D.1

Calculating Field Strength

IB PHYSICS | FORCE FIELDS

Warm Up

D.1

Calculate F_g for a 75-kg student on the surface of the earth

$$F_g = mg$$

$$F_g = (75)(9.8)$$

$$= \mathbf{735\ N}$$

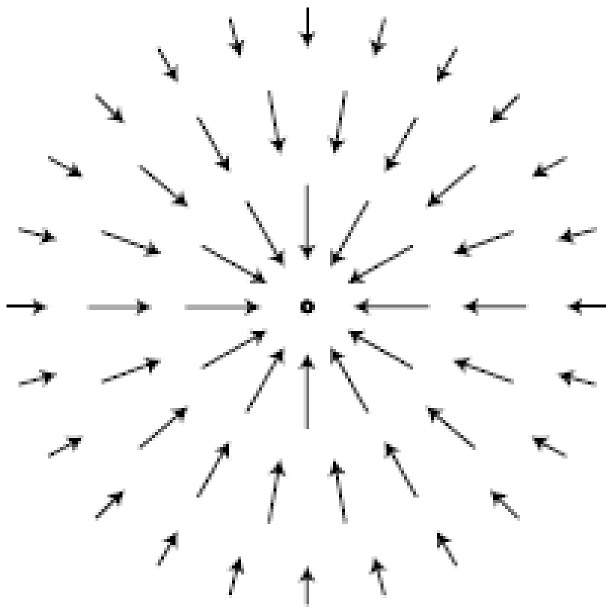
$$F_g = G\frac{m_1 m_2}{r^2}$$

$$F_g = (6.67 \times 10^{-11})\frac{(75)(5.97 \times 10^{24})}{(6{,}378{,}000)^2}$$

$$= \mathbf{734\ N}$$

Force Fields

Vector field that describes the force that would act on a particle at various positions



	Electric Field	Gravitational Field
Symbol	$\boldsymbol{E}$	g
Unit	$\frac{\mathrm{N}}{\mathrm{C}} = \mathrm{N\ C^{-1}}$	$\frac{\mathrm{N}}{\mathrm{kg}} = \mathrm{N\ kg^{-1}}$

IB Physics Data Booklet

D.1

D. Fields

Standard level and higher level	
D.1 Gravitational fields	$F = G\frac{m_1 m_2}{r^2}$ $g = \frac{F}{m} = G\frac{M}{r^2}$
D.2 Electric and magnetic fields	$F = k\frac{q_1 q_2}{r^2}$ where $k = \frac{1}{4\pi\varepsilon_0}$ $E = \frac{F}{q}$ $E = \frac{V}{d}$
D.3 Motion in electromagnetic fields	$F = qvB\sin\theta$ $F = BIL\sin\theta$ $\frac{F}{L} = \mu_0\frac{I_1 I_2}{2\pi r}$

$$F_g = mg$$

$$F_g = G\frac{m_1 m_2}{r^2}$$

Remember g?

$g = 9.8\ \text{m s}^{-2}$

g representing acceleration is not the whole story…

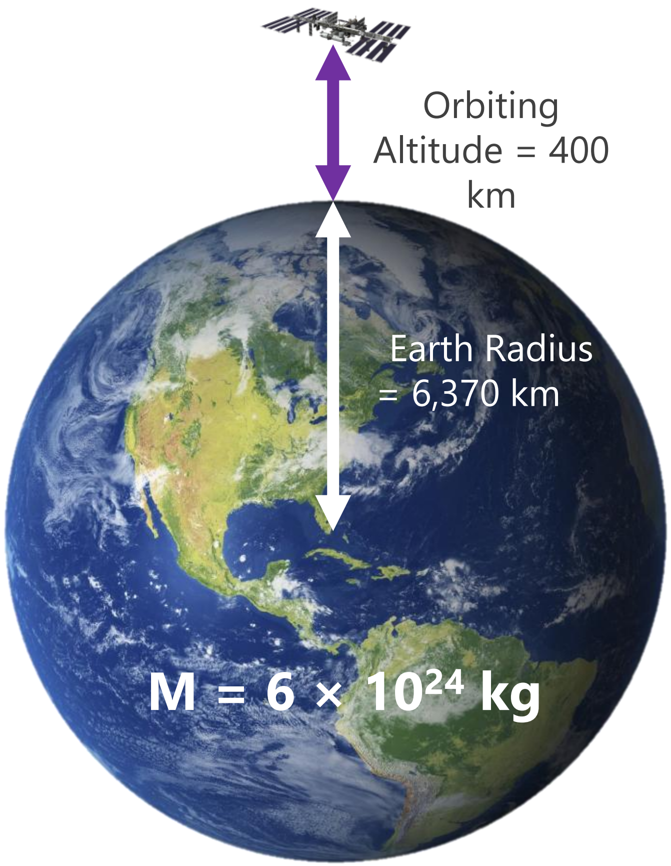
g → Gravitational Field Strength

$$g = \frac{\text{N}}{\text{kg}} = \frac{\cancel{\text{kg}} \times \text{m s}^{-2}}{\cancel{\text{kg}}} = \text{m s}^{-2}$$

Wait, does that mean g changes?

D.1

$$400\ km + 6370\ km = 6770\ km$$

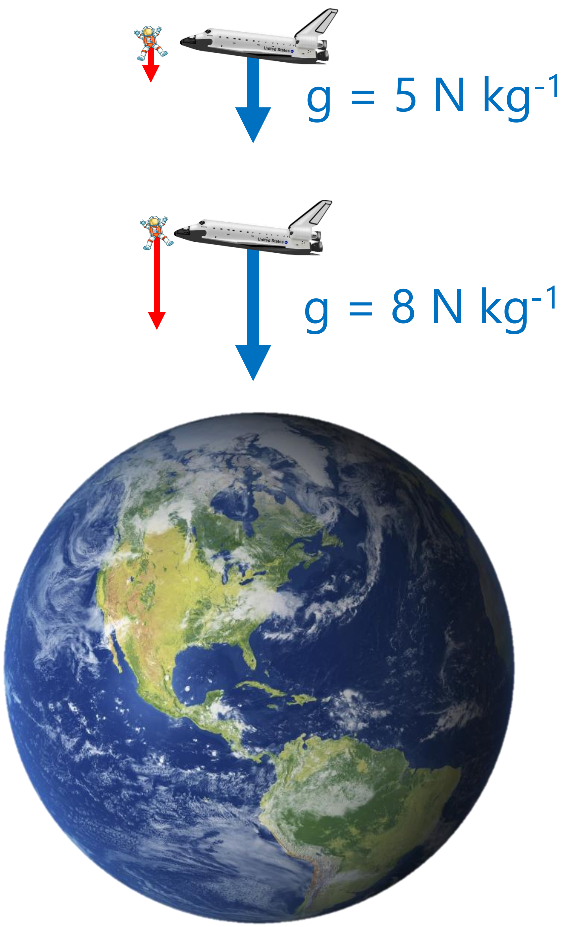


$$g = G\frac{M}{r^2}$$

$$g = G\frac{M}{r^2} = (6.67 \times 10^{-11})\frac{(6 \times 10^{24})}{(6{,}770{,}000)^2}$$

$$g = 8.73\ \mathrm{N\ kg^{-1}}$$

Using g



 = 2,000,000 kg  = 75 kg

What is the force of gravity for each position?

$F = (75\ kg)(5\ N\ kg^{-1})$

$F = \mathbf{375\ N}$

$F = (2{,}000{,}000\ kg)(5\ N\ kg^{-1})$

$F = \mathbf{10,000,000\ N}$

$F = (75\ kg)(8\ N\ kg^{-1})$

$F = \mathbf{600\ N}$

$F = (2{,}000{,}000\ kg)(8\ N\ kg^{-1})$

$F = \mathbf{16,000,000\ N}$

Try This

What is the electric field strength if a particle with a charge of +6.3 μC experiences a force of 0.0025 N?

$$E = \frac{F}{q} = \frac{0.0025\ \text{N}}{6.3 \times 10^{-6}\ \text{C}}$$

$$E = 397\ \text{N C}^{-1}$$

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D. Fields

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Try This

$$E = \frac{F}{q}$$

$$E = \frac{V}{d}$$

A pair of parallel plates with a potential difference of 700 V are separated by 160 mm. What is the electric field strength between the plates?

$$E = \frac{V}{d} = \frac{700\ \text{V}}{0.16\ \text{m}} = \mathbf{4375\ V\ m^{-1}}$$

or $\mathbf{N\ C^{-1}}$

What is the electric force acting on an alpha particle (2 protons and 2 neutrons) placed between these charged plates?

