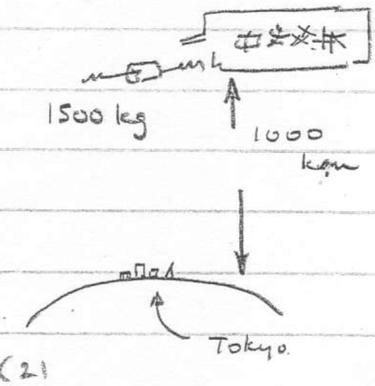
Gravity – Question – 3 (The Final Resurrection)

A Physics
Gravity Fields

C

1. A satellite is in orbit at 1000 km altitude above the Earth.



(a) What does "altitude" mean? (1)

Calculate it's gravitational potential energy....

(b) on the ground, (2)

(c) in orbit. (2)

(d) What is the satellite's gain in grav. P.E.? (2)

(e) What is the minimum volume of fuel needed, if 1 litre provides 40×10^6 Joules of energy? (2)

(f) More fuel than this will be needed – why? (1)

(g) If the rocket motor provides a constant thrust as it ascends the rocket's acceleration will increase. There are 2 reasons for this – what are they? (2) $\boxed{12}$

2. Sketch graphs to show how 'g' and "V" change with distance from the Earth, up to a distance of 3 Earth radii. (HINT – you need a couple of key values of g and V – and then use the relationships with distance.) $\boxed{6}$

axes labels + scales!

3. A satellite, mass 1200 kg, in a low, 200 km, orbit falls back to Earth. What is its grav. potential energy ...

(a) in orbit, (2) (b) on Earth. (2)

(c) What would the satellite's maximum possible velocity be on hitting the ground? (to simplify – consider satellite as initially stationary in space.)

(d) Why would it not reach this velocity? Where would the grav. P.E. "go"? (2 $\boxed{8}$

4. (a) Show that the escape velocity from a planet P, mass M_P radius R_P is $V_{escape} = \sqrt{2GM_P/R_P}$. (2)

What are escape velocities for (b) Earth? (2) (c) Moon? (2) $\boxed{6}$

5. (a) The normal formula for gravitational P.E is "mgh"

Explain why this is true only for small changes in height.

(b) A lift, mass 500 kg, is raised from the ground level to the top of a skyscraper 600 m high. Calculate the gain in grav. P.E. using the simple "mgh" formula, and also the more accurate gravity potential formula.

TJW
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Gravity – 3 Answers   A Physics

C 1. (a) altitude = height above Earth's surface. /1

$V_g = -GM/r$ J/kg [1] so... (b) $V_g = -9.42 \times 10^{10}$ J [1] for 1500kg craft

(c) V_g orbit $= -8.15 \times 10^{10}$ J /2

(d) gain in V_g = V_g up there − V_g down here $= -8.15\times10^{10} - (-9.42\times10^{10}) = +1.27\times10^{10}$ J /2

(e) need $1.27\times10^{10} / 40\times10^{6}$ = 317 l fuel. /2   (f) – mass of whole rocket /1 – air resistance.

(g) (1) mass of rocket + fuel will ↓ ∴ since $a = F/m$ then a will ↑

(2) g↓ as gain altitude, so grav. attraction ↓   14

2. at Earth's surface ...

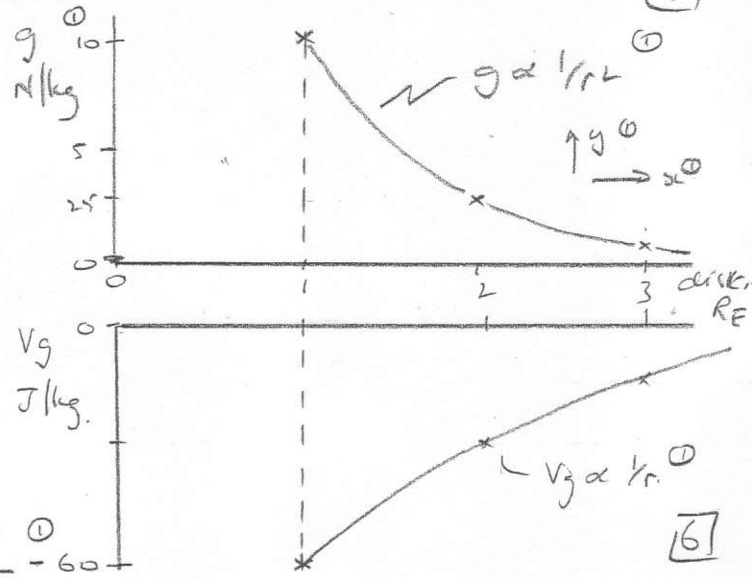
$g = 10$ N/kg. (you could calculate $g = GM_E/R_E^2$...)

$V_g = -GM_E/R_E$

$= -63 \times 10^6$ J/kg

then $g \propto 1/r^2$ $r \to 2r$... $g \to g/4$

$V_g \propto 1/r$ $V_g \to V_g/2$



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3. (a) V_g orbit $= -G\frac{M_E m_s}{r_{sat}} = -7.31\times10^{10}$ J [1]

(b) V_g Earth $= -7.54\times10^{10}$ J.

(c) PE loss = KE gain ideally

$2.28\times10^{9} = \frac{1}{2} m_s v_s^2 \to v_{max}$ = 1950 m/s /2

(d) Air resistance : friction with air would → heat /2   8

4 To escape planet's grav. field KE = V_{grav}

$\frac{1}{2} \cancel{m_s} v_{esc}^2 = \frac{GM_p \cancel{m_s}}{R_p} \to v_{esc}^2 = 2GM_p/R_p \to v_{esc} = \sqrt{\frac{2GM_p}{R_p}}$

(a) Earth v_{esc} = 11,200 m/s   (b) Moon v_{esc} = 2350 m/s   6

5 (a) Gravity field strength 'g' changes with height. [1] You can only use 'mgh' – assuming constant 'g' [1] for small changes in 'h', where g changes very little /2

(b) Accurate method $V_{surface} = -\frac{GM_E m_e}{r_E} = -3.140625\times10^{10}$ J

$V_{top} = -3.140331 \times 10^{10}$ J V_g diff $= 2.9400 \times 10^6$ J

$g_{Earth} = -\frac{GM_E}{R_E^2} = 9.814453$ N/kg   gain in PE = mgh = 2.9443×10^6 J (not a lot)

Difference 4,300 J

PE gain by mgh must be larger, because you use a higher value of 'g'.

TRN
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