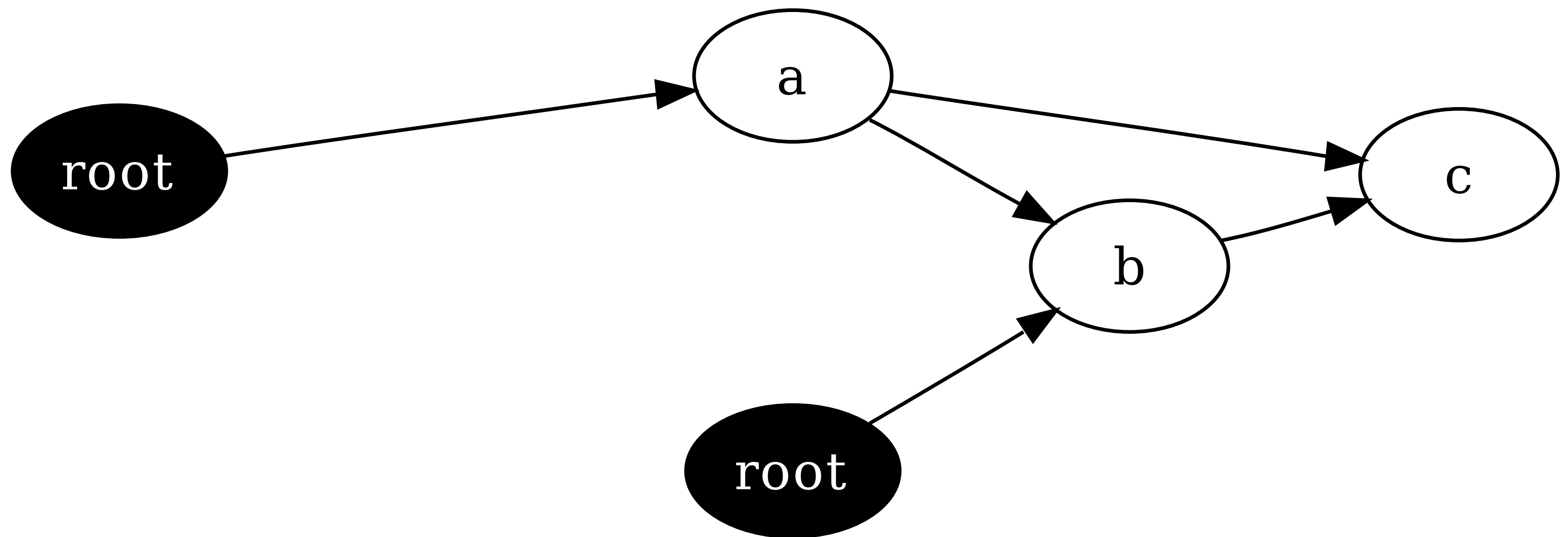
If the reference to D goes away...



We can no longer reach D or E.



So the collector reclaims them.



The GC can't do everything.

- > Some things require manual cleanup.
 - Listeners
 - File descriptors
 - Native memory
 - External state (`IdentityHashMap`)
- > Tools at your disposal:
 - `finally`
 - Overriding `Object.finalize()`
 - Reference queues

Try `finally` first.

- > Reasons to not use `finally`:
 - More work for programmers
 - More error prone
 - Cleanup happens in main thread

What is a finalizer?

```
public class Foo extends Bar {  
    @Override protected void finalize() throws Throwable {  
        try {  
            ... // Clean up Foo.  
        } finally {  
            super.finalize(); // Clean up Bar.  
        }  
    }  
}
```

Finalizers are seductively simple, but...

- > Not guaranteed to run, especially not timely
- > `System.runFinalizersOnExit()` is deprecated for similar reasons as `Thread.stop()`
- > Undefined threading model, can run concurrently!
- > You must call `super.finalize()`.
- > Exceptions are ignored (per spec)
- > You can resurrect references.
- > Keeps objects alive.
- > Can make allocation/reclamation 430X slower (Block, Effective Java)

An external resource

```
public class NativeResource {  
    public NativeResource() { init(); }  
  
    /** Allocates native memory. */  
    private native void init();  
  
    /** Writes to native memory. */  
    public native void write(byte[] data);  
  
    /** Frees native memory. */  
    @Override protected native void finalize();  
}
```

Let's play War!

SegfaultFactory can cause a segfault if its finalizer executes after NativeResource's.

```
public class SegfaultFactory {  
    private final NativeResource nr;  
    public SegfaultFactory(NativeResource nr) {  
        this.nr = nr;  
    }  
  
    @Override protected void finalize() {  
        // 50/50 chance of failure  
        nr.write("I'm taking the VM with me!".getBytes());  
    }  
}
```



Use protection.

Extend `NativeResource` and make it safe.

```
public class SafeNativeResource extends NativeResource {  
    private boolean finalized;  
  
    @Override public synchronized void write(byte[] data) {  
        if (!finalized) super.write(data);  
        else /* do nothing? */;  
    }  
  
    @Override protected synchronized void finalize() {  
        finalized = true;  
        super.finalize();  
    }  
}
```

Reachability

- > An object is *reachable* if a live thread can access it.
- > Examples of heap roots:
 - System classes (which have static fields)
 - Thread stacks
 - In-flight exceptions
 - JNI global references
 - The finalizer queue
 - The interned String pool
 - etc. (VM-dependent)

Dante's Heap - The Levels of Reachability

- > Strong
- > Soft
- > Weak
- > Finalizer
- > Phantom, JNI weak
- > Unreachable

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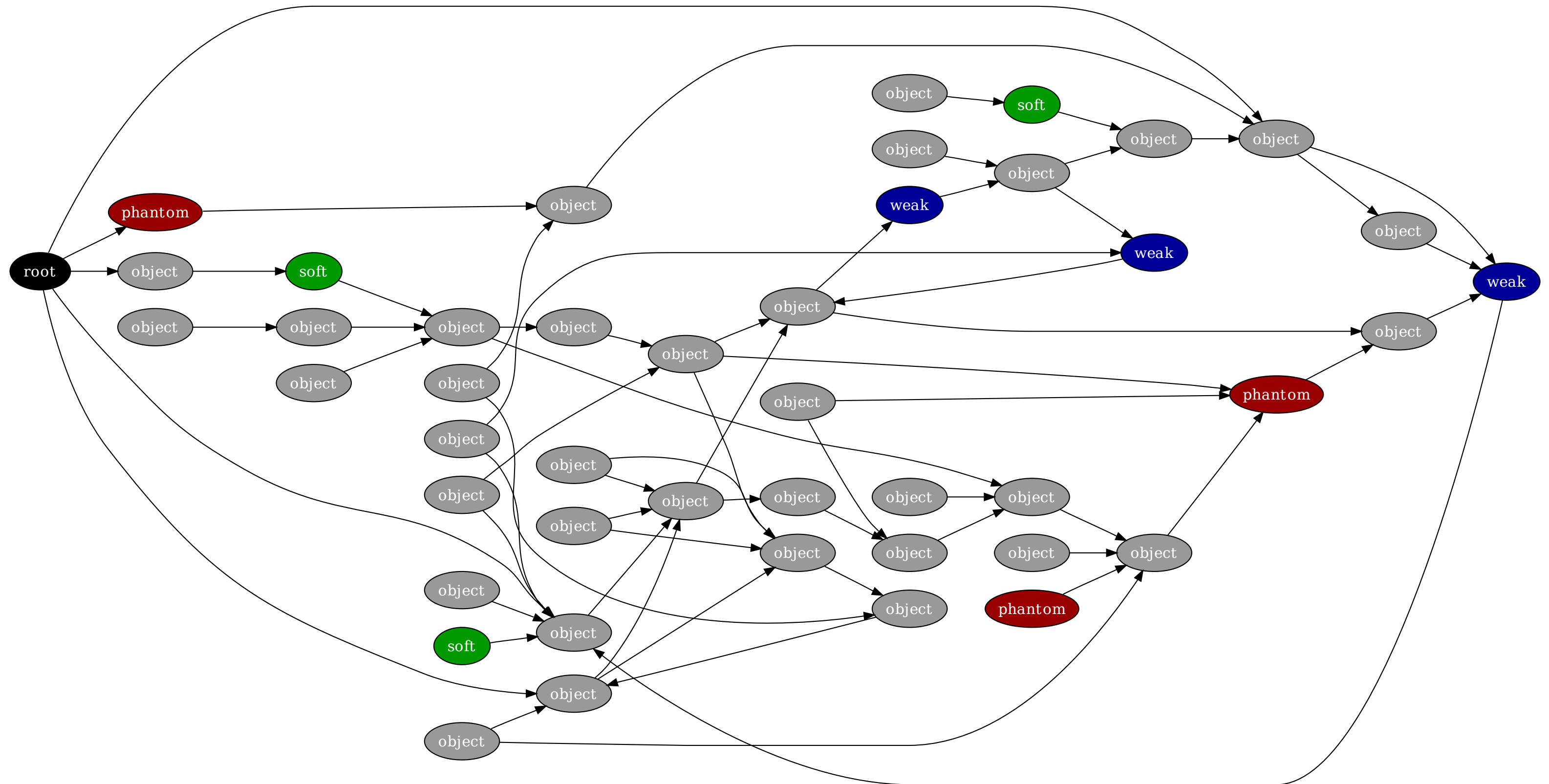
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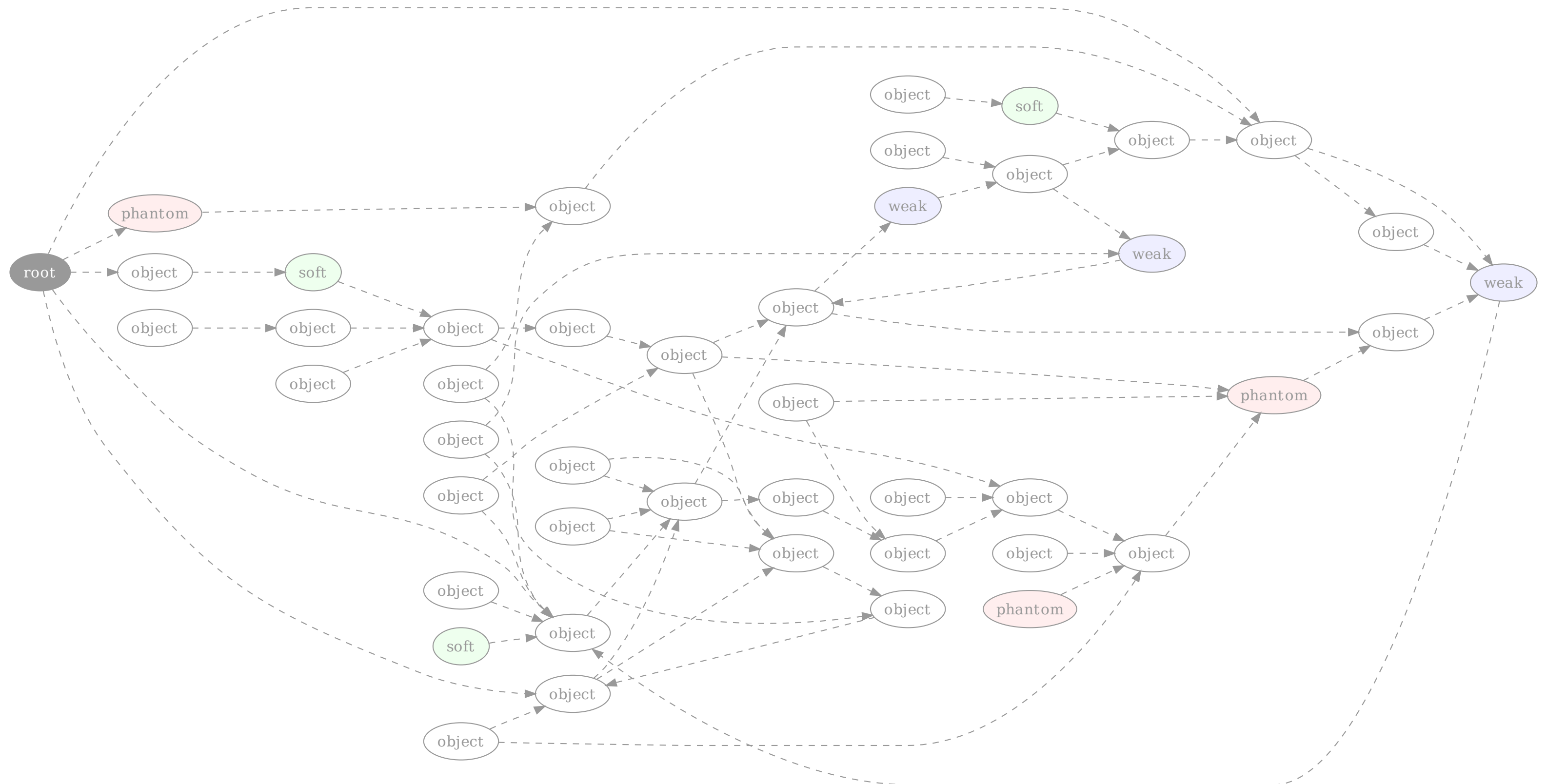
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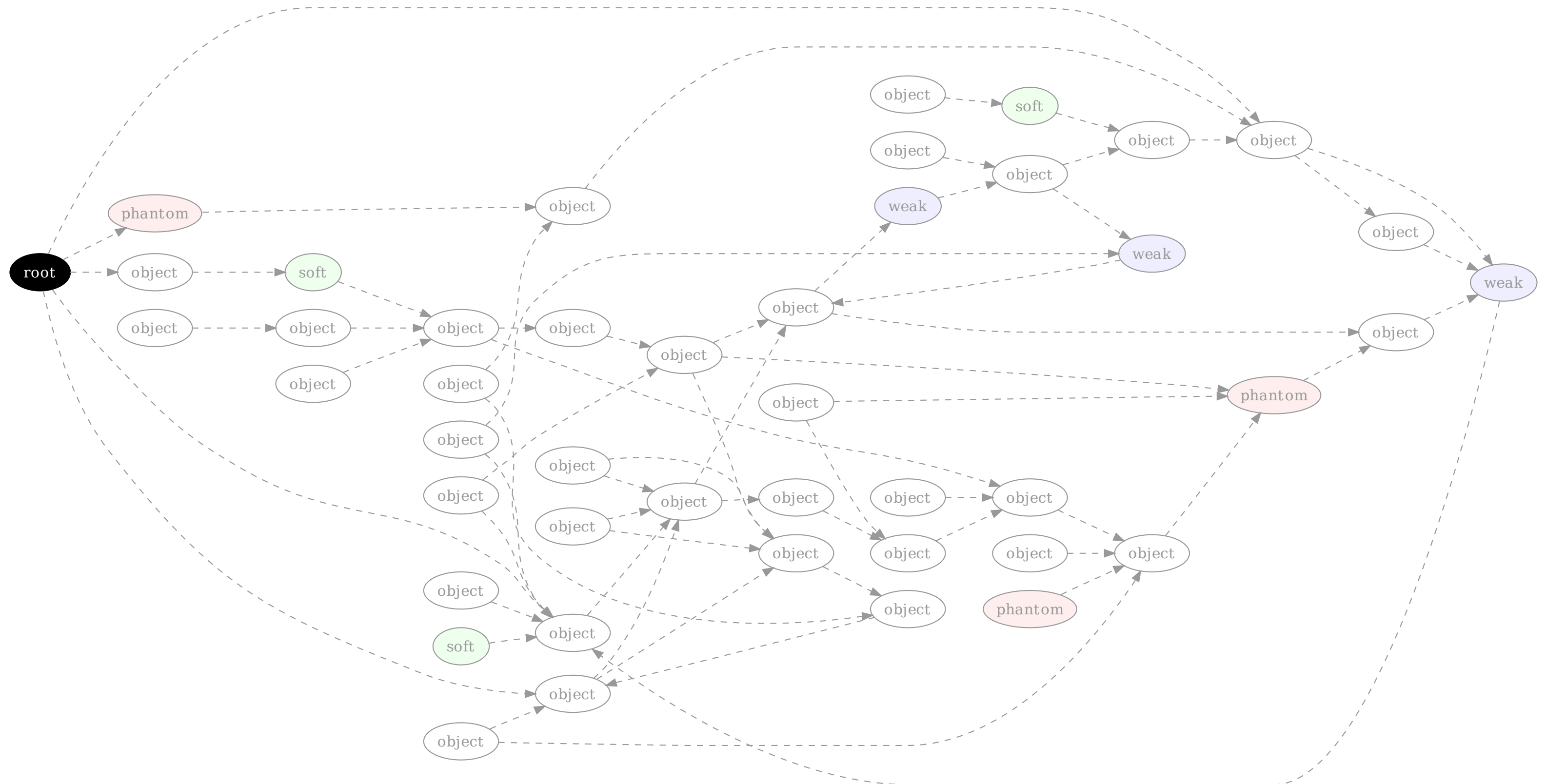
Let's mark and sweep a heap!



No objects are marked at first.



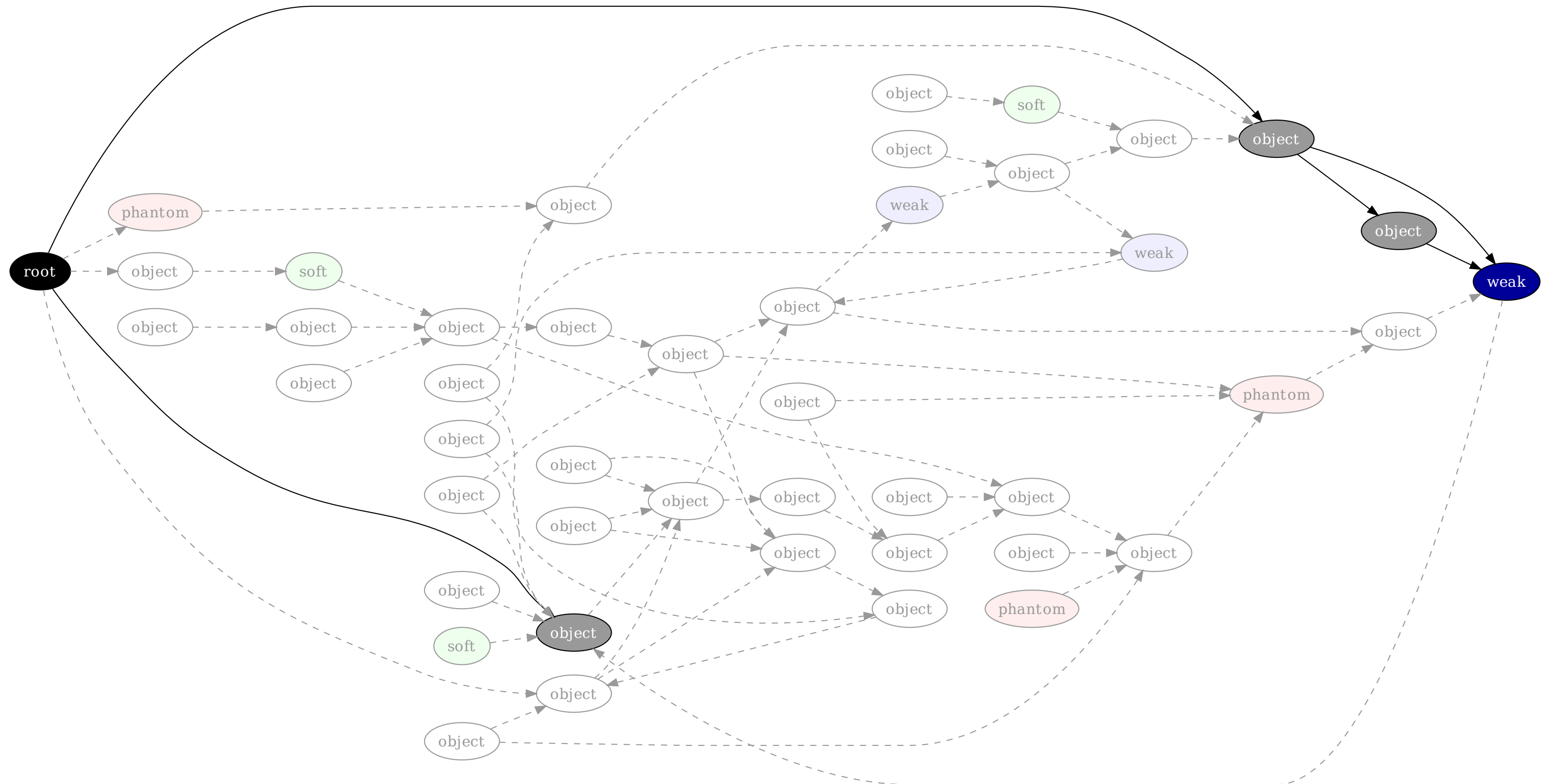
1. Start at a root.



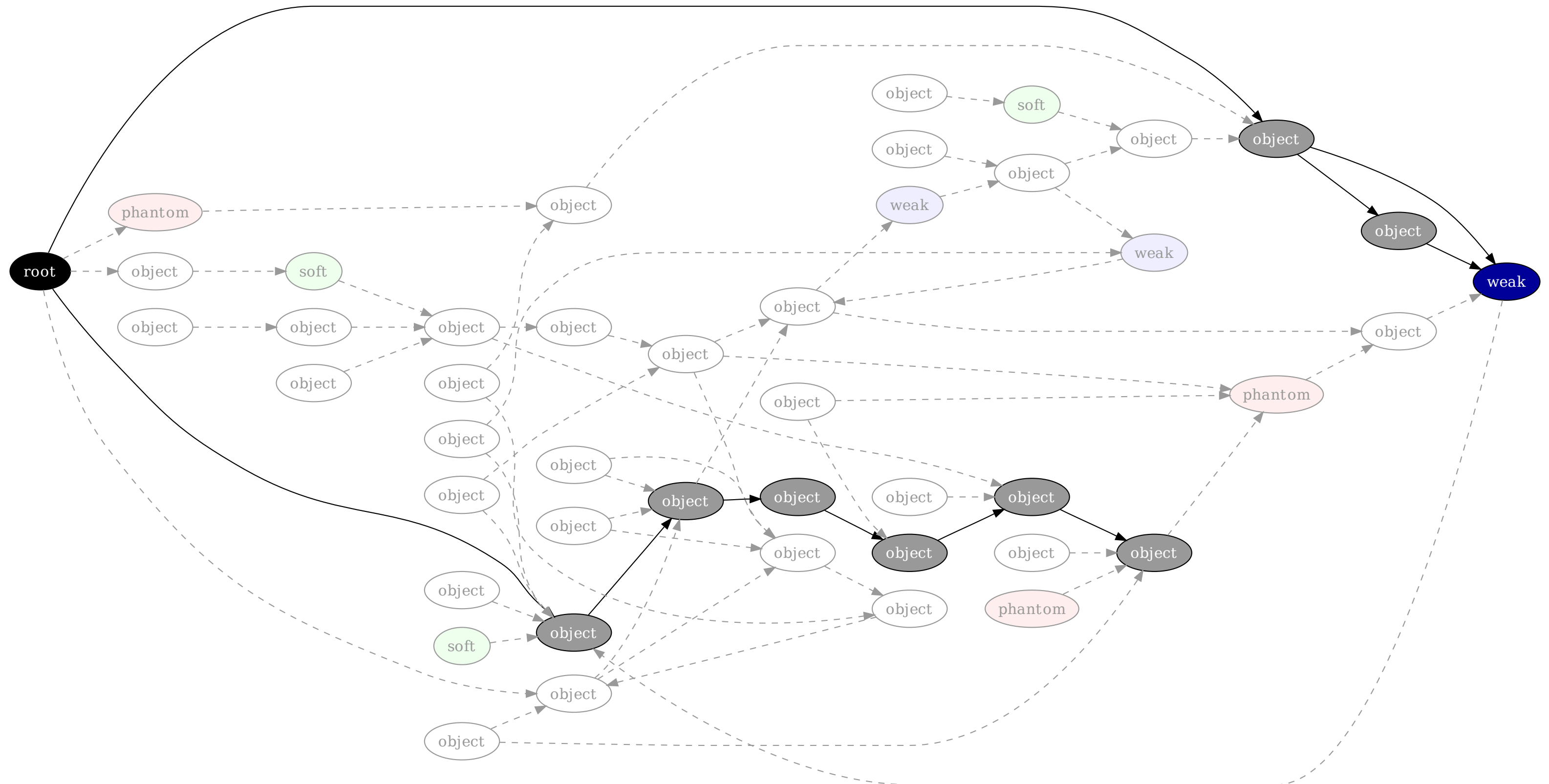
2. Trace and mark strongly-referenced objects.



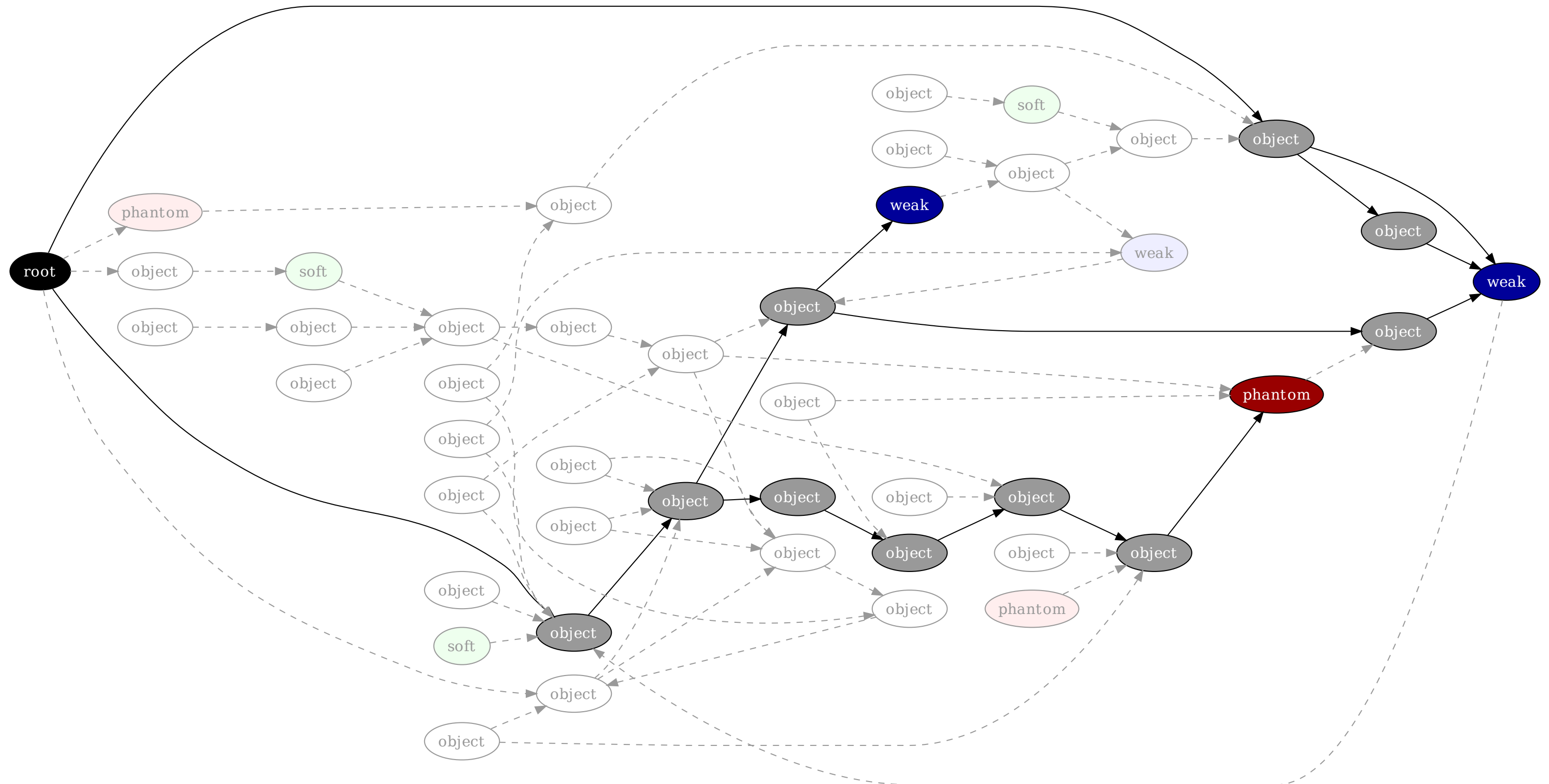
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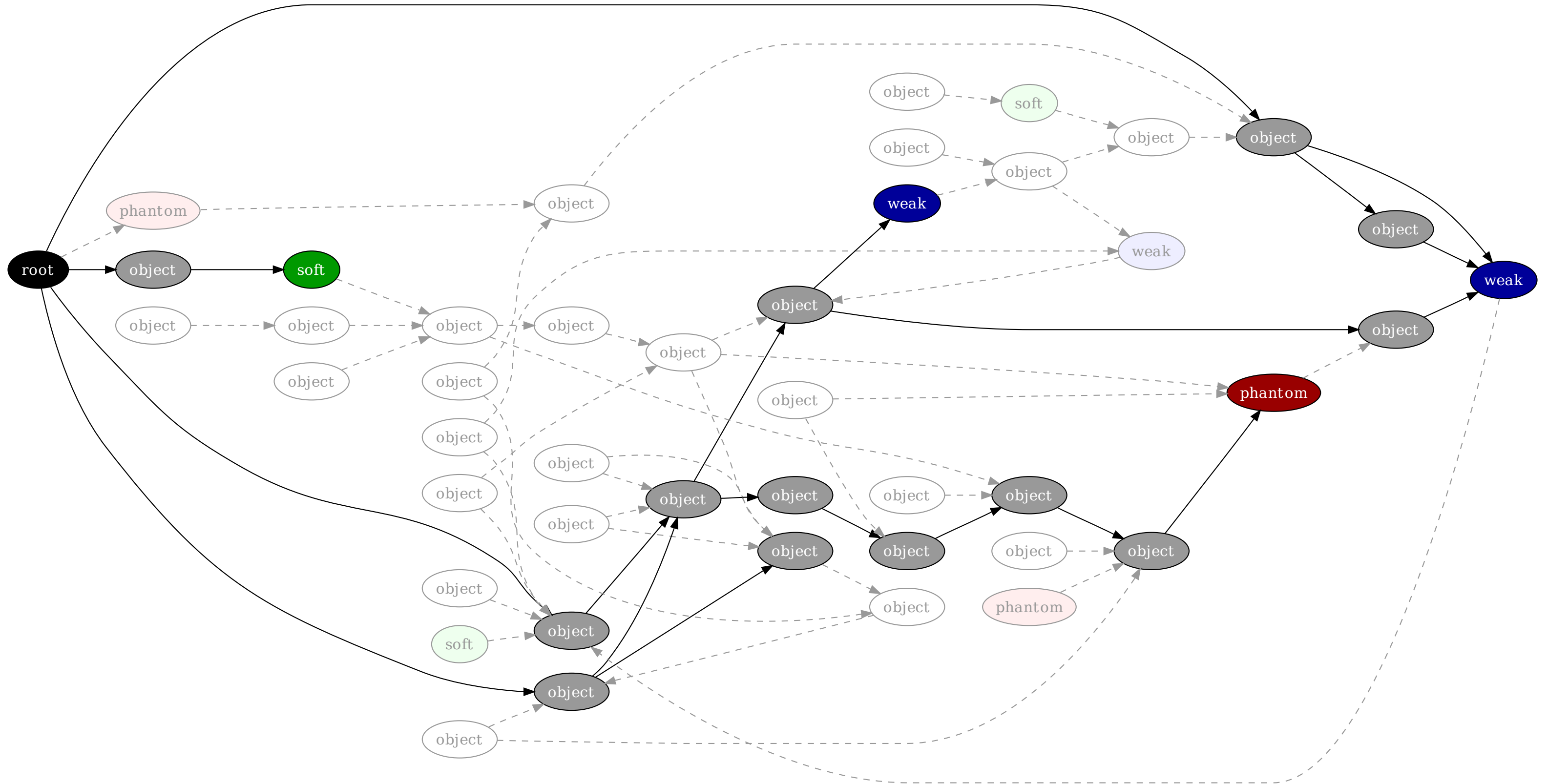
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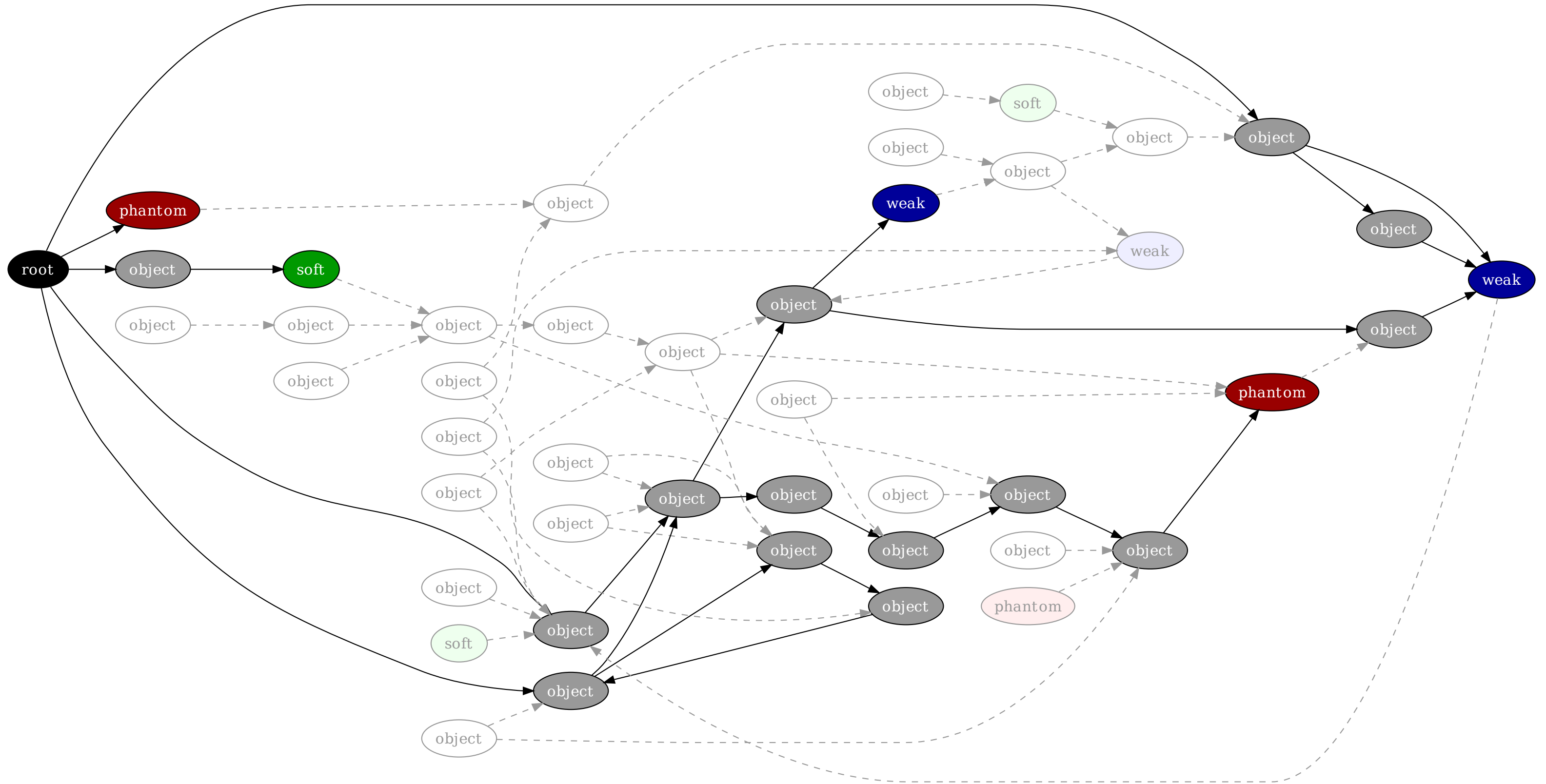
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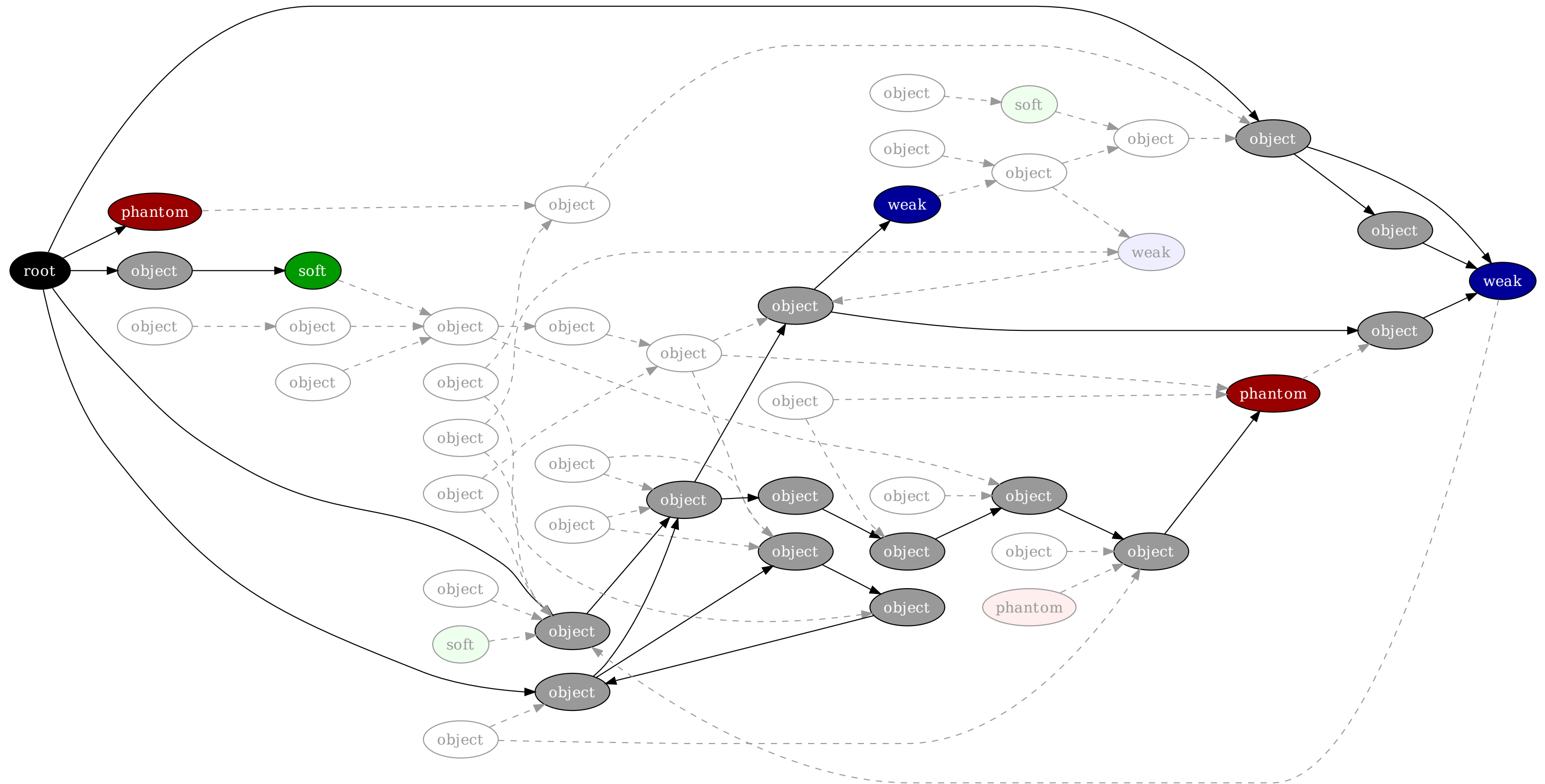
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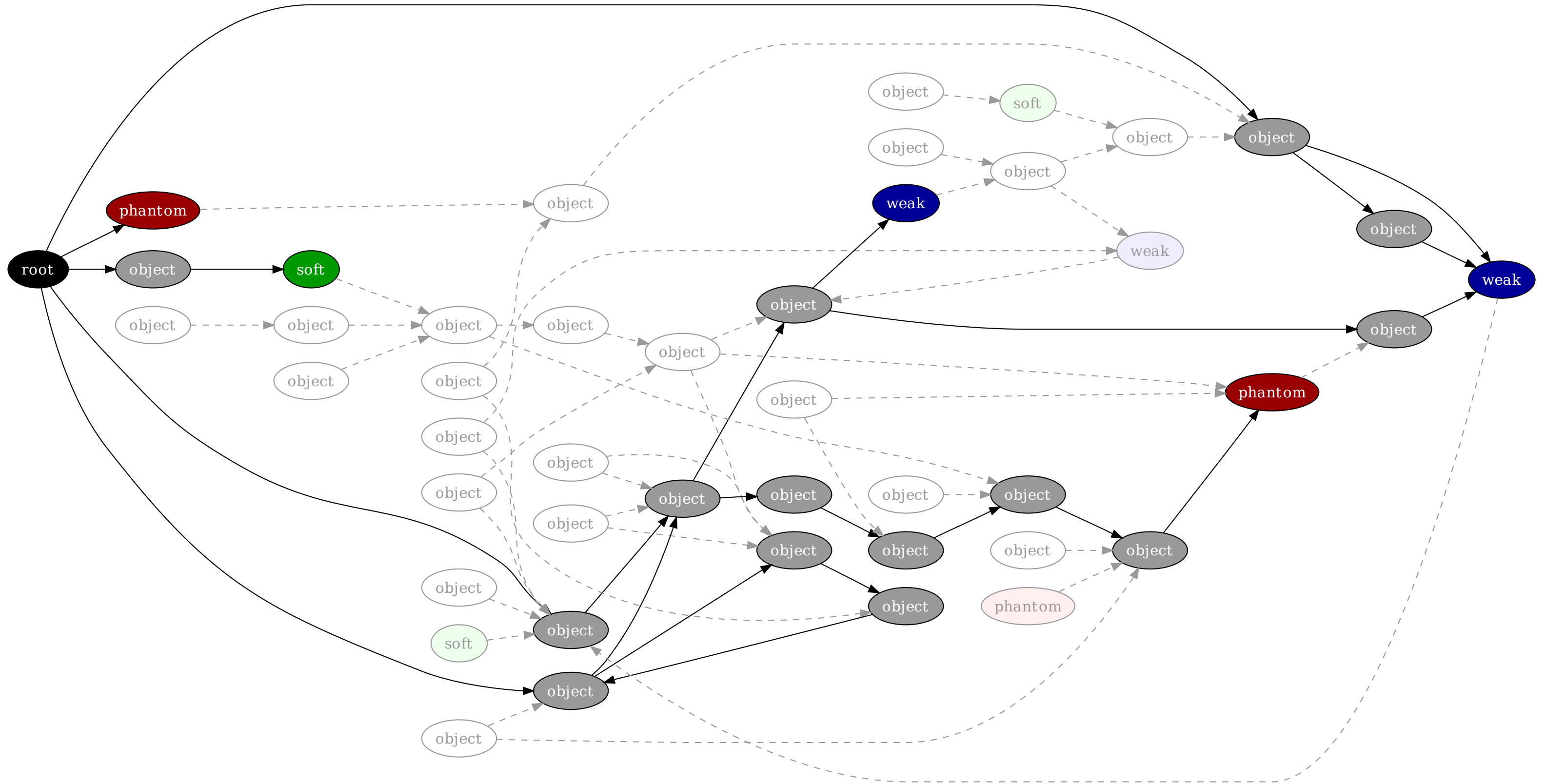
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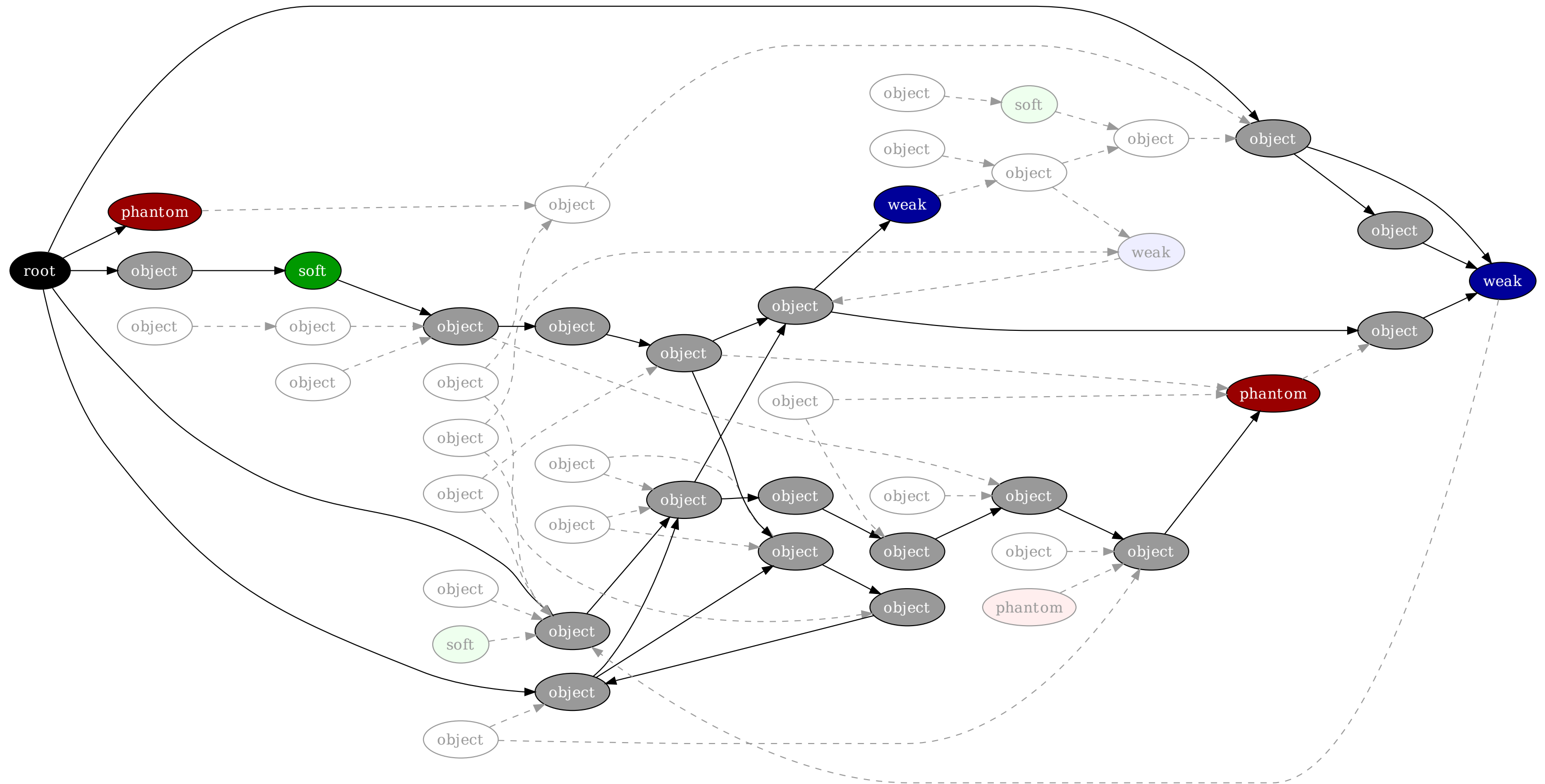
3. Optionally clear soft references.



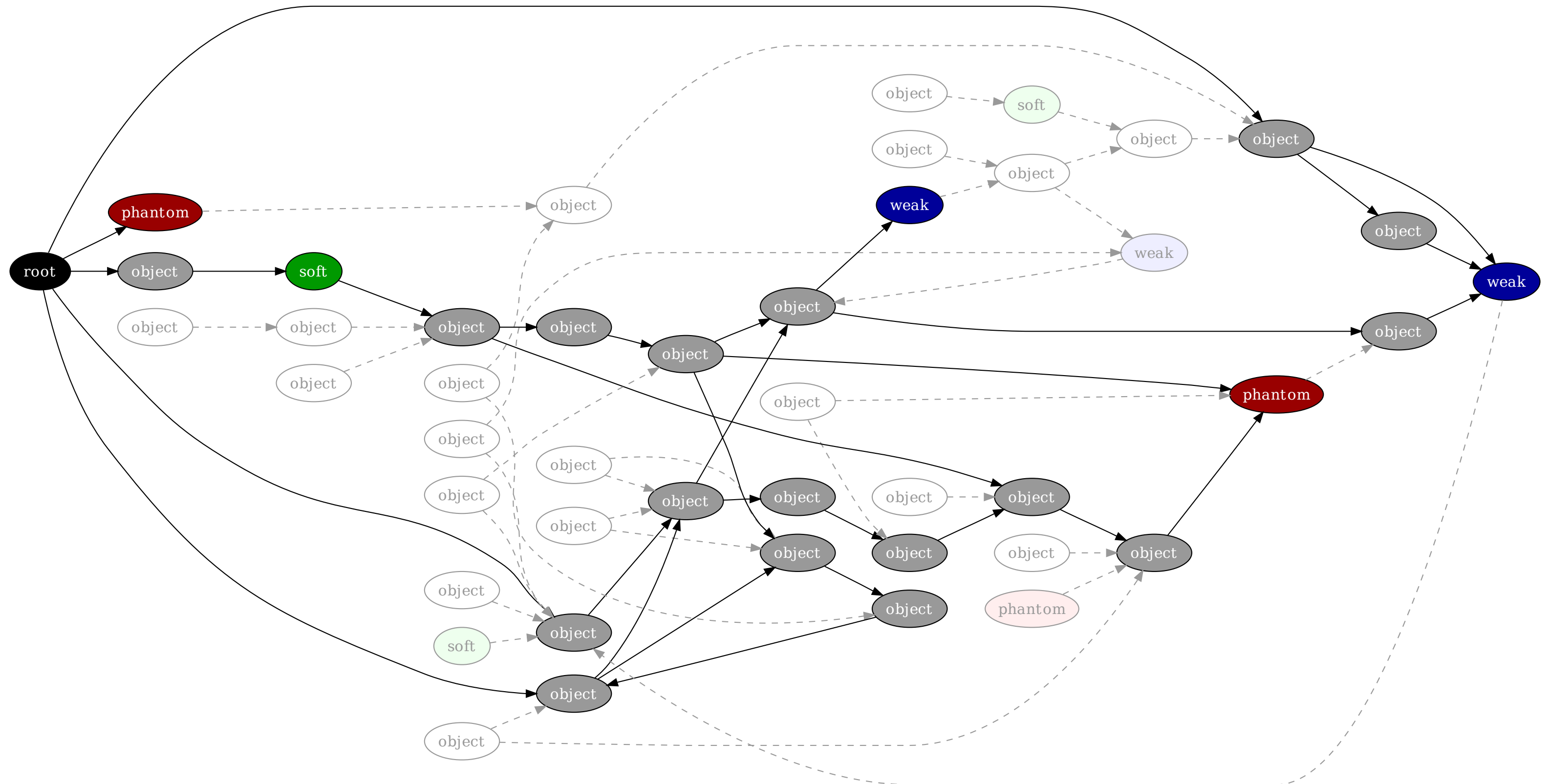
4. Trace and mark softly-referenced objects.



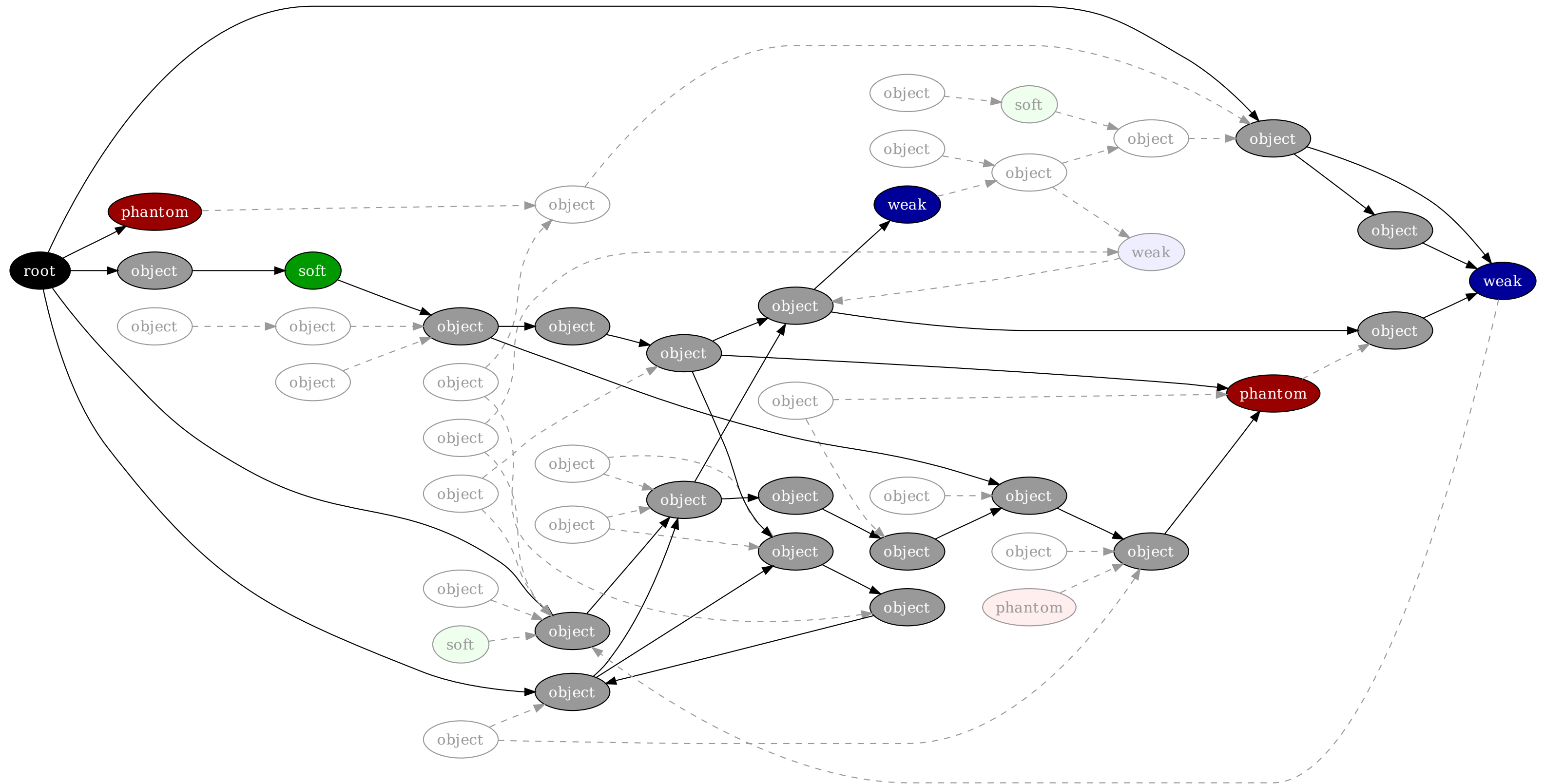
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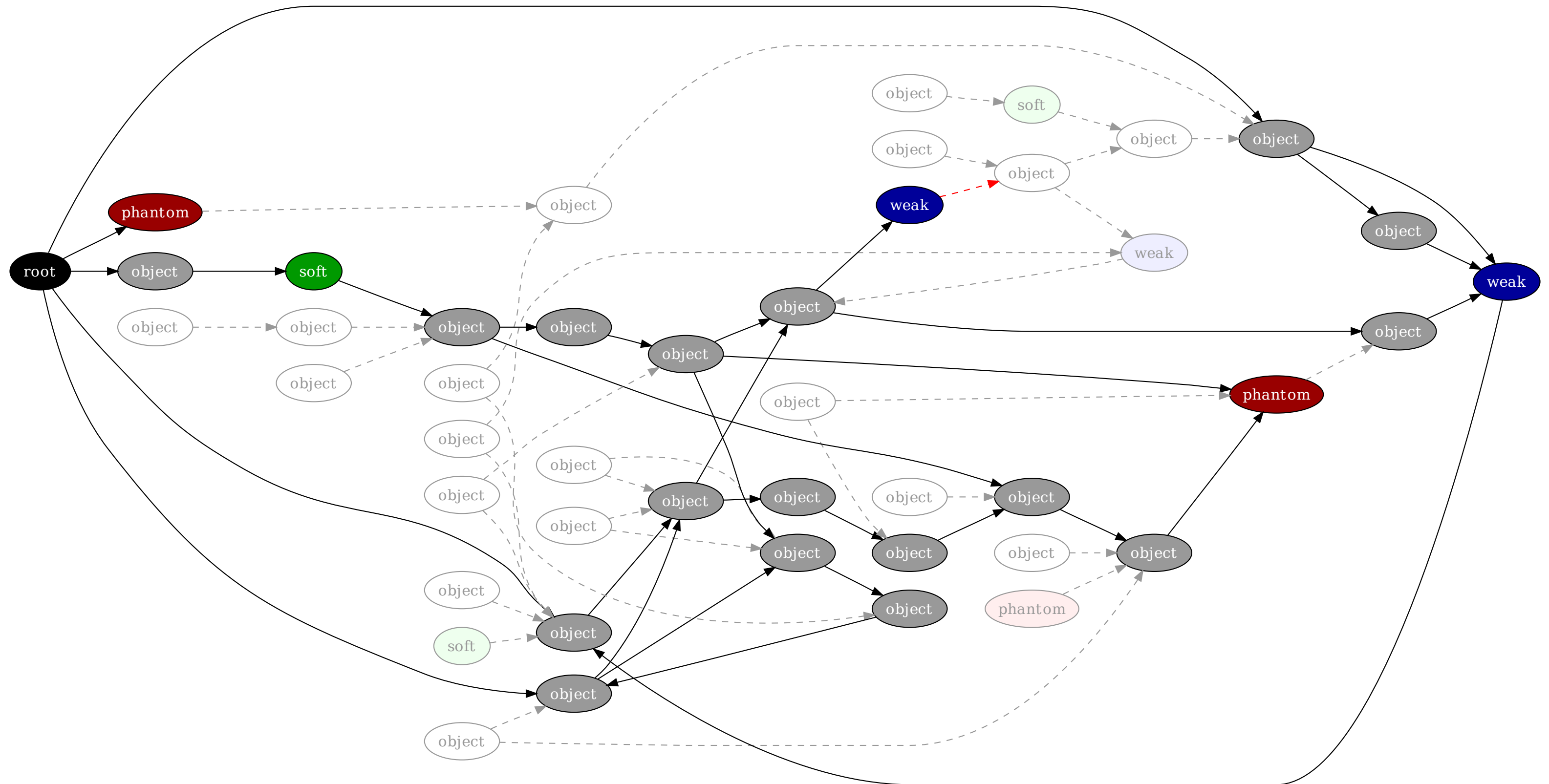
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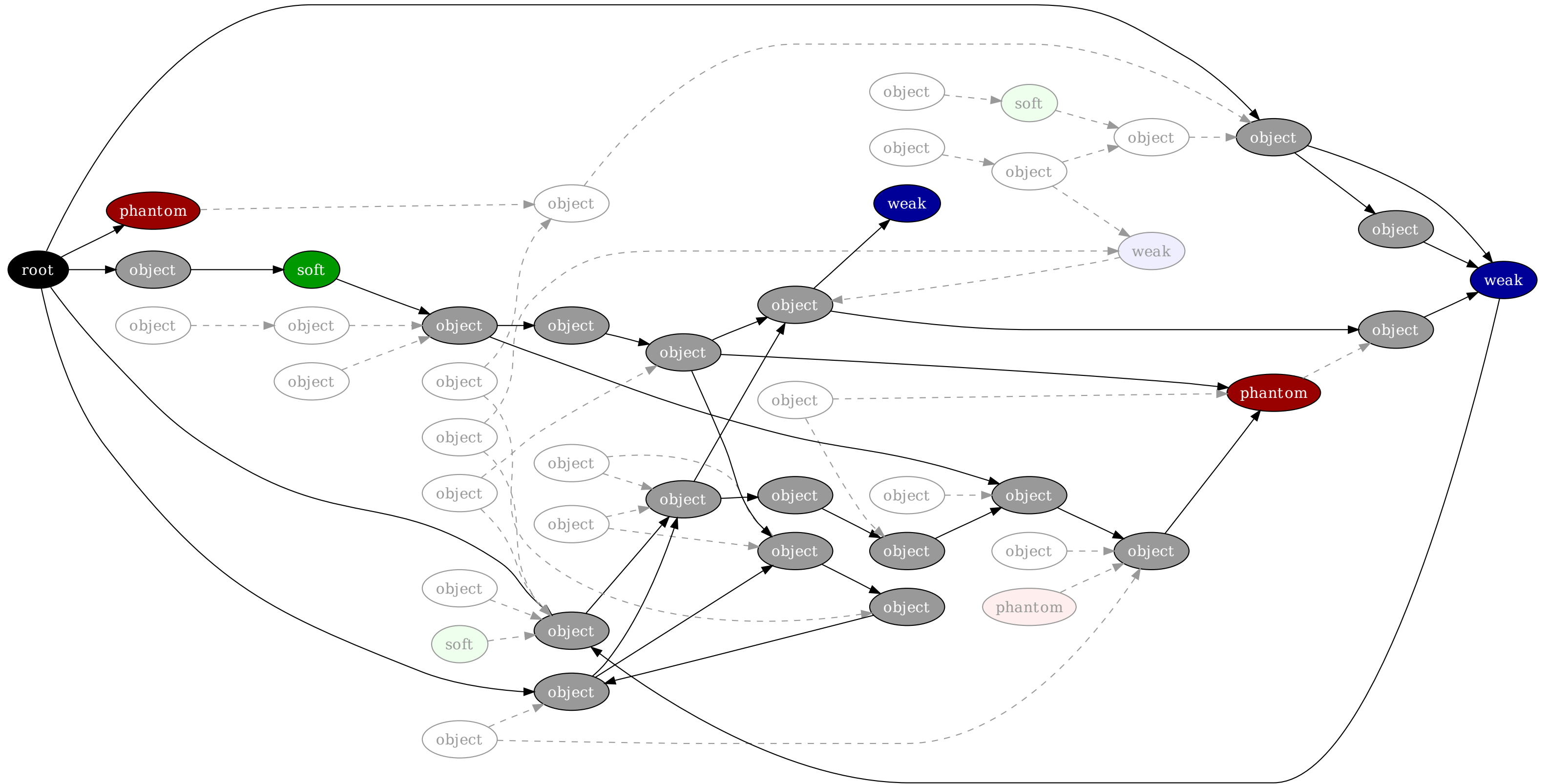
5. Clear weak references.



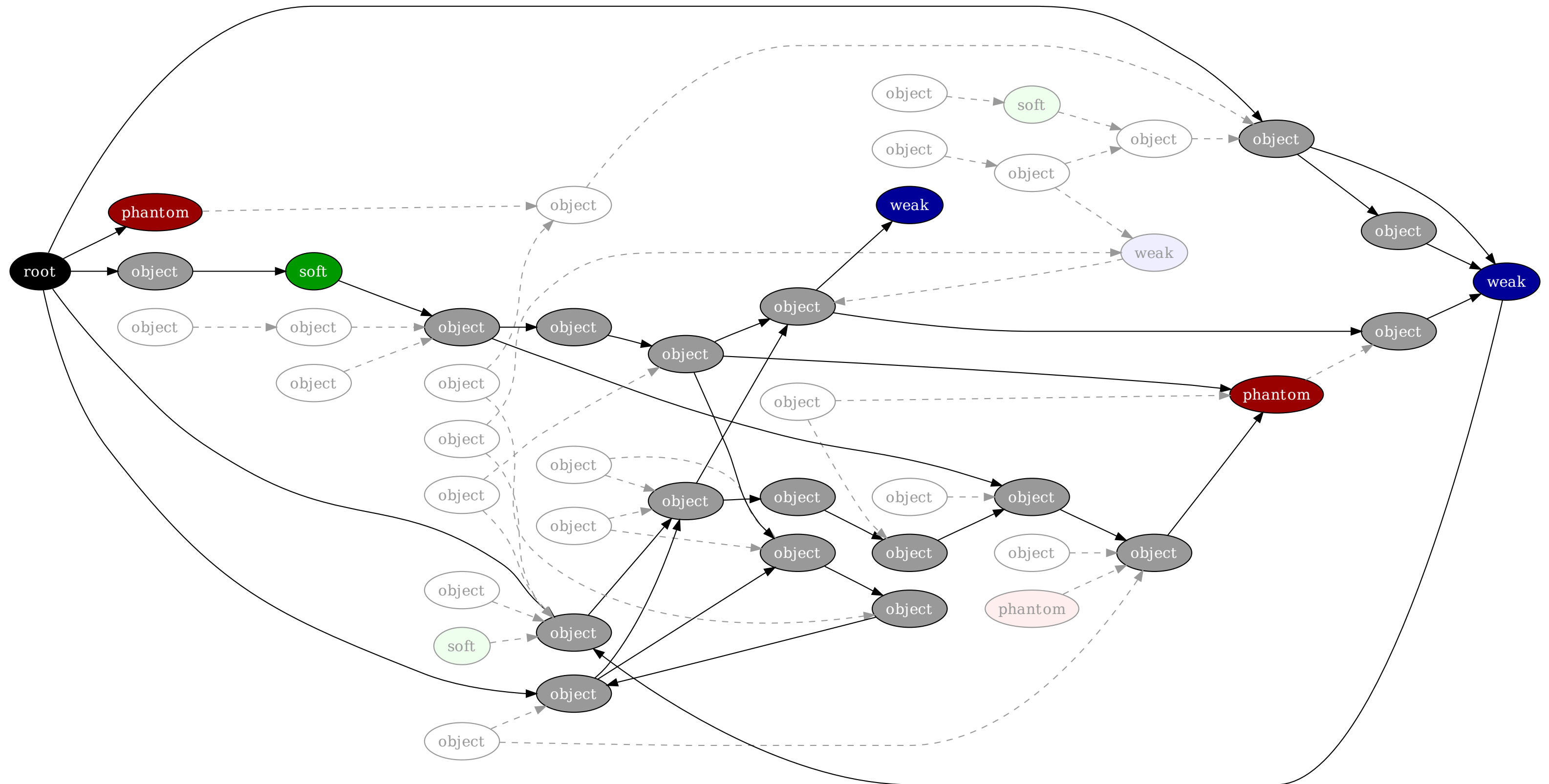
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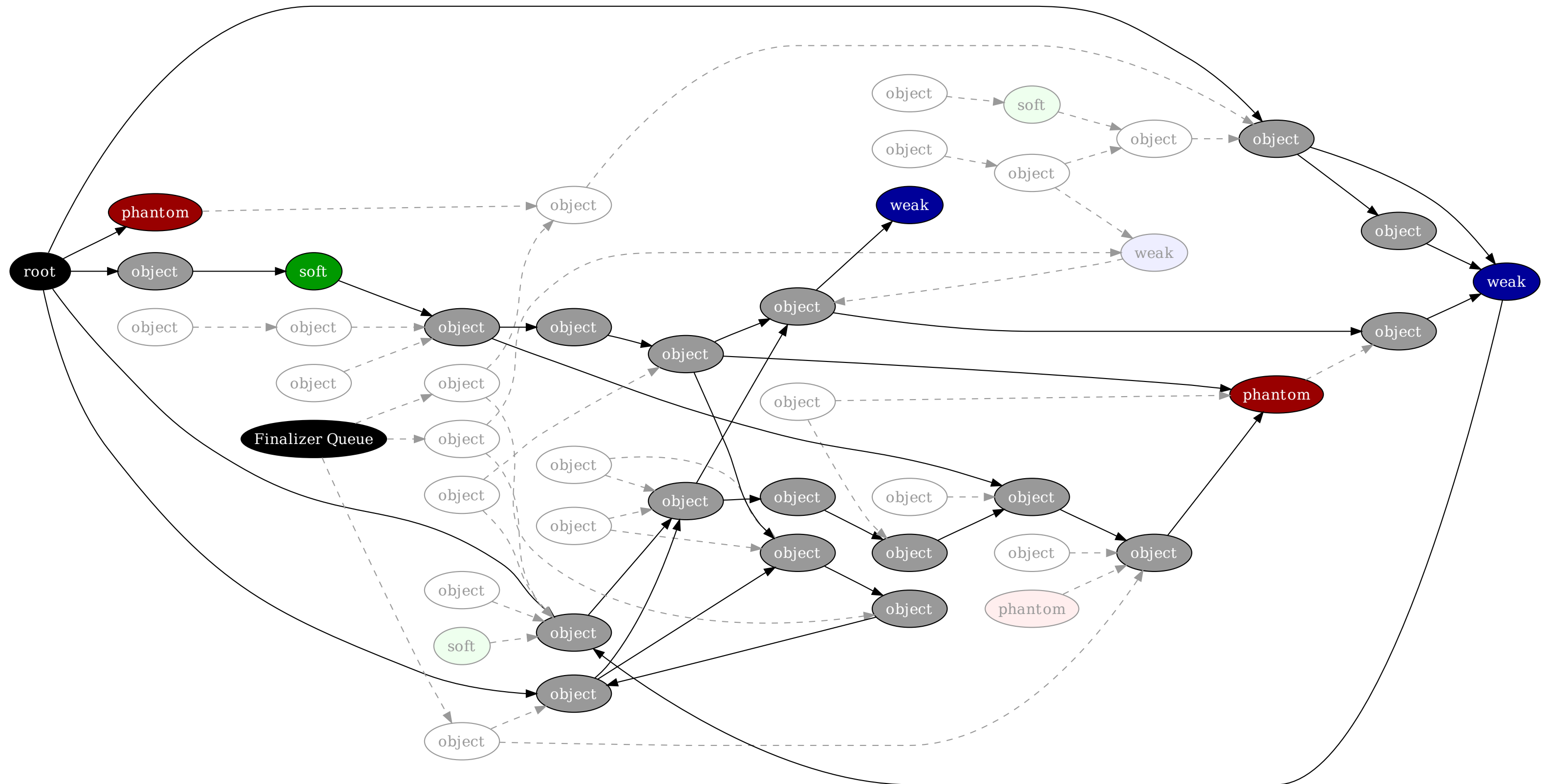
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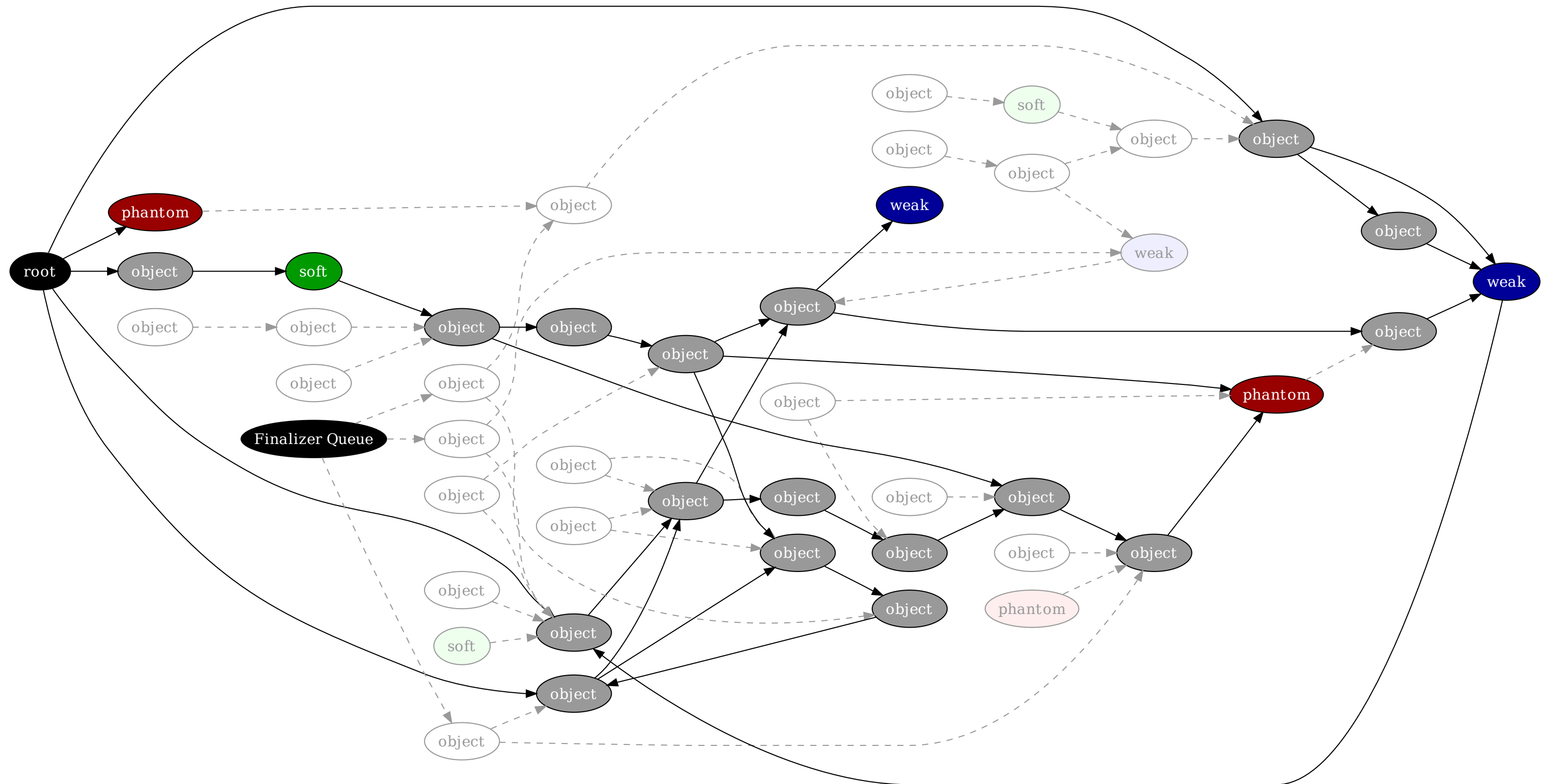
6. Enqueue finalizable objects.



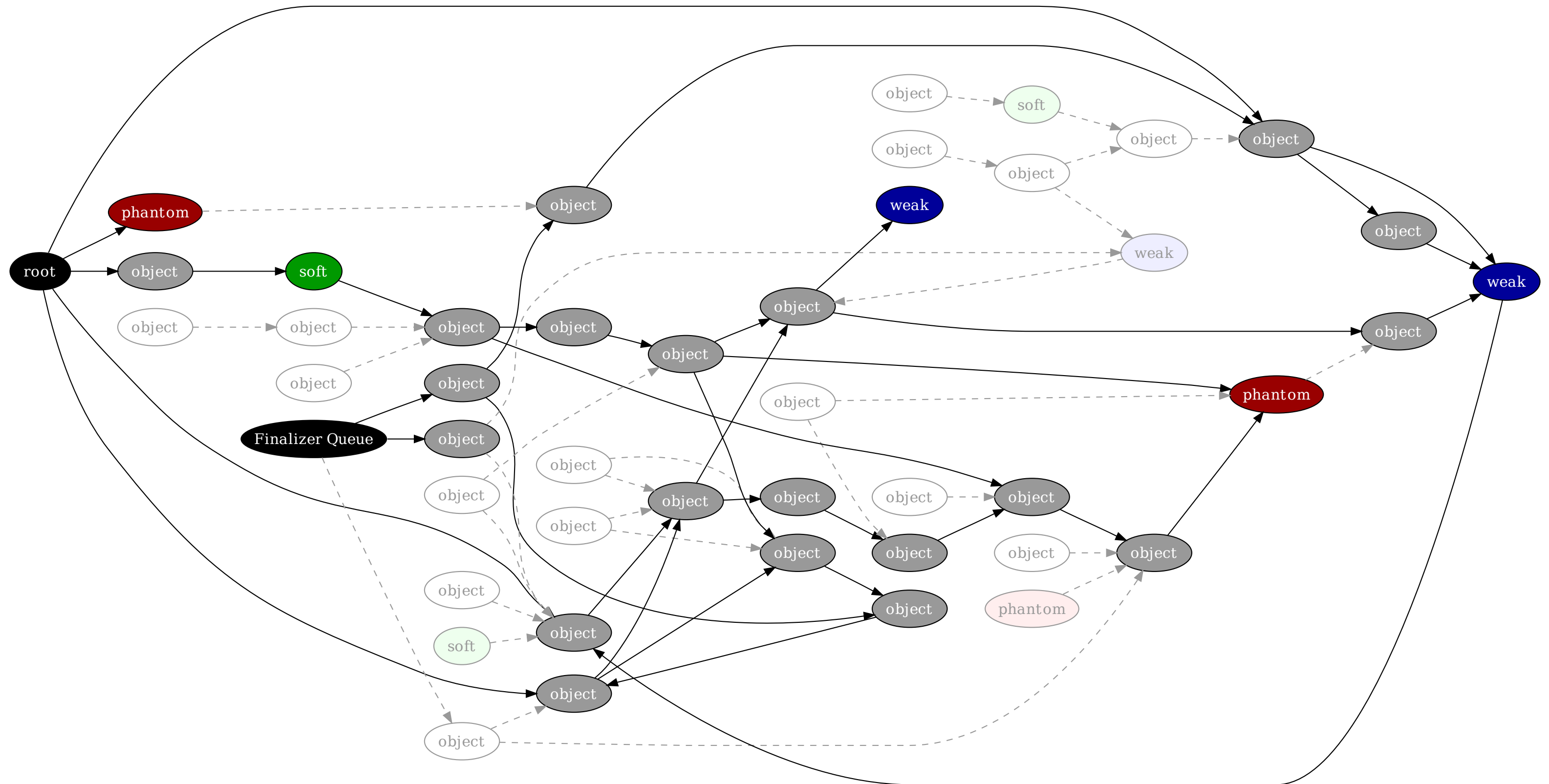
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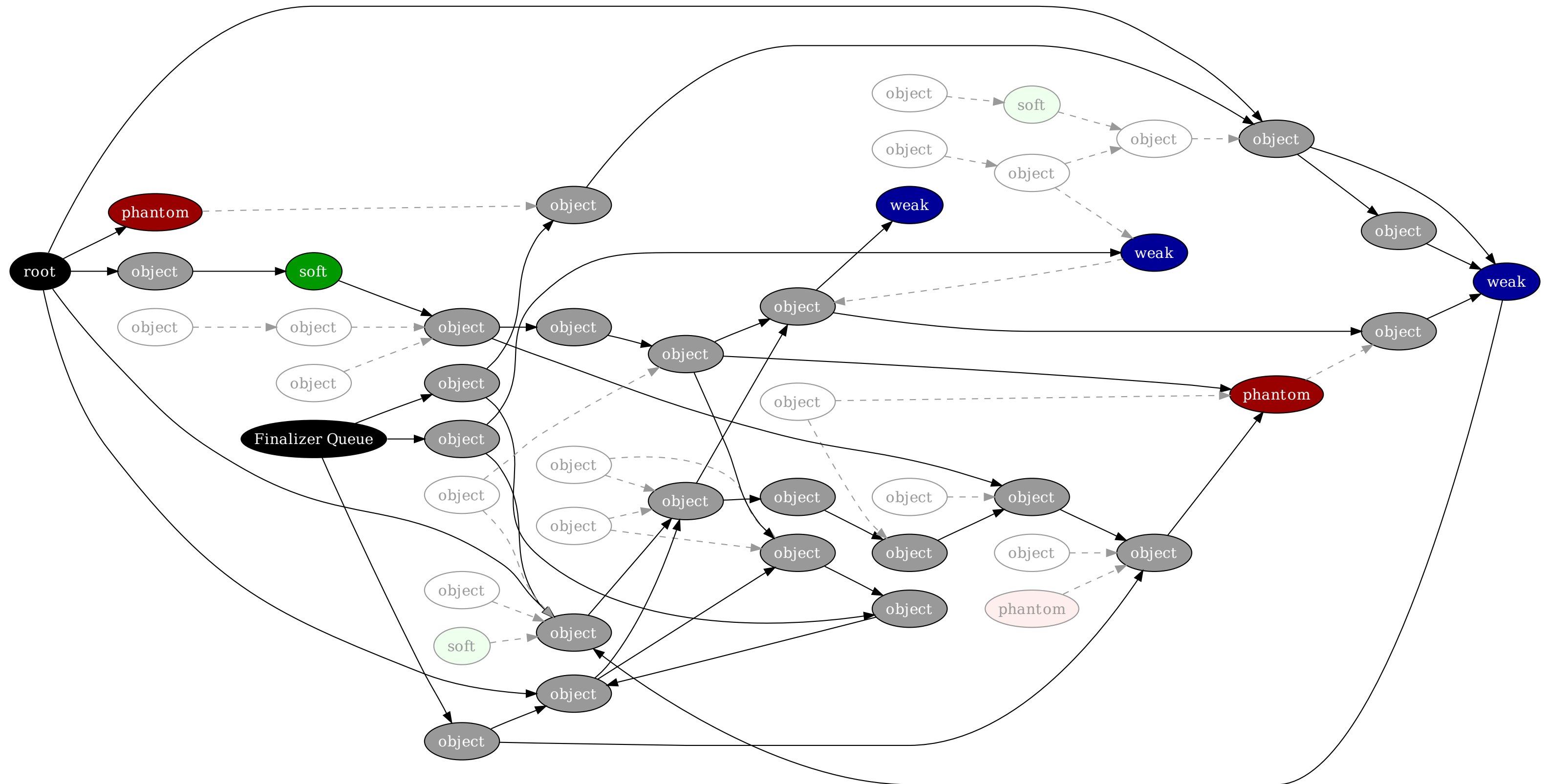
7. Repeat steps 1 through 5 for the queue.



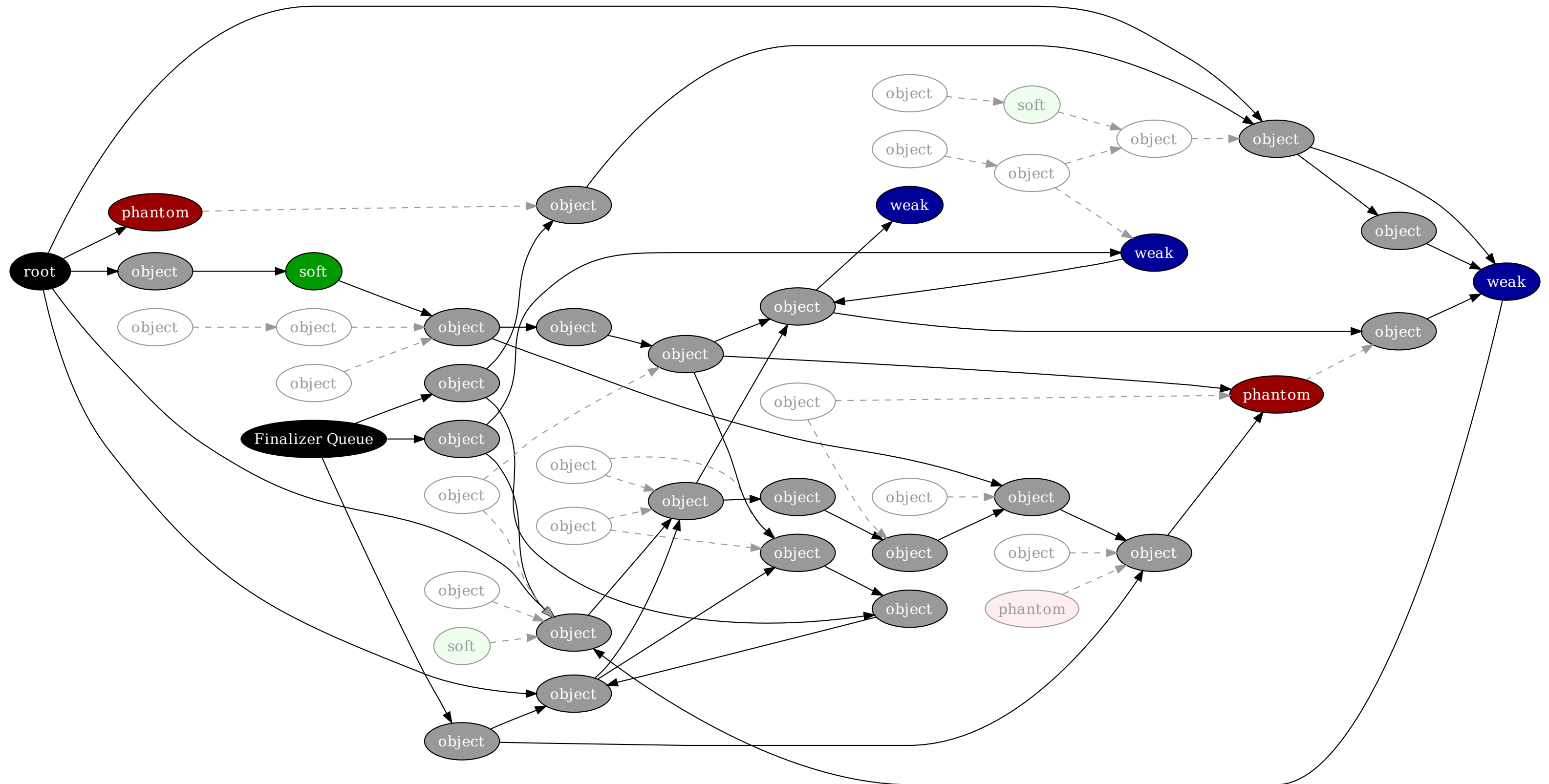
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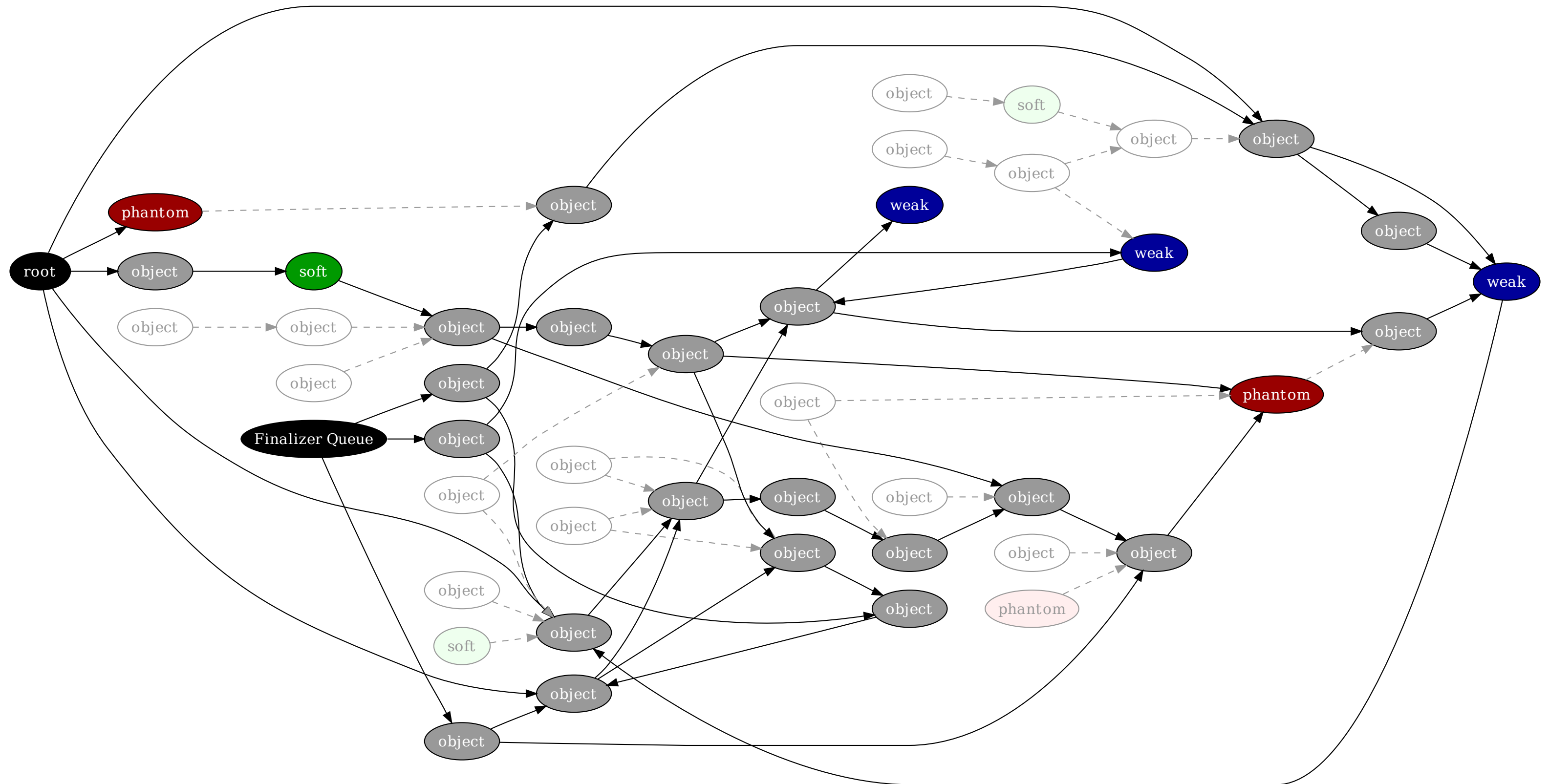
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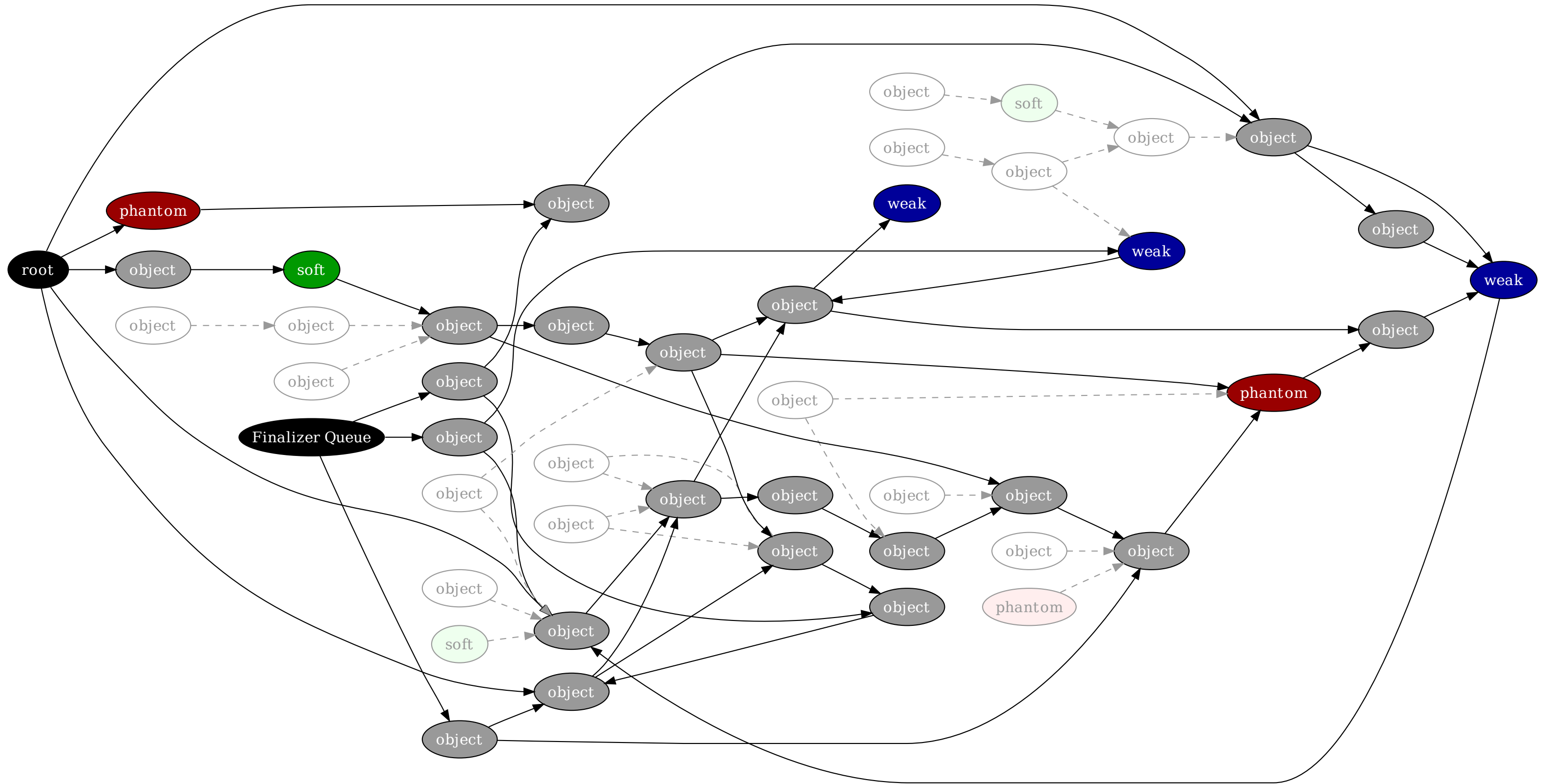
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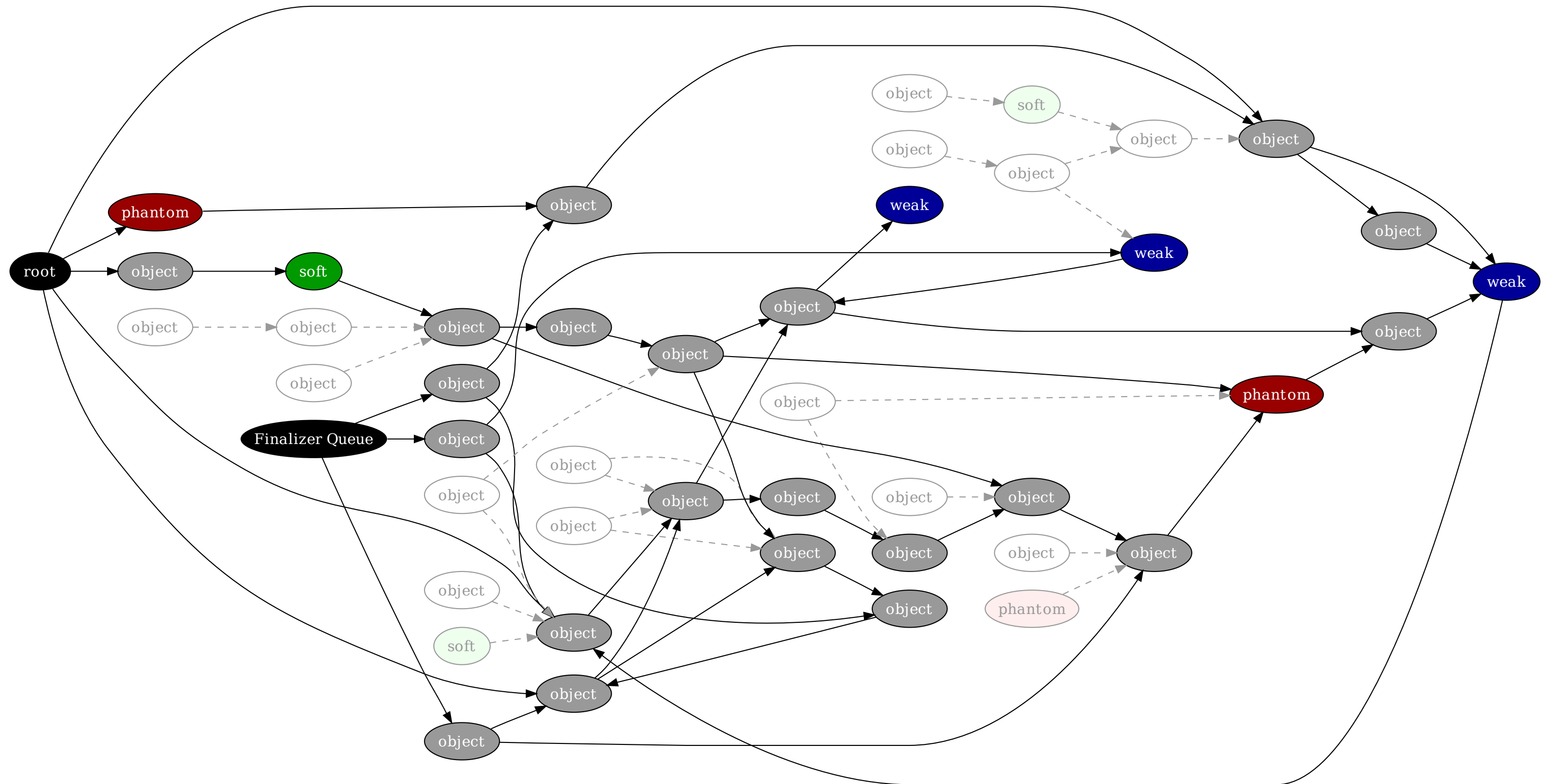
8. Possibly enqueue phantom references.



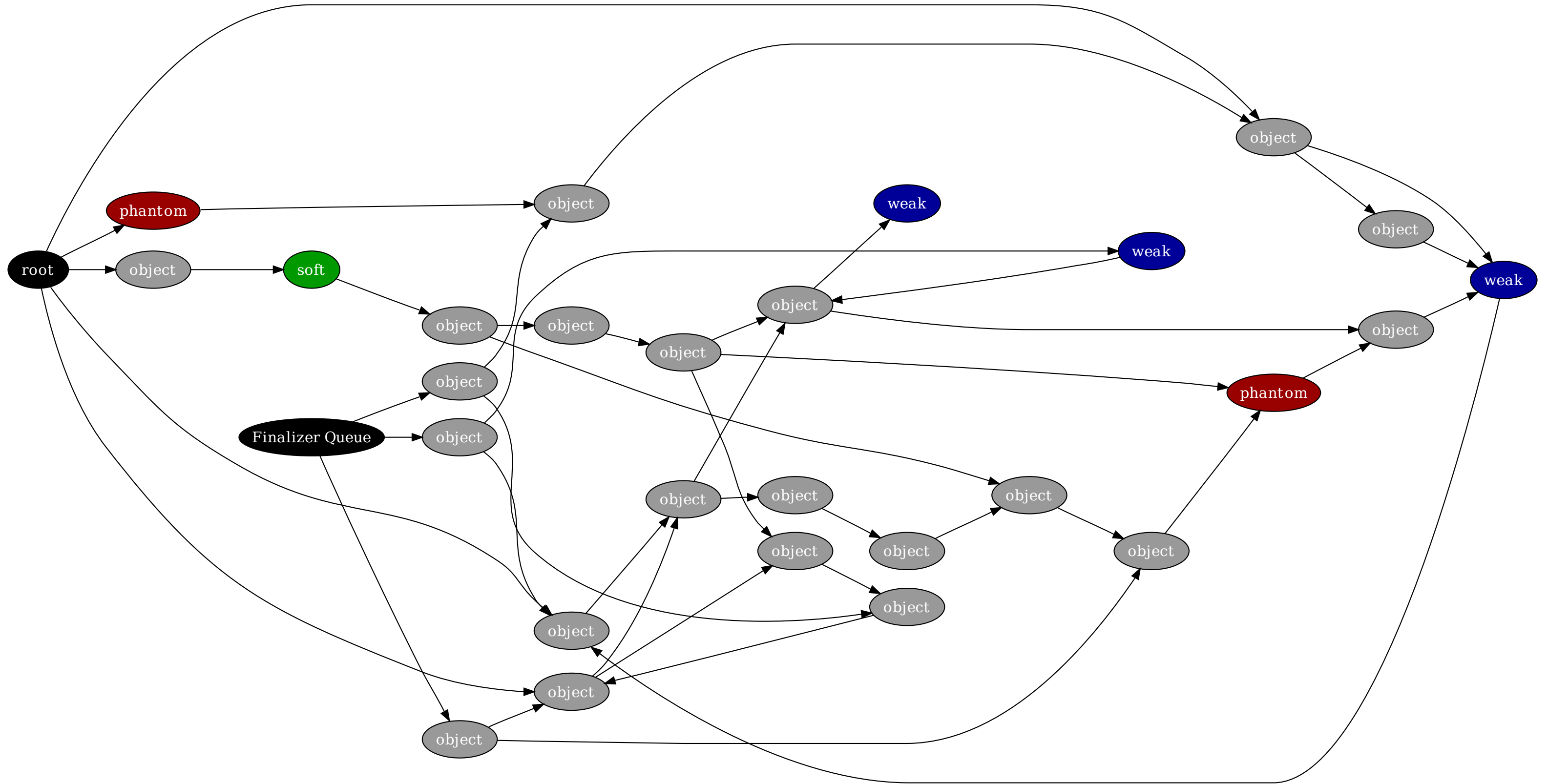
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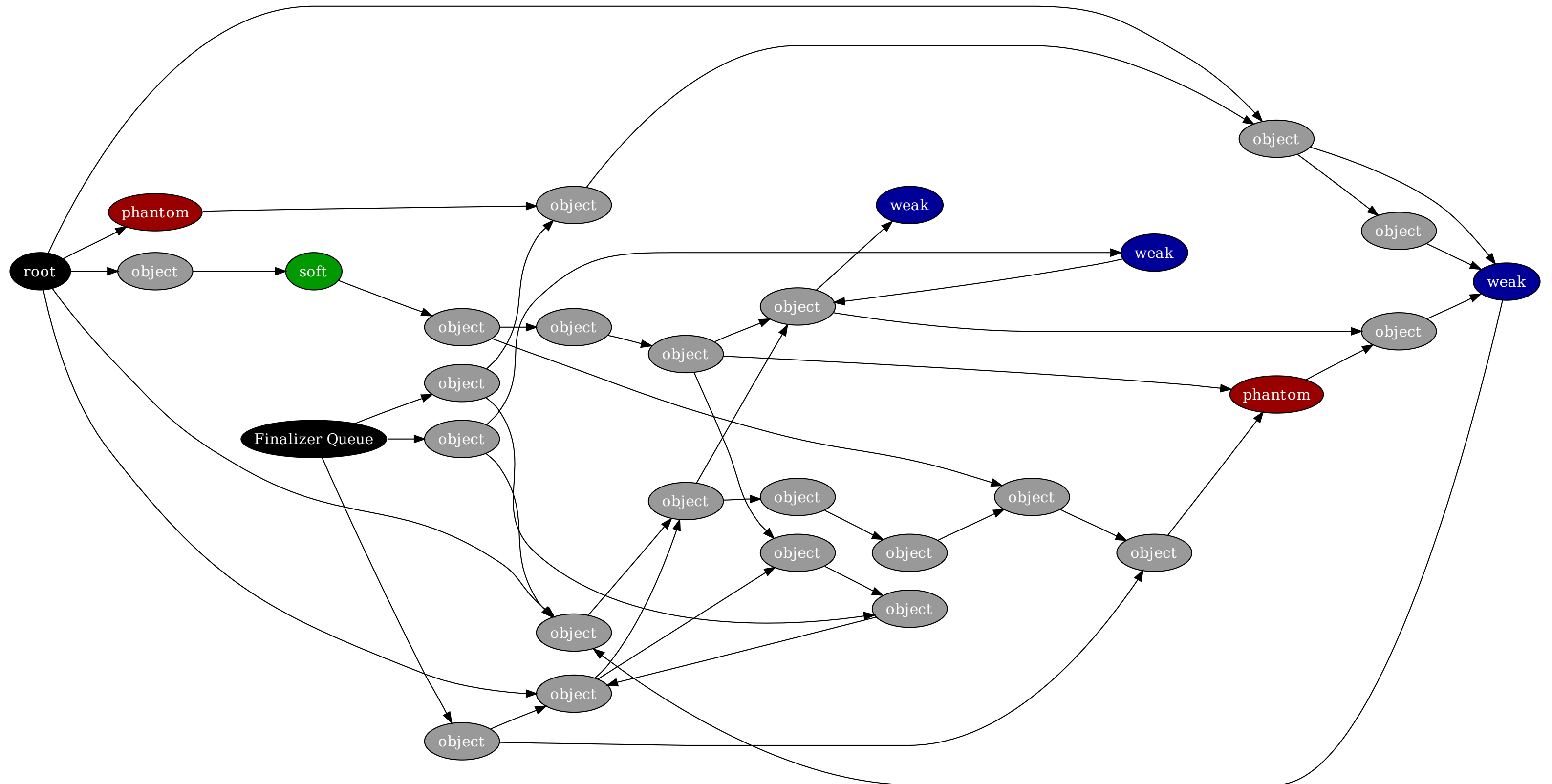
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10. Repeat.



Recap

1. Start at a root.
2. Trace and mark strongly-referenced objects.
3. Optionally clear soft references.
4. Trace and mark softly-referenced objects.
5. Clear weak references.
6. Enqueue finalizable objects.
7. Repeat steps 1 through 5 for the queue.
8. Possibly enqueue phantom references.
9. The remaining objects are dead.
10. Repeat.

Two options for freeing native resources

- > Use a finalizer.
 - You must defend against subsequent use!
- > Or use a phantom reference.

Weak references aren't for caching!

- > Many collectors will reclaim weak refs immediately.
- > Use soft reference for caching, as intended:

“Virtual machine implementations are encouraged to bias against clearing recently-created or recently-used soft references.”

- The `SoftReference` documentation