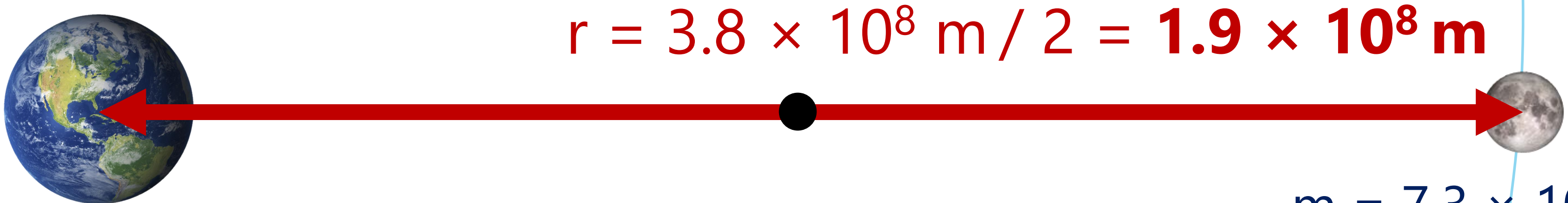
$$q = 2 \times (1.60 \times 10^{-19}) = 3.2 \times 10^{-19}\ \text{C}$$

$$F = Eq = (4375)(3.2 \times 10^{-19}) = \mathbf{1.4 \times 10^{-15}\ N}$$

Try this

What is the gravitational field strength halfway between the centers of the earth and the moon?

r = 3.8 × 10^8 m / 2 = **1.9 × 10^8 m**



m = 6 × 10^{24} kg

m = 7.3 × 10^{22} kg

$$g = (6.67 \times 10^{-11})\frac{(6 \times 10^{24})}{(1.9 \times 10^{8})^2} = \mathbf{0.011\ N\ kg^{-1}}$$

$$g = (6.67 \times 10^{-11})\frac{(7.3 \times 10^{22})}{(1.9 \times 10^{8})^2} = \mathbf{0.00013\ N\ kg^{-1}}$$

