INKPHYSICS FLASHCARDS

Gravitational fields

Year 13 · 16 cards · fronts and backs

Print double-sided, flipping on the long edge, and each answer lands behind its question. Cut along the card borders.

Definitions in mark-scheme wording, the equations that are not on the data sheet, each lesson's check question, and the misconceptions that lose marks. The same cards run on the website with spaced-repetition scheduling, at inkphysics.co.uk/flashcards.

DEFINITION

Define: Force field.

THE FIELD CONCEPT

CHECK YOURSELF

State two similarities and one difference between gravitational and electrostatic forces, and give one situation where each field would be drawn as uniform.

Hint: Think of the shared mathematics first, then who is allowed to repel.

THE FIELD CONCEPT

SPOT THE ERROR

Say what is wrong with this claim:

Forces need contact.

THE FIELD CONCEPT

DEFINITION

Define: Gravitational field strength.

NEWTON'S LAW OF GRAVITATION

CHECK YOURSELF

The ISS orbits about 400 km above the Earth's surface. Taking $M = 5.97 \times 10^{24}$ kg and $R_E = 6.37 \times 10^6$ m, calculate g at the station, and explain why astronauts float despite your answer.

Hint: Build r from the centre first, then ask what free fall feels like from inside.

NEWTON'S LAW OF GRAVITATION

SPOT THE ERROR

Say what is wrong with this claim:

There's no gravity in space.

NEWTON'S LAW OF GRAVITATION

DEFINITION

Define: Gravitational potential.

GRAVITATIONAL POTENTIAL

CHECK YOURSELF

At the Earth's surface $V = -6.26 \times 10^7$ J kg^{-1}, and at a satellite's orbit $V = -0.94 \times 10^7$ J kg^{-1}. Find the energy needed to lift a 1200 kg satellite between the two, ignoring its kinetic energy.

Hint: The energy needed is m times the potential difference.

GRAVITATIONAL POTENTIAL

CHECK YOURSELF

Similarities: both obey an inverse-square force law, and both are described with the same apparatus of field lines, potentials and equipotential surfaces.

Difference: masses always attract; charges may attract or repel.

Uniform cases: the gravitational field near the Earth's surface over small distances, and the electric field between parallel charged plates.

THE FIELD CONCEPT

DEFINITION

A region in which a body experiences a non-contact force.

THE FIELD CONCEPT

DEFINITION

The force per unit mass on a small test mass placed in the field: $g = F/m$, in $N\ kg^{-1}$.

NEWTON'S LAW OF GRAVITATION

SPOT THE ERROR

Gravity, electricity and magnetism all act with no contact at all. The field is the modern bookkeeping: a region where a body feels a force, mapped before the body ever arrives.

THE FIELD CONCEPT

SPOT THE ERROR

Orbiting astronauts float not because gravity is absent — at the ISS it is still about 90% of surface g — but because they and their station are falling together. Gravity follows the inverse square; it never switches off.

NEWTON'S LAW OF GRAVITATION

CHECK YOURSELF

$r = 6.37 \times 10^6 + 4.0 \times 10^5 = 6.77 \times 10^6$ m.

$g = GM/r^2 = (6.67 \times 10^{-11} \times 5.97 \times 10^{24}) / (6.77 \times 10^6)^2 = 8.7\ N\ kg^{-1}$, about 89% of the surface value.

Astronauts float because station and crew are both in free fall, accelerating identically under that g while perpetually missing the ground. Gravity up there is nearly full strength; support forces are what vanished.

NEWTON'S LAW OF GRAVITATION

CHECK YOURSELF

$\Delta V = (-0.94 \times 10^7) - (-6.26 \times 10^7) = +5.32 \times 10^7\ J\ kg^{-1}$: the climb is out of the well, so ΔV is positive.

$\Delta W = m\Delta V = 1200 \times 5.32 \times 10^7 = 6.4 \times 10^{10}$ J.

Sixty-four gigajoules just to be there, before a single joule of orbital kinetic energy: launch costs are mostly the well's depth.

GRAVITATIONAL POTENTIAL

DEFINITION

The work done per unit mass to move a small test mass from infinity to that point; zero at infinity and negative everywhere else.

GRAVITATIONAL POTENTIAL

SPOT THE ERROR

Say what is wrong with this claim:

It takes energy to move anywhere in a gravitational field.

GRAVITATIONAL POTENTIAL

DEFINITION

Define: Geostationary orbit.

ORBITS AND SATELLITES

DEFINITION

Define: Escape velocity.

ORBITS AND SATELLITES

EQUATION — NOT ON THE DATA SHEET

Orbit condition: gravity as the centripetal force:

$\mathbf{(GMm)/(r^2) = ?}$

ORBITS AND SATELLITES

EQUATION — NOT ON THE DATA SHEET

Kepler's third law, from Newton:

$\mathbf{T^2 = ?}$

ORBITS AND SATELLITES

EQUATION — NOT ON THE DATA SHEET

Escape velocity:

$\mathbf{v_{esc} = ?}$

ORBITS AND SATELLITES

CHECK YOURSELF

Show that the geostationary orbit has a radius of about 4.2×10^7 m. ($M = 5.97 \times 10^{24}$ kg; take the period as 24 hours.)

Hint: Kepler's derived law, rearranged for r cubed.

ORBITS AND SATELLITES

SPOT THE ERROR

Say what is wrong with this claim:

A satellite needs its engines running to stay in orbit.

ORBITS AND SATELLITES

DEFINITION

An equatorial orbit with a 24-hour period in the direction of the Earth's spin, so the satellite stays above one point on the surface.

ORBITS AND SATELLITES

SPOT THE ERROR

Moving against the field costs energy; moving with it releases energy; and moving along an equipotential — at constant r — costs none at all. That is why potential, not distance travelled, does the accounting.

GRAVITATIONAL POTENTIAL

EQUATION — NOT ON THE DATA SHEET

$$\frac{GMm}{r^2} = \frac{mv^2}{r}$$

ORBITS AND SATELLITES

DEFINITION

The minimum launch speed at which an object leaves a body's gravitational field without further propulsion.

ORBITS AND SATELLITES

EQUATION — NOT ON THE DATA SHEET

$$v_{esc} = \sqrt{\frac{2GM}{r}}$$

ORBITS AND SATELLITES

EQUATION — NOT ON THE DATA SHEET

$$T^2 = \frac{4\pi^2}{GM} r^3$$

ORBITS AND SATELLITES

SPOT THE ERROR

An orbit is free fall, not powered flight: gravity alone supplies exactly the centripetal force, and with nothing to slow it, the satellite keeps its speed. Engines are only for changing orbit.

ORBITS AND SATELLITES

CHECK YOURSELF

$T = 24 \times 3600 = 8.64 \times 10^4$ s. Rearranging the derived law: $r^3 = GMT^2/4\pi^2$.

$r^3 = (6.67 \times 10^{-11} \times 5.97 \times 10^{24} \times (8.64 \times 10^4)^2) / 4\pi^2 = 7.5 \times 10^{22}$ m^3.

$r = 4.2 \times 10^7$ m from the Earth's centre, about 36,000 km above the surface, in the equatorial plane. One radius, shared by every geostationary satellite ever flown.

ORBITS AND SATELLITES