$g = 0.011 - 0.00013 =$

$$g = 0.0109\ \mathrm{N\ kg^{-1}}$$

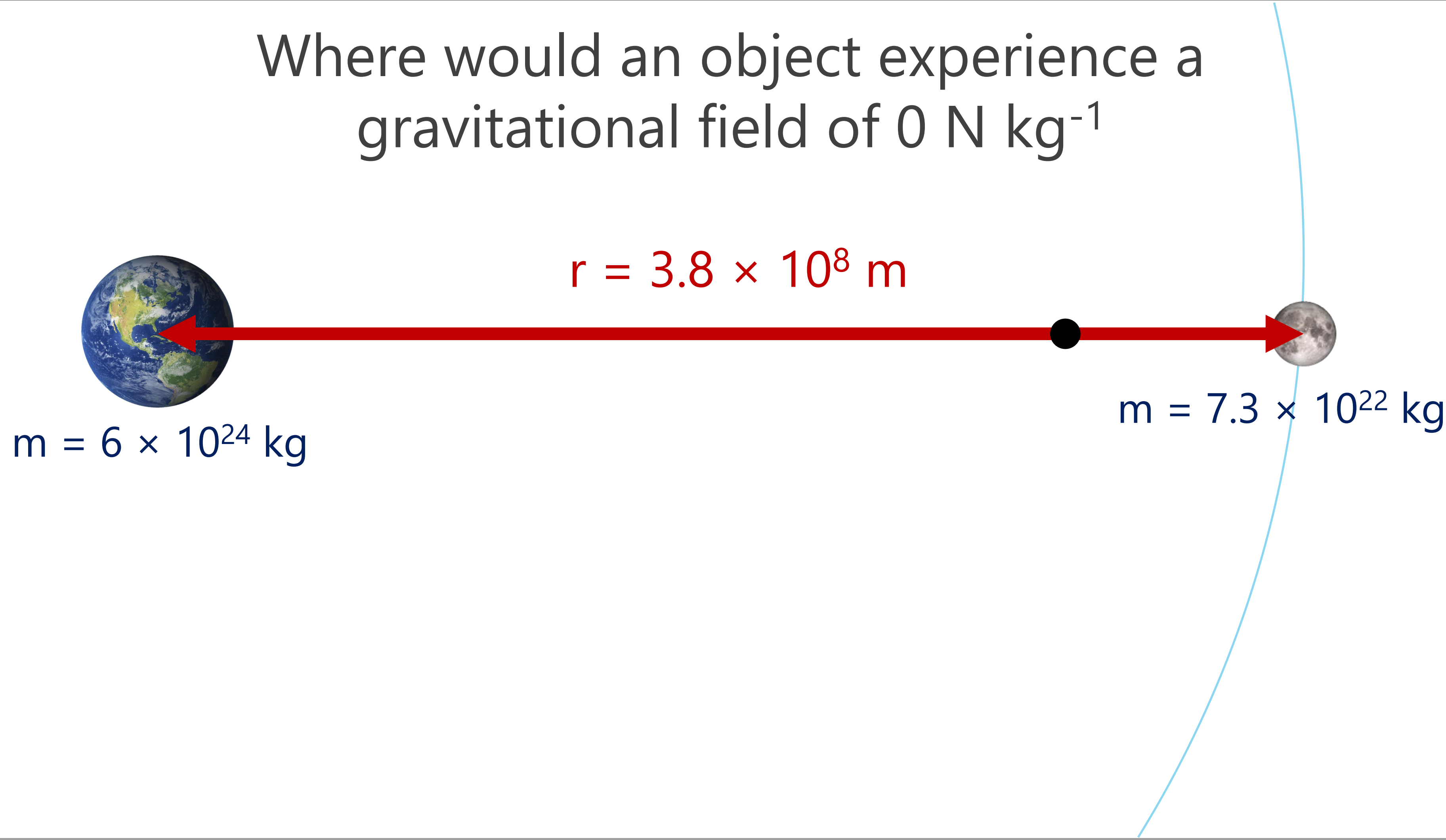
$$g = G\frac{M}{r^2}$$

G = 6.67 × 10^{-11} $\frac{N \times m^2}{kg^2}$

Try this | Hard Mode

D.1

Where would an object experience a gravitational field of $0\ N\ kg^{-1}$



Answer on the next slide…

Try this | Hard Mode

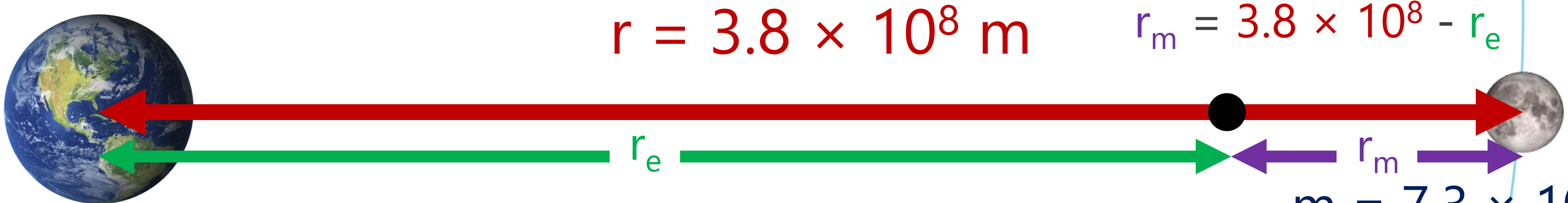
D.1

Where would an object experience a gravitational field of 0 N kg^{-1}

$$G\frac{M_e}{{r_e}^2} = G\frac{M_m}{{r_m}^2}$$

$r = 3.8 \times 10^{8}$ m

$r_m = 3.8 \times 10^{8} - r_e$



m = 6 × 10^{24} kg

m = 7.3 × 10^{22} kg

cancel out G
and
square root everything

$$\sqrt{G\frac{M_e}{{r_e}^2}} = \sqrt{G\frac{M_m}{{r_m}^2}}$$

$$\frac{\sqrt{M_e}}{r_e} = \frac{\sqrt{M_m}}{r_m}$$

$$\frac{\sqrt{6 \times 10^{24}}}{r_e} = \frac{\sqrt{7.3 \times 10^{22}}}{(3.8 \times 10^{8} - r_e)}$$

$$(9.31 \times 10^{20}) - (2.45 \times 10^{12})r_e = (2.70 \times 10^{11})r_e$$

$$(9.31 \times 10^{20}) = (2.72 \times 10^{12})r_e$$

$$r_e = 3.42 \times 10^{8}\ \text{m}$$

$$g = G\frac{M}{r^2}$$

G = 6.67 × 10^{-11} $\frac{N \times m^2}{kg^2}$

Lesson Takeaways

- ❑ I can use the universal law of gravitation and circular motion to describe the motion of an orbiting body
- ❑ I can describe and calculate electric and gravitational field strength
- ❑ I can calculate resultant field strength from multiple